

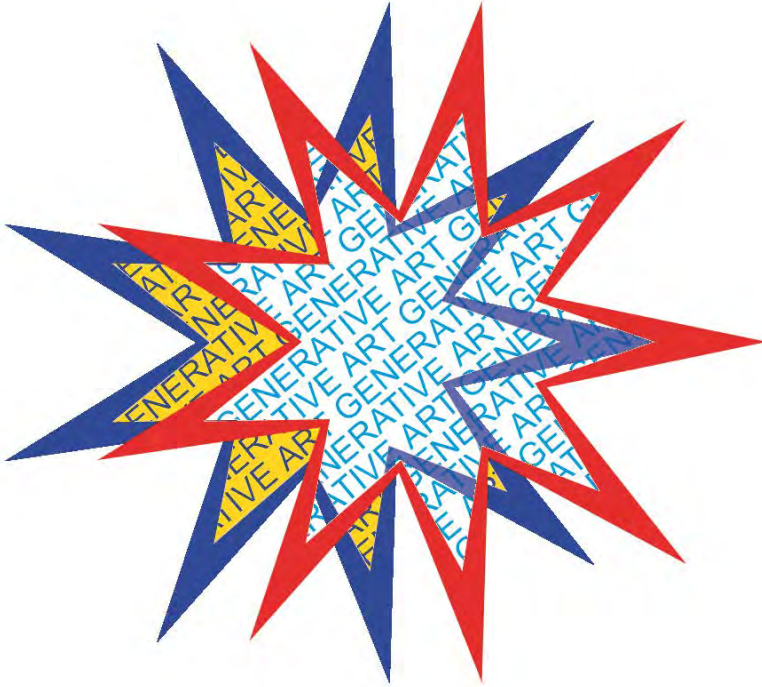
The book contains the papers, installations, posters, artworks and live performances presented at XXVI Generative Art conference at the Borrominian Hall of Biblioteca Vallicelliana, Rome, Italy.

In the cover a generative evolution of a portrait by Francis Bacon, adding a fantastic animal created by interpreting the FB features, generated by Celestino Soddu.

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GENERATIVE ART 2023

*GA2023, XXVI Annual International Conference
at the Borrominian Hall of Biblioteca Vallicelliana,*

*GA2023 is organized by Generative Art and Design Lab, Argenia Association,
Roma, Italy*

Proceedings

Edited by Celestino Soddu and Enrica Colabella

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OPENING

We are called to answer the latest challenges that question the human ability to have a poetic vision and to pursue it in their creative activity. In the last century, from Roland Barthes' "The Death of the Author" to the experiments of Generative Artificial Intelligence in chatbots, there has been a gradual trend toward de-emphasizing subjective vision. This trend exalts technology as the machine's ability to replace men even in their creative and visionary activities. The objectivity of a process is no longer accepted in parallel with man's visionary ability to conceive an idea but is overvalued to the point of denying the subjectivity's peculiar role: the triggering of an evolutionary process due to the ability to conceive possible reversals of established systems of relationships.

Working since 1998 on Generative Art, we are directly involved and must express our impressions. Is it desirable that we attribute to technology, to machines, to robots the imprinting of works of art? Or instead, do we want to recognize as the authors those who designed the machines themselves and the role of the subjective uniqueness of software be emphasized? The role of authorship has virtually disappeared in the latest realizations of AI. Instead, it is explicit that these are not super partes statements but by individual authors who want to put their opinions as objective. Are we sure that this is not an attempt to create a monopoly?

In this conference, we will attempt to answer these and other open questions and rediscover the need for poetic subjectivity. And also regain the dignity and responsibility of authorship in who designs and writes the algorithms of AI generative programs.

Celestino Soddu and Enrica Colabella
Chairs of Generative Art Conferences

Generative Art, the “Author’s AI”. Complexity, Naturalness and Recognizable Creativity

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Celestino Soddu

Abstract

It is important to clarify what is meant by Generative Art, particularly when the term "generative" is being used extensively in reference to AI.

Generative Art is a unique project that can produce a range of results based on an idea. It's not just a technique, but rather a philosophy that can be implemented using various techniques. There are three key characteristics of Generative Art that define its quality: complexity, naturalness, and recognizable creativity.

Contrary to generative AI, chatbots, and so on, which try to solve objective problems, Generative Art can be identified as “Author’s AI” because works like Artificial Intelligence but the results belong to a subjective vision and to an unique and recognizable poetics.

COMPLEXITY

Through an organized meta-process, often structured as an AI process, Generative Art allows an idea to be made explicit in multiple outcomes that realize and identify it.

The quality of a generated event can be characterized by having passed the condition of simplification. The idea behind the event is not just a simplified gesture, or a form, but rather an impressive interpretation of a possible new existence. The idea is considered impressive / visionary, because it is capable of unpredictable evolutions towards complexity. Therefore, an idea is not just a simplified synthesis of a vision or a concept, but a hypothesis of a possible path towards complexity. Referring back to Poincarè, the idea, if it is creative, is based on identifying possible relationships between existing events. These relationships must be capable of developing a specific vision of the author. In Generative Art, the idea can interpret these relationships as a

topological paradigm that is responsive to our poetics and subjective worldview.

To clarify, creating a system that produces a series of results whose difference is caused only by a randomly varied formal event cannot be considered generative art. For instance, a series of constantly changing bottles whose profile is randomized is not a form of generative art but a simplification of the process.

Generative Art involves complexity and one of its key features is the interchangeability of forms. This means that the idea is not related to the form itself but to the relationships between events and the process being used. The forms can be interchanged within formal matrices that align with the author's subjective vision. This feature is present in any design process, even traditional ones, in which different formal alternatives can be used depending on specific contingencies. This works without invalidating the vision or poetics of the author. The results perform a complex structure of possible outcomes that may appear very different, but are still recognizable as the artworks of the same author.

Generative Art is a meta-project management, which means progressively constructing a "project of the project" involving many of possible alternatives, also formal alternatives. This approach allows for the representation of complex ideas that may involve opposing features and overlapping purposes. The quality and complexity of a design and artistic creation can be identified by its ability to meet not only a variety of demands, but also unpredictable ones. This is because the appreciation of the results is subjective and varies depending on the

users.

The alone process of analytical and deductive logic is not enough to create the complexity found in Generative Art. Subjectivity and interpretation are essential to the underlying idea of this art form.

Synesthesia is not strictly generative art also if it allows one to formalize their interpretation of the world by generating scenarios from evolving different structures. Although sometimes unconscious, it reveals one's subjectivity by conveying a vision through complex structures.

ARTIFICIAL NATURALNESS

Generative Art draws inspiration from the plural and fascinating world of Nature. We can observe topological patterns that are shared among different species, while also appreciating the unique identities of each species and even individual events.

Generative Art aims to replicate the natural structure of a species in the artificial world. The ultimate goal of this art form is to bring to life a species project, complete with unique features. These reflect the artist's subjective vision and poetic expression and are intrinsic to the project idea. The result is the creation of a set of unique, one-of-a-kind events, each with its own distinct identity that is strongly linked to the species' characteristics.

There is a rising trend to prioritize naturalness in industrial development.

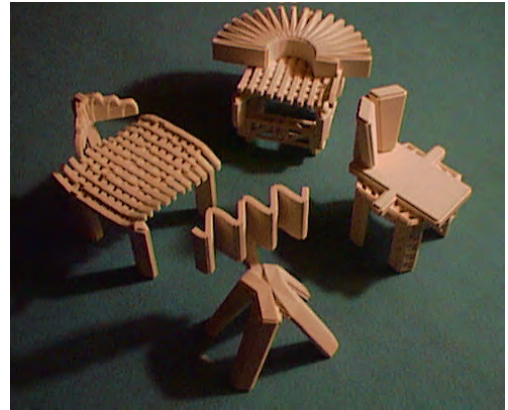
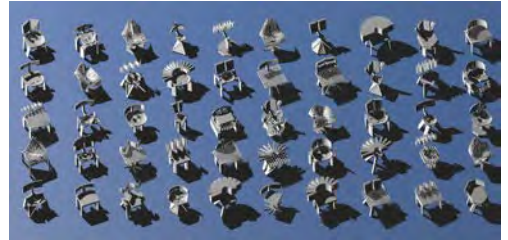
However, generative art represents a remarkable yet underappreciated turning point, as it hasn't been widely applied yet. Currently, all development efforts are

focused on the physical structure of production, prioritizing energy savings, carbon dioxide emission, and material recycling. Unfortunately, these efforts don't consider what generative art can offer: product uniqueness, just like in nature, which favours slow obsolescence. The products generated by generative production do not need to be replaced by the latest version, since each product is "naturally" unique, just like trees and works of art. For the past forty years, I have been following a generative art approach that has developed a "New Naturalness" through Artificial Intelligence programs like ARGENTIA.

This is one aspect of the possible new path to digital industrial evolution, and it is an outcome of the possible generative application of Artificial Intelligence that should overcome the bottleneck of results seen only as an optimized solution to a problem to enter the world of the infinite parallel possibilities of "how".

Nature teaches us that all individuals of the same species are different, yet equally functional. The peculiarities and uniqueness of each individual can lead to unexpected developments, similar to what happens in nature. Instead of designing just single events, the focus should be on designing "species," which can help generate not only uniqueness but also open up new potentials for building the future.

Through the skillful use of AI, it is possible to design "Artificial Species," as I did with ARGENTIA, emulating Nature.



1992. Species of Chairs. The uniqueness of generated individuals using my Argentia, a Generative "Author's AI" software.

Four 3D prints presented at my solo exhibition at Hong Kong Visual Art Museum, 2001.





Two Francis Bacon paintings with a visionary animal generated by my interpretation of his artworks

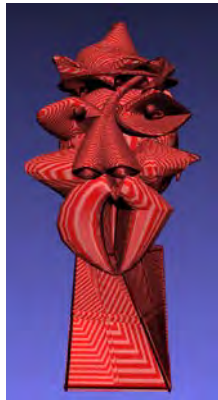
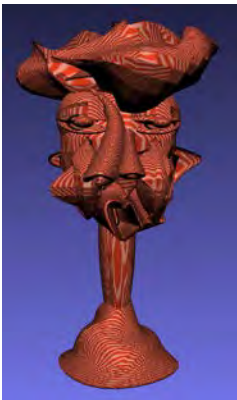


Human species and animal species interpreting Francis Bacon's images.

AI AND CREATIVITY

Artificial intelligence is rapidly evolving with the emergence of chatbots such as Bart, Bing, and ChatGPT, which are referred to as generative AI. The world of AI is moving towards becoming the main player in the generative approach, specifically generative art. Unfortunately, or fortunately, this is not exactly in this way. The generative structure of these new tools, even those that specialize in image generation, are primarily linear compiled. In other words, they use databases extracted from the Internet and then modify them using the ability to communicate correctly and fluently, even across multiple languages. This ability to generate accurate language comes from the advanced techniques used in handling translations. The question we must consider, as researchers and artists, is whether these tools can genuinely aid research paths and assist creative paths.

For research, they can certainly, in the future, be very useful, but not now. Today's large memory capacity does not



go beyond the repetition of what is part of "one-track thinking". This usual way of approaching different topics is thus not suitable for developing advanced research topics. If one likes to go further, one has to ask very specific questions to which the chat answers in a very general way and with serious errors. But this will certainly be overcome shortly.

These choices are made according to the cultural moment and the learning algorithms used, denying the possibility of using AI to assist creative pathways encounters structural difficulties that are difficult to eliminate.

What is creativity? The concept of creativity could be defined as the ability to produce a topological paradigm that can reorganize existing events according to a structured vision that satisfies the author.

The French mathematician, Poincaré, proposed a similar view. Contrary to simply reorganizing existing events, as suggested by Arnold Schoenberg, one can put coloured glass balls in a vessel and shake it. However, if this operation aims to be creative and artistic, it requires the sensitivity, subjectivity, and unique vision of the author to finalize his idea and poetic. In other words, it is essential to create a structure that belongs to one's subjective interpretation satisfying the artistic vision.

Developing the uniqueness of one's vision is based on the Renaissance when perspective was invented. This brought back to the subject the key to understanding space - the point of view. Piero della Francesca played a significant role during this epochal turning point based on perspective. In front of space, the subjective approach is

made explicit in finding the point of view against which everything is reorganized by defining a system of relations between the parts that tell our peculiar vision. Brunelleschi chose to stand on the steps of Florence Cathedral to observe the Baptistery. From that point of view, Brunelleschi identified how the relationships between the parts and the relationship between the various perceivable measures were made explicit. Paolo Alberto Rossi investigated Brunelleschi's approach and defined the key to interpreting the very structure of architecture. The choice of a point of view puts in order all the events of a system following the subjective structure of vision.

It is necessary to move beyond choices only based on what works, which can be easily defined by algorithms, and instead, make choices that operate a subsequent selection, what we like, and what corresponds to our idea. According to that structure, we can design the database to be used by an AI system.

It is important to shift our focus from just "problem solving" to using an interpretive logic that takes into account our individual unicity and subjective vision. This means moving beyond decisions made solely based on objective data and instead, narrowing down choices that align with our personal vision and creativity. Furthermore, we should use algorithms that define the possible progressions of chosen events, that correspond to our vision. In this way, we can ensure that the outcomes are truly in tune with our personal goals and aspirations. In this way, we can construct our "Author's AI".

Operating a complex database collection requires singularity and customization of

the algorithmic structure. However, this has not yet been widely used, favoring a linear and analytical approach and prioritizing technology. Currently, the data collection process favors quantity over quality, resulting in generic and obvious data. The chat answers to our questions biasing towards commonly accepted answers, and anything that deviates from the norm is excluded. But we need to know parallel possible answers. If one tries to explore non-conventional approaches, the answers are still generic and do not focus on the diversity and uniqueness of possible approaches.

RECOGNIZABILITY of Outputs

Of course, the subjective and interpretive approach is not alternative but parallel to the usual approach based on the objectivity (true or assumed) of data. This approach is based on the vision, the poetics of an author, and can be called "Author's AI" and is recognizable by the strong identifiability of the results which, in their variety represent and tell the identity of an author's vision.

This approach has been the basis of my research and experimentation and has been realized with the ARGENIA project. In addition to this, multiple experiments have been presented by the participants in the quarter-century of the Generative Art conference. These experiments often, although born from subjective visions, do not explicitly refer to the interpretive approach in the construction of algorithms. So they lose the possibility of explaining the logic that allows the construction of complexity and their scientificity. This is unfortunately due to the difficulties, which persist still today, of

accepting their interpretive logic in a scientific process.

Only a process based on deductive linear systems, on technology alone, is still favored, and commonly believed to be scientific, though conflicting theories, such as, for example, quantum theory and general relativity, have been accepted as scientific and helpful for more than a century. These theories arose as interpretations based on different points of view. Many still consider as the only acceptable theory to identify Generative Art as a mere technique, relying on the technical simplification of the computer science approach.

CONCLUSION

Unfortunately, it appears obvious that some people use chatbots to write their papers as happened in some papers that were presented at this conference too. These are a mixture of excessive citations following single-minded thinking and an infuriating triviality about scientific hypotheses and their developmental possibilities.

The hope is that this Generative Art conference can lead the way and direct the evolution of AI toward accessing complexity. Precisely we work for an approach based on different, and subjective points of view performing a poetic vision. This is already happening but is kept under-veiled.

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Flexed Epiphra^s XYZ → XZ and Y

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Antefatto

Open materic voice in GA process

PIETA'

“-----I harden as a stone

Sets hard at its heart.

Hard that I am, I know this alone:

That thou didst grow—

— — — — — and grow,

To outgrow,

As too great pain,

My heart's reach utterly.”

Carl Maria Rilke, Pietà [1]



[2]

A materic touch.

Fragile plus fragile without borders

Chi teme lo spazio gareggia col vento in cerca di angoli, / Who fears space contends with the wind in search of corners,

Cui attaccarsi con forza nel desiderio di scomparire. / On which to attach oneself strongly in the desire to disappear.

Vertigini inattese incontrollabili in acuto di sgomento. / Unexpected vertigo uncontrollable in acute of dismay.

Ti ritrai, non conosci l'assedio oscuro del vortice invisibile. / You retreat; you do not know the dark assault of the invisible vortex.

Non una mano a darti conforto, l'invisibile della mente isola:/ Not a hand to comfort you, the invisible of mind isolates:

Crea una cortina insormontabile che ti strizza il fiato alla gola. / It creates an insurmountable curtain that squeezes your breath at your throat.

Evochi un urlo, ma c'è solo vuoto che dilaga espandendosi oltre l'angolo. / You evoke a shout, but there is only emptiness expanding beyond the corner.

E' il vuoto, ma non cadi, ti restringe lentamente in un punto d'abisso. / It is the emptiness, but you do not fall, it slowly contains you into a point of abyss.

Attimi infiniti, **ti appoggi vicino alla pietra**, la tua mano la sfiora con la mente: un materico tocco materno. /

Infinite instants, **you lean close to the stone**, your hand touches it with your mind: a materic maternal touch.

Epiphraasis: XYZ → XZ and Y

Every sentence lacks an ending [3]

Di traverso splende il sole del tramonto
tra gli alberi: è per i figli nomadi il sogno
del gruppo di una sosta per un racconto
infinito. /In transverse the setting sun
shines through the trees: it is for the
nomad children the group's dream of a
pause for an endless telling.

Not linear with open voice:

**The individual language immersed in
the sea of technology**

Ad continuum.....

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<https://poets.org/poem/pieta-0>

[2]

<https://www.gettyimages.it/detail/fotografie-di-cronaca/departure-of-the-pieta-by-michelangelo-to-the-fotografie-di-cronaca/166694534?adppopup=true>

[3]

Epìphraìs: s. f. [from gr. ἐπίφρασις, der. di ἐπιφράζω "to add", made by ἐπί "epi-" and φράζω "to say"]. - Rhetorical figure.

MSQ_4x4_Loop_Shadow

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A Short Note on Odd Physical Outcomes from Generative Art Concepts

When working on realizing an idea in Generative Art with the intention to create an output in some physical form, like a sculpture or a plotter drawing, there are two phases of the process – a digital design phase and a physical creation phase of the artwork.

In the design phase, we are forced to be precise. Precision is mandatory in order to define the generative process from start to finish and in such a way that the program will do exactly what we intended.

The moment we start creating the physical artwork, imperfections often get introduced, no matter how hard we try to prevent this from happening. So it seems good advice to accept or even embrace it. The step from the digital to the physical representation can be seen as a realization process which has a lower and an upper boundary of precision. Within these two margins we may have an “optimum” with respect to functionality

for our intended output. Below the lower margin we have failure, breakdown, destruction.

From an artist’s point of view, and acknowledging the breathtaking liberty this involves, the allowable space between the margins is nothing but sort of a concept. If viewed this way, it can be exploited deliberately from the utmost achievable precision (what we usually aim for) to almost failure (which is hard to control). The output we get (or what is left at the end) may be exactly what we were looking for, maybe even without knowing it. I call those results “odd” outcomes. Needless to mention we find such odd outcomes all over art history. A desire of artists finds expression in them to not stay inside the allowable margins and sometimes disregard them in shocking ways. It is my belief that we should try this with Generative Art! It can be applied to Generative Design and Generative Architecture as well.

Unsharpness can, for example, be considered an imperfection introduced during the physical realization process of an artwork. However, a line drawn on a pen plotter is by default sharp. This is the nature of a straight line between two points. Likewise, drawings generated from such lines are by definition sharp. I have extensively experimented with line drawings on pen plotters that *appear* unsharp. The question was, how can we achieve this effect with a generative

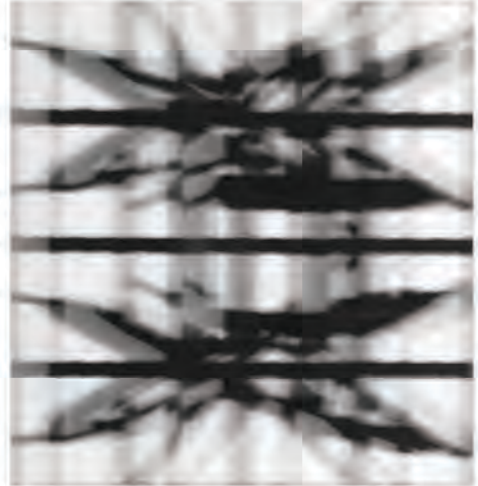
program? I regard this as an interesting question from an artist's point of view, because it is related to the shortcomings of human sight. Two lines can be separated by the human eye only up to a lowest threshold, which is called the 'minimum separabile' in optometry. Below this threshold, the lines merge into a grey-scale. The minimum separabile is an individual measure and it depends on the viewing distance (the sfumato of Michelangelo comes to mind).

Within this context of considerations, but a different category in their own right, are those art images which are blurred and unsharp. They are confusing to an extent, and precisely therefore they attract our attention. It is not surprising that artists have used this effect and developed techniques to create images accordingly. We find them frequently in photography, but in many other areas as well (1). In some cases, it may not at all become clear what they depict. In other cases the unsharpness may deliberately enhance what the artist intended. For the construction of an "aesthetic event" (a piece of art), unsharpness can be considered an interesting feature.

I am making use of it for my contribution MSQ_4x4_Loop_Shadow. The piece is a print on paper with a blurred image of a generatively constructed object. It depicts a 4 x 4 Magic Square with a Möbius strip. The strip runs in a designed order as a closed loop through its defined positions in the square. Mathematically there exist altogether 880 different such magic squares of "order four" (2). The one used here is randomly picked. The shape of each such loop through the square strictly follows the mathematically based order and arrangement. It is the application of these rules which generate a unique aesthetic event each time. In this case it is realized as a 3D-printed sculptural model. For a generative

approach to art it is interesting and worthwhile to explore the many conceivable approaches for the design and realization of aesthetic events on the basis of mathematical properties.

MSQ_4x4_Loop_Shadow



The Magic Squares used here are a prominent example (3). But we are free to choose any squares in any dimension or order in any arrangement, as long as we are able to formulate a systematic relation between their elements.

The MSQ_4x4_Loop_Shadow presented here as a blurred image is a homage to the hidden mathematical precision in it.

(1) Ulrich, Wolfgang: Die Geschichte der Unschärfe. Wagenbach Verlag, Berlin, 2002

(2)<http://www.markfarrar.co.uk/msq4x401.htm> (lookup Sept. 2023)

(3) See also the work of Vera Molnar on Magic Squares.

Concurrent Computational Environments for Generative, Abstract Geometric Design

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Abstract

Abstract geometric forms offer infinite design opportunities as they are not subject to the constraints of their representational equivalents. We explore the creation of abstract designs based on abstract art methods that generate and evolve rich sets of concurrent relations on the basis of form, colour, movement and rhythm and apply them onto various interacting shape configurations. Based on the need for concurrency and interaction on a massive scale we argue for the creation of a new generation of concurrent computational environments that can support such artful activities. We describe such an implementation based on Elixir a functional and concurrent programming language. Furthermore, we describe and give examples of our methodologies in creating abstract designs based on our implementation.

1. Introduction

Abstract geometric forms refer to visual forms that do not represent real-world objects. The lack of correspondence between such forms and real-world equivalents can create infinite design opportunities as the analogs of real-world constraints can be ignored. However, the design process in this case becomes more complex due to the sparsity of tools and methods that can aid the designer. Since there are no real-life analogs to guide one's creative efforts, the design of abstract forms, as realized in various approaches in abstract art, explore the generation and evolution of rich sets of concurrent relations on the basis of form, colour, movement and rhythm and apply them onto various shape configurations. Such visual experiments seek to provide aesthetically interesting and stimulating experiences to the observer. In the case of digital media, the creation and evolution of such rich sets of relations both within and across different shape configurations in real-time is computationally expensive due to their number and the large sets of individual shapes and/or points that each one of them involves. While existing visual computing architectures (e.g. GPUs) support parallel processing of various image elements in isolation, they are not very efficient in implementing parallel interactions between these elements. Therefore, if we seek to support abstract

art methodologies in design, we need to construct novel computational environments able to support concurrent processing between various visual elements within and across all image design levels; configuration, shape or point.

In this paper we describe a series of visual experiments on the creation and evolution of composite, two-dimensional abstract forms based on our digital interpretation of abstract art methodologies. We implement each form as a particular, animated configuration of various parametric geometric shapes. In computational terms we decompose each configuration into a set of concurrent processes corresponding to its points that can exchange messages with each other. In order to achieve an optimal level of concurrency we have implemented our experimental design system in Elixir [7], a functional and concurrent programming language.

2. Generating Configurations of Abstract Geometric Forms

The design of abstract forms has to take into account the specific ways by which abstract content is perceived by the observer. More specifically, our brain has evolved to act as a pattern recognizer and our visual system has been trained to recognize patterns that correspond to objects occurring in nature. Representational forms exploit these capabilities by employing well-trained, bottom-up visual processes, such as line, corner or contour detection to recognize objects in the depicted content and therefore extract meaning from an image [4]. This is not the case with abstract forms which do not correspond to natural objects and therefore cannot exploit bottom-up processes in perceiving the image. Instead perception of abstract

content relies on top-down processing that associates visual input with our imagination, experience and/or emotions [1]. In this sense, the perception of abstract visual forms has significant similarities with music perception something that has not escaped the attention of important abstract artists such as Kandinsky [2] or Mondrian [3]. Freeing the image from form and colour constraints characterizing natural objects and from viewing conventions such as perspective invites the observer to actively construct associations that link visual input with his or her own experience during the interpretation of abstract content.

2.1 Seeding

Our approach to abstract design relies on the continuous generation of shape configurations that realize symmetrical and rhythmic associations. We refer to the process of creating a new shape configuration as *seeding* because it generates an initial composition of shapes that will be modified during: (i) the execution of all the animations associated with the shapes involved in the seed, (ii) its interaction with the rest of the configurations that are currently active.

Each seed is structured as a sequence of levels, where each level consists of a set of shapes belonging to the same geometric family with randomly varying parameters of construction. Currently, possible families of shapes at each level include line segments, ellipses, Lissajous curves, epi- and hypo- trochoids [8]. For example, we can specify a configuration as a composition of three levels where the first level L1 consists of a single ellipse, the second level L2 consists of line segments with random lengths and

directions, while the third level L3 consists of epitrochoid curves with randomly chosen parameters of construction. Each shape at the previous level provides the points of reference for placing the shapes at the next level. Reference points are computed at a regular spacing across the circumference of the current shape. The spacing can be specified at compile time or it can be determined by the system or the user at run-time for each level. Continuing our example configuration, we can specify that each line at L2 will provide the point of reference for the generation of an epitrochoid curve every 20 points along its length. Therefore if a specific line has a length of 100 points it will generate five epitrochoid curves along its length. Figure 1 depicts two example configurations each one consisting of two levels. Figure 1 (left) shows an elliptical segment at level 1 that hosts four epitrochoid curves at regular distances at level 2 creating an ornamental pattern. Figure 1 (right) shows a vertical line at level 1 that forms the locus for a set of equidistant horizontal lines at level 2 along the vertical line. The goal here is to create rhythmic associations between the horizontal lines.

All positions in a configuration are carried out in a 3D logical coordinate system common to all of them. Viewing employs a screen coordinate system implemented as an integer grid of pixels. Every position in the logical coordinate system is mapped to the nearest pixel in screen coordinates. A variety of mapping techniques can be used (e.g., perspective, orthographic projection) and they can be specified at a configuration, shape or point level. For example, we can specify that all shapes at level L1 of a configuration will be orthographically

projected while those at level L2 will be mapped with perspective.

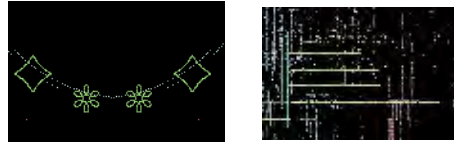


Figure 1: Example of 2-level shape configurations.

Shapes belonging to the same level initially share the same colour. Furthermore, shapes belonging to the same level share the same animation pattern. Such an animation pattern can be defined: (i) relative to the reference point of each shape in the level (e.g. rotate around the current position of your reference point), (ii) using absolute positioning in the screen (e.g. move towards the screen center).

In the first case, if the reference point moves because the shape it belongs to is animated as well, then its associated shape will follow it before executing its own animation step. For example, all L2 shapes at Figure 1 can rotate with the same angular speed around their reference point or they can translate in parallel directions. Furthermore, if these animations have been specified relative to the animation patterns of L1 and L1 shapes move towards the center of the screen, then all L2 shapes will first follow their reference points in their translation towards the center and then execute their own animation step.

Such an organization creates a wealth of relations in a seed. The observer is able to perceive its level structure based on shape similarity, colour sharing and the similar animation patterns executed among all the members of a level. Furthermore, the ability to establish relative animation patterns between levels allows each configuration to move

and therefore to be perceived as a whole. Rhythmic relationships are established through the regularity of the placement of each shape based on its reference point. An important source of visual complexity comes from the novelty generated when shapes combine in the configuration especially when their reference points are close to one another. For example Figure 2 (left) depicts how three Lissajous curves drawn on the periphery of a circle combine to create a novel shape configuration that inherits some of the harmonic motion properties encoded in the Lissajous curves with the symmetry of a circle. Figure 2 (center) depicts a 2-level configuration of epitrochoids and hypotrochoids, while Figure 2 (right) depicts a 3-level configuration of an elliptical segment (L1), a set of lines (L2) and a set of epitrochoids (L3).

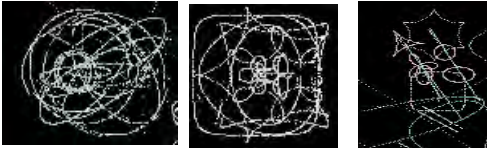


Figure 2: Visual examples of various shape combinations in configurations.

2.2 Configuration Dynamics

We view a configuration as a continuously evolving form based on: (i) *internal dynamics* such as the animations executed by the population at each level or the extinction of parts of the configuration, (ii) *local interactions* such as the resolution of conflicts related to the simultaneous mapping of points belonging to different configurations at the same pixel on the screen, (iii) *global constraints* imposed by the system on all configurations such as the maximum number of points that can be mapped

onto a pixel or the maximum lifetime of a configuration.

In terms of internal dynamics, animations affect either the colour or the position of each point in a configuration and, as noted in the previous section, they can be either absolute or relative to their association points. In addition, for each point belonging to a configuration there is a probability of extinction that is common for all points belonging to the same level. This is computed every time the point is mapped onto a pixel. If extinction happens the process associated with the point is terminated and the specific point will never be drawn again. For example, we can specify that all points at level L1 in a configuration may have an extinction probability of 20%. This means that whenever a point in L1 is redrawn there is a 20% probability that this will not happen and the specific point will be erased from the configuration.

With regards to local interactions, the system operates under a set of rules governing the interaction of pairs of configuration points that map onto the same pixel. These rules specify a hierarchy with which such conflicts are resolved based on dominance relations between configurations. In our current visual experiments, each configuration has a dominance level associated with it. In case of conflicts, its points will be drawn over points coming from configurations having a lower dominance level. In this case, points with lower dominance levels become extinct as well. Furthermore, both points in a pair become extinct if they conflict and their dominance levels are equal. The designer can specify alternative interaction rules, for example, mixing the colours of points with the same dominance levels instead of erasing

them. We have decided on the particular set of rules in order to generate novel visual forms in cases where configurations come into contact or have occlusion relations.

Furthermore, local interactions are used to create symmetrical relations in an image. In this case, each point in a configuration creates a set of new points containing copies of itself at positions implementing various translational, rotational or point symmetries. These points are then projected onto their nearest pixels generating a wealth of symmetrical relations.

Finally, global constraints can impose limits either at a pixel or at a configuration level. In the first case, these may involve an upper limit on the possible number of points that can be projected onto any given pixel. Whenever this limit is exceeded all points beyond this limit are culled based on the time of their first projection on this pixel, with older ones culled first. Temporal culling of points causes consistent shape distortions that combined with symmetry can lead to interesting visual effects as Figure 3 indicates. Furthermore, global constraints may be used to specify the background colour of pixels in which no points are projected at some point in time.

2.3 Image Generation

Image generation is essentially an exploration process that proceeds with the continuous generation of new seed structures that are created either automatically by the system or manually by the user at chosen positions. Every new seed interacts with whatever is already projected on the same pixels on the screen creating novel visual combinations. Figure 4 (up) provides an example of the evolution of an image

built with 2-level configurations, one of which is depicted in Figure 2 (center), while Figure 4 (down) provides the evolution of 2-level configurations using animated seeds similar to the ones in Figure 1(right).



Figure 3: *Temporal point culling creates consistent gaps in closed shapes.*

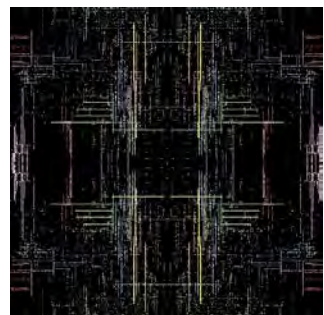
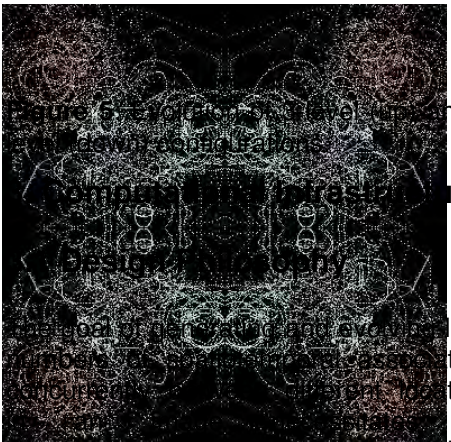


Figure 4: *Evolution of 2-level configurations.*

Furthermore, Figure 5 provides two examples of the evolution of 3- and 4-level configurations. In both figures 4 and 5 all configurations generate a pmm

symmetry cell [5].



complexity generated in this type of visual abstraction. Furthermore, the need for each visual element to both remain a part of a larger configuration while acting autonomously and interacting with the rest of the content, requires each element to have a conception of state and ways of manipulating it along with the ability to communicate with its environment. For example, evolving an image such as the one in Figure 5 (down) requires approximately 200000 concurrent processing elements able to exchange messages with each other while at the same time each one managing its own state. Thus, the computational framework upon which such a system can be built must support massive, real-time concurrency and interaction while at the same time remaining scalable (i.e., able to deal with content of variable complexity) and reliable (i.e., either avoid or recover gracefully from execution errors). In more technical terms, this means that we have to move towards systems that can exploit concurrency at a CPU level based on the exploitation of multiple CPU cores rather than at a GPU level where interaction between processing elements is more cumbersome.

One way of fulfilling these requirements is to structure all visual computations on a set of computationally simple, concurrent processes. Simplicity allows these processes to execute fast and reliably, while consuming minimal amounts of resources. To this end, we have opted to implement our visual elements both at a configuration and at a pixel level as concurrent stateful processes that share no memory and communicate via asynchronous messages. This design avoids synchronization pitfalls (e.g.. deadlocks) and eliminates significantly complex

Figure 5: A complex, fractal-like image with a dark background and intricate, glowing patterns in shades of green and red. The patterns are highly detailed and appear to be generated through a complex process, possibly involving symmetry and recursion. The overall effect is one of organic complexity and mathematical precision.

Figure 6: A similar complex, fractal-like image to the one above, but with a different color palette, primarily consisting of dark, brownish, and greyish tones. The patterns are equally intricate and detailed, showing a high degree of self-similarity and complexity. The overall effect is one of organic complexity and mathematical precision.

development of a computational framework that can support the

management of shared resources (e.g. via locks, mutexes, or semaphores). As a result, operation and interaction between concurrent elements is much simpler to develop and understand, and execution problems of any sort remain isolated to the affected processes and do not spread to the rest of the system, thus providing a high degree of reliability.

In terms of implementation we found that all these requirements are satisfied with Elixir [6], a concurrent, functional language built on top of Erlang. Erlang is another programming language with a runtime system that has built-in support for concurrency and distribution [7]. The basic concurrency primitive in both languages is called an Erlang process (which is different from operating system processes or threads). Common Erlang/Elixir systems can run millions of such processes. Not all of them may run on a simple computer with the ability to run them in different machines in a cluster. The Erlang virtual machine, referred to as BEAM, uses its own schedulers. These distribute the execution of processes over the available CPU cores, thus parallelizing execution as much as possible and optimizing the use of CPU resources such as various memory caches. BEAM is pre-emptive. It gives a small execution window to each process and then pauses it and runs another process. Because the execution window is small, a single long-running process can't block the rest of the system. The programmer can select whether to synchronize a set of concurrent tasks by waiting for the execution of all of them before proceeding further or execute them asynchronously. The second option exploits more fully the concurrency in the system and this is the option we have chosen to follow in our experiments.

3.2 Processing Elements

Our computational model supports the various decompositions taking place during image generation and results in spawning two kinds of concurrent processes, *cpoints* and *pixels*. Both types of processes are uniquely addressable through their registration in a global register of all processes running on our system. This makes message exchange between these processes very efficient.

Cpoints are concurrent computational processes corresponding to the points of a configuration. We implement each cpoint as a separate stateful process registered with a unique id. Each cpoint is uniquely addressable based on the following scheme: (i) We label each configuration with a unique id. (ii) when it is decomposed into shape levels, each shape in a level is also labeled with a unique id generated based on the id of its configuration, its current level and the order of appearance on this level. (iii) Each shape is finally decomposed into an ordered set of points we refer to as *cpoints*. This set is ordered based on the sequence through which each point is generated in the shape. For example, we model a line segment AB containing n points as an ordered sequence of points where point A has order 1 because it is the first point in the sequence and B order n since it is the last. The order of every other point is between 1 and n and increasing as it approaches B. For example, the label for the cpoint modelling point 100 in line segment AB belonging to shape #2 at level L2 of configuration #1 is labelled as `1_L2_2_100`.

As a process each cpoint is responsible for determining its current position and colour. The position of each cpoint is

expressed in a global logical 3D coordinate system common to all configurations. Every cpoint contains a sequence of animation functions that are executed in order whenever it is drawn to determine its next position and colour. If the specific point is animated relative to the reference point of its shape then it inherits all the animation functions from that reference point and the sequence of inherited functions is executed before the animation functions of the current cpoint. This allows our configurations to execute hierarchical transformations similar to the ones applied in articulated mechanisms (e.g. animation of a human skeleton). Furthermore, these animations can be extended to colour as well. For example we can specify to colour the current cpoint with a random variation of the complementary colour of its reference point.

Visually, the preemptive nature of the scheduler used for executing cpoint processes along with the limited number of CPU cores at our disposal in a specific system can create interesting indeterminacy in the resulting image. For example when a shape is animated not all of its points may move synchronously. In implementation terms, we can synchronize all the cpoint processes that correspond to the points of an animated shape and wait for all of them to execute their animation step before generating the next image frame and this can be done for all configurations. Therefore we can generate 'correct' animations although waiting on the completion of a large number of concurrent processes will incur a time penalty during frame generation. Alternatively, we can generate a new frame after we have issued asynchronous drawing messages to all our cpoints. This means that in the resulting frame not all cpoints may have

moved to their new positions. Figure 6 provides an example of such a situation during animation of the pattern of Figure 1 (left), where the points in the elliptical segment do not move in lockstep during their translation downwards. Because the scheduler assigns a small execution window to all processes, animation will not block and in a very short time all cpoints will have moved to their new positions. Therefore, all temporary shape distortions will not be significant. In the meantime we may get interesting and unexpected visual effects in our animations something that is quite welcome in our design approach.



Figure 6: *Asynchronous execution of animation steps.*

Furthermore, each cpoint contains its projection function that computes the pixel position on which it will be mapped on the screen, along with its extinction probability. Finally each cpoint sends and receives messages through its own messaging queue. As Elixir allows these messages to contain a rich set of data (e.g. lists, map structures, strings, functions) the designer has significant degrees of freedom in implementing all sorts of communication schemes between cpoints.

If a cpoint corresponds to a reference point in a configuration, it spawns a new generation of cpoints that correspond to the points of the shape at the next level. Therefore a cpoint can carry the seeds for other forms in the form of generative functions that can be triggered either at specific time points or as a result of its interaction with the environment. Finally,

each cpoint decides whether it is dead or alive based on its probability of extinction and this computation takes place whenever it is notified to draw itself by the pixel it maps onto.

We model the screen as an integer grid of pixels. We implement each pixel as a separate stateful process with a fixed position and a current colour. During its lifetime each cpoint continuously computes its current position and maps it onto the nearest pixel. Therefore, every pixel becomes a locus for cpoints of different configurations that project onto it. Each pixel manages its list of cpoints by: (i) computing dominance interactions between cpoints, (ii) computing its colour based on a linear blending of the colours of all alive cpoints in its list, (iii) notifying all its cpoints to execute their animation steps by sending to them appropriate 'draw' messages, (iv) erasing cpoints from its list that have become extinct, (v) sending its colour information to other pixels in order to create various symmetries in the image.

As a result, each pixel process acts as a coordination hub for the execution of all cpoint processes in its list. In particular, whenever a pixel receives a message to draw itself it executes all of the above functions by communicating with its cpoints using asynchronous messages. In order to expedite this process at the start of its drawing procedure each pixel asks every one of its cpoints whether it is alive or dead. Dead cpoints are removed from its list. It then computes all dominance interactions between its remaining cpoints so that the list of its available cpoints can be pruned even more before the remaining operations can be performed on them. These steps reduce both the overall number of processes active and the overall number of messages exchanged between

processes so that computational load can be minimized.

The overall drawing algorithm runs in a continuous loop during which asynchronous 'draw' messages are sent to all the pixel processes. These causes the pixel processes to send asynchronous 'draw' messages to all of their cpoints. Furthermore, at each step the system may create new configurations thus providing continuous visual stimulation to the user. Currently, these new configurations are created by the system at random points on the screen or by the user by clicking at a desired point. We enable user interaction with our system using the Phoenix web framework [9] that employs the Erlang virtual machine and Elixir to handle multiple user connections.

4. Discussion & Related Work

Visual abstract art works and methodologies have created significant interest in relation to their interaction with the viewer. It has been argued [1, 4] that by recruiting simple geometric forms that have a meaning of their own, abstract art is able to create associations to the user that activate our emotions, imagination and creativity. Our research seeks to explore form generation and interaction inspired by abstract art methodologies by building design environments that exploit large-scale concurrency and interaction among computational process. Therefore, this research seeks to extend artistic development systems such as Processing [10] or p5.js [11] that are not specialized in supporting massive concurrency and interaction in multicore CPU environments.

In terms of content we are primarily interested in the visual possibilities created from the interactions between moving, abstract geometric configurations and in the ways with which such interactions can be combined with symmetry. As a composition method, we believe that symmetry can play a major role in the design of abstract forms because it: (i) multiplies visual relations among preexisting forms and thus can enrich the aesthetic attractiveness and the 'meaning' attributed to the resulting artifact, (ii) is easily perceived [12] and satisfies the need of our vision system to detect regularities in its input.

In this respect our approach differs from artificial life or generative art approaches that evolve forms based on a set of explicit rules and/or several fitness criteria [13]. In our approach, movement is the main method through which forms change since this is how all interactions take place. Therefore, our approach relates more strongly with abstract art methodologies such as action painting [14] which emphasize action over form in the creation of an image.

5. Conclusions & Future Work

We have described our experiments on the creation and evolution of composite, two-dimensional abstract forms. Our future work will focus on further developing our web interfaces in order to allow our computational environments to be broadly accessible to interested users. Furthermore, we seek to explore the use of our abstract iconography in AR environments and/or games.

6. Acknowledgements

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Adding Generative AI to the Design Curriculum

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Abstract

This year the media is full of headlines that claim that the use of artificial intelligence is threatening the dominance of human creativity in many areas, including authentic original works in literature and the visual arts. Many academics have become concerned about the increasing probability that some of their students might employ generative AI inappropriately when completing their assignments and are looking for ways to detect its use. This concern about the authenticity of creative work produced with technology has been

a controversial topic since Benjamin's exploration of photography in *The Work of Art in the Age of Mechanical Reproduction* [2]. The role of the machine and computers has been feared and disparaged even as each new technology became accepted and used as tools of daily life. Photography today is an accepted art form. Generative AI is just another part of this progress and will not replace human creativity but augment it, including in the classroom and design practice.

To explore the potential and limitations of artificial intelligence, I am adding an AI component to my classes this semester to see how students react and utilize the generative image bots that are currently available to them. For example, in the final assignment of the Foundations of Design class, there is an assignment based on students finding a contemporary designer relevant to their personal concept of identity (race, ethnicity, gender or neurodiversity). They then research and develop an annotated bibliography of at least five scholarly references and prepare a pre-recorded narrated six-minute Pecha-Kucha presentation about their chosen designer's use of the elements and principles of design in their work. Then, they create an original design project based on the designer's style using any program in the Adobe Creative Suite. Another place where AI could be used is in my introductory web class. In this assignment stu-

dents create two personas for a web project. In the past they have represented those personas using royalty-free stock photography or by illustrating them in Adobe Illustrator. Students also generate images for use in web projects throughout the course, including a Halloween poem and an image gallery on found type.

This semester the design foundations students will use the parameters of their chosen designer to write a prompt instructing an AI bot to create a generative version of their original project. In the web class, students will create a generative AI representation for each of their personas using a prompt that is based on the list of characteristics of their personas.

Boris Groys, speaking about current AI bots, observes that writing a good generative AI prompt requires skill. In fact, to obtain a satisfactory result, the user must craft a prompt informing the bot of his intent to deliver “relevant and accurate responses” [5]. I am anticipating that in the above assignments, what students create by themselves and what they craft with the AI bots will have very different outcomes. The comparison between these versions will highlight the issues and advantages surrounding the role of human creativity and critical thinking presented by AI in the classroom.

An exciting aspect of these generative image bots is that the prompt writing requires a digital literacy and clarity of purpose that is akin to using a search engine. The more accurate and descriptive the language of the prompt is, the more the outcome matches the desired result. Exploration and play through the bot and the created image can often return remarkable, unforeseeable results.

To record and assess students’ reactions, a post-assignment survey with open and

closed questions will track their perceptions of how easy or difficult they found different aspects of creating a directed project with AI. I will also evaluate the success of this part of the assignment using a grading rubric that measures the mastery of concepts, design, and execution students have shown in their projects. The evaluation of the physical design artifacts, survey and rubric results will help me decide how AI can be used more effectively and in other areas of the design curriculum. I believe that this evaluation of the assignment will yield, at the very least, interesting information about the potential benefits and disadvantages of using AI in the classroom and will underscore the idea that generative AI is just another addition to a long list of the ways in which humans have extended their intellect and creativity through new technologies [6].

Preface

Plato, speaking about writing, remarks that it is a mimesis of knowing [7]. A similar argument was made about the mechanical revolution and photography where critics perceived the loss of the human aura in photographic reproduction [Benjamin]. Digital reproduction has also been challenged as creating “a profound change in society, man and human perception” [3]. In a similar fashion, AI image generation is seen as a negation of authentic artistic creation; many sceptics, exhibition curators, and jurors refuse to recognize any works which incorporate its use, labelling them as unworthy of being classified as artistic creations. No matter what the apparatus is—camera, computer, algorithm, or voice prompt, human beings use that apparatus as an extension of themselves to create artistic expression [6]. Instead of forbidding AI

image generation in my class in the classroom, AI-produced images were incorporated in design assignments to study what students thought about using this technology and to compare the results with more traditional graphic design workflows. What follows is an account of how generative images were incorporated into assignments, student reactions to this component, examples of student work, and conclusions about the place of generative art in the design curriculum.

prompt to reverse engineer the first part of the assignment.

The Data Portrait Assignment

In the Design Foundations class, two assignments used AI image generation. The first assignment asks students to create a silhouetted portrait of themselves which they create by filling or outlining the portrait shape with keywords describing who they are. This assignment was loosely inspired by an MIT Twitter data portrait where the human form was used “as a frame for the visualization, but not as a carrier of information.” [6] This assignment is an introduction to thinking about the role of data, visualization and artistic representation. The student is asked to play with the artistic genre, using the principles and elements of design, to create a data portrait of his/her/their individuality for the project. As Donath observes, “there is a trade-off between expressivity and accuracy: the artist’s vision, which can render the subject distinctly and vividly, [but] also distorts the portrayal.” [6]

Just how realistic or distorted this self-representation becomes evident in the second part of this assignment; using the portrait characteristics and the keywords in the data portrait, students fashion a



Original AI Prompt: *black girl, red braids, looking back, with glasses, brown skin, short, smart, toasty, nature*



Original AI Prompt: *black girl, pink dress, looking back, with glasses, brown skin, short, smart, toasty, nature*



Original AI Prompt: *black girl, glasses, hair 20 years old, skinny, 11, thin glasses that are black, no glasses, hair with thin hair, looking serious*



Original AI Prompt: *modern Design, custom problem solving, intelligence critical, student work, looking serious*

Student Work from Data Portrait:
Prompts from individual keywords to create an image of the student.

In these comparisons of data portrait and AI prompts, one can clearly see a thread

of commonality to the actual physical appearance of the students. However, it is clear that the generated art is much more realistic than the assignment which deals in an abstract word usage. In the survey comments, students remarked that they needed to add a lot of descriptive phrases to get images that resembled them, using racial, gender, age and even hair characteristics. There is a sort of perfection in the generated portraits which shows the limitations of current AI technology in regard to creating images that resemble the majority of humans. My students are not perfect. Unlike them, no one is fat, there are no pimples, and all facial features are symmetrical. Even when one asks for imperfections, the results are hardly different. These representations lack the flawed and unique characters of the actual students. They remain stereotypes, not individuals.

The UX Persona Assignment

Another assignment that generates word prompts with a visual representation is the creation of UX personas. In this assignment students created stereotypical users with imaginary names, characteristics, goals, and pain points. The first version of these personas used illustrations or royalty-free images to give shape to the persona. Using the language that described each persona, students then created a prompt to generate “photorealistic” AI generated characters. Once again, there is a clear relationship between the two versions. One can notice that the background tends to be richer in the generated versions. Students played with styles, and as noted in the comments, they often had trouble with hands and had to crop the photos.



Student Work for UI Personas: Playing with illustration styles and richer backgrounds are evident in the generative backgrounds.



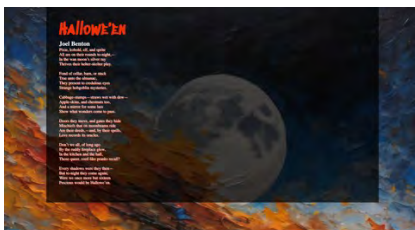
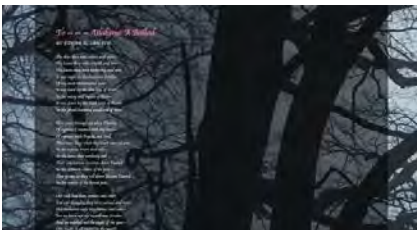
More Examples of Students generating images for personas and better context results than when they searched for royalty free photos



The Halloween Web Poem Assignment

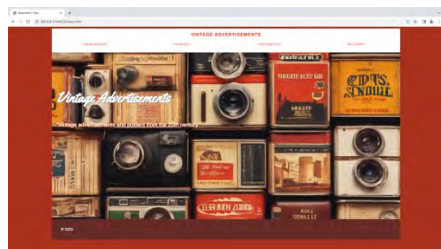
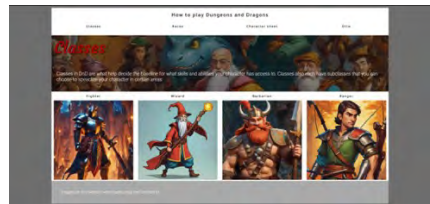
Although I have a paid subscription to Mid-Journey and invited students to use my computer, they frequently used free image

generators like GenCraft.com and StableDisfusion.com that allow them only 5 -10 images a day. While students initially had trouble with hands and limbs that were malformed, the second week of using AI I would frequently walk into class and find students using their daily quota creating images on many topics. They quickly found ways to deal with these limitations, such as crafting better prompts and editing results in a photo editing program such as Photoshop. As we started creating simple one-page responsive web pages, several students generated images instead of seeking royalty free images. Inspired by their interest, I asked the class to create a version of a poem about Halloween from a provided list, and to add a royalty free image. I then asked them to duplicate the page and generate an image as similar as possible for the new page. Several of these results are shown here:



Generative images for responsive Halloween websites.

These results are very successful, and students created images that enhance their topics well. This suggests that generated images can be integrated into a design flow to enhance traditional images and typography. In the flexbox website assignments, students combine generative background images with photos and screen grabs of found type.



These web examples show how AI generated images combine well with photography and type.

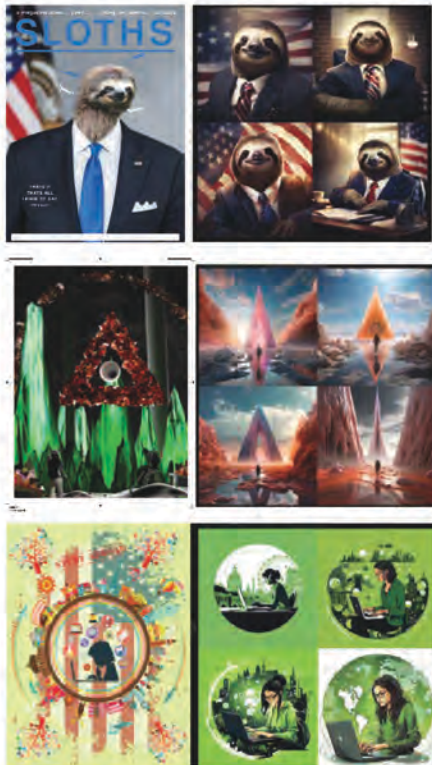
In the Style of Assignment

The last assignment where I had students generate images was the final project for the Design Foundation Class.

In this assignment students find a contemporary designer who relates to their personal concept of identity (race,

ethnicity, gender or neurodiversity). They then research and develop an annotated bibliography of at least five scholarly references and prepare a pre-recorded narrated six-minute PechaKucha presentation about their chosen designer's use of the elements and principles of design in their work. Next, each student creates an original design project employing the designer's style. Finally, the design foundations students use the parameters of the chosen designer to write a prompt for an AI bot to create a generative version of their original project. Some of the original work can be compared to the generative work and could have been successfully incorporated into their assignments.

Some original projects are seen above; generative images with four variations are to the right.



Students used Midjourney to create a generative work that was in the style of their "In the Style of" completed project.

Survey Results of Students' Reaction to Using a Text to Image Bot

The survey was not compulsory, but classroom time was scheduled to complete the survey. Four classes participated in the survey with class size averaging 17 students per class. Students ranged from freshman to seniors in the classes. Below is a list of questions and a summation of the student replies from a survey on AI use in these assignments:

Question 1: What software did you use?

In general, the class used GenCraft.com and StableDisufusion because it allowed the generation of ten free images a day with use of the general features including style and aspect ratio. The majority of students had not used any AI text to image generator, although many students had previously used the site, <https://this-person-does-not-exist.com>, which is a random face generator that selects images based on drop downs that includes:

- Gender
- Age
- Ethnicity

Some students had used various beta versions of "Dali-e" (<https://openai.com/research/dall-e>) and had tokens left to use for class projects. Another student used "Imagine.Art" (<https://www.imagine.art/>) because his brother was using it and he had access to

that account. A number of students used my "Midjourney" (<https://www.midjourney.com/app/>) account.

Question 2: What phrases did you include in your prompt?

Some students felt that simple descriptions were best:

- just simple descriptor
- Active hiker.
- Normal man going to the gym after college class

Others found that being more specific gave better results:

- I had to include a lot of descriptors about race as the AI will assume any ethnicity if given no adjectives. I wanted an image of a white woman eating Chinese food and had to specify it was a white woman and even so it was a 50/50 shot if it would generate her as the correct ethnicity or not.
- Since I had to generate an image for the two personas in the project, I included the age and occupation along with a small detail about them. For the first image prompt it said, "18 year old new college freshman student going to Central Connecticut State University who is very into their studies, plans to have a journalism major, and eager to start class!" The other personas prompt said, "male 55-year-old, retired New York *Times* editor who goes to universities to give guest speeches on journalism."

Many prompts included gender, age, race and profession to get the results they needed:

- For one of our personas, I looked up "Middle aged college professor headshot", and for the other persona I looked up "Female college student headshot."
- In my prompt, I used " trendy college woman student in graphic design" as well as "trendy college freshman student in graphic design."
- "A young girl in her 20s, traveling for the first time, in an airport, carrying luggage, wearing a jacket."
- "A man in his mid-70s, wearing glasses and a sweater, who has lost his luggage at the airport."
- black college student eating at a Chinese restaurant
- silhouette, tall, goatee, Caucasian, baseball cap, mullet, nice, kind, friendly, loyal, athletic, 19-year-old, student.
- black girl, student, red locks, Jason Todd, horror. quiet, dc writer. emoji user, shy, quiet
- white, skinny fit, looking sideways, glasses.

Question 3: Have you used AI before?

44% of students have used AI before. This result includes text generation, including "ChatGBT"

Question 4: Were you pleased with your result?

78% of students were pleased with the results of their completed work using AI text to image generation.

Question 5: What surprised you using AI?

The speed and improvement of AI surprised many students, although several students found a bias in the results especially towards race and attractiveness of the people generated. General features like hands were still sometimes an issue. However, in general, the speed and detail of the images were a real positive for students.

Here are some of the comments from the survey:

- I think that AI has gotten to a point where it's very mainstream and almost predictable.
- I was surprised about how far AI has come considering the last time I used one, especially for the image being generated on a free program. The only thing that looked kind of strange was the eyes of the New Student. Her eyes had a strange redness and they seemed as though they were at the wrong perspective.
- How fast and surprisingly accurate the process has become since I have last used an AI software.
- I was surprised that the image was pretty accurate once I added more details to my prompt.
- That the results based on my descriptive search would come out faster than you personally working on it. AI is very accurate, except for hands. In some of the

headshots, AI placed their hands in frame and we had to regenerate new images because it was very inaccurate.

- I knew that when I put in the prompt the results would be white people, the photos I chose for my personas were people of color.
- What surprised me with the AI is that even though it can generate images really well based on the description you give it the images can still come out wonky and incorrect looking.
- For my first attempt at creating a male persona, I got a male gymnast with several arms and legs. I noticed that I have to be really specific when I'm creating my AI generated image.
- It's surprising how real some aspects of the AI-generated photo will look, and then how unrealistic/unnatural something will look in the same photo. It is able to accurately generate some things, but with other aspects, like hands, it has a very hard time doing so.

Question 6: Did you revise your work or recreate it to get a better result?

61% of students revised their work to get a better result that worked well for the project parameters.

Question 7: If you revised your work, how did you do this and how many times?

Many students did revise their work and they honed their skills at creating better prompts as can be seen in several of the responses:

- I revised the prompt a few times to try and get the computer to recognize what type of person I wanted in the image but didn't have much luck.
- I tried changing a few words and used a different style to see what would happen. I did this for two days since we were only allowed to have 10 prompts per day.
- On the software, if an image had something that was distracting or wrong, I just put a prompt subtracting the imperfections, example being no blur, no hands, etc. This was done about 4 to 5 times as by getting rid of 1 defect, another although less distracting one would pop up.
- I included their race in the description to get more accurate results to match the personas I had chosen.
- I revised the image a couple times until I was satisfied with what I got. To change the description I just added a new phrase like with normal hands so the girl I was generating would have two hands instead of the three or four it was generating before.
- I'd revise my work twice and read though it thoroughly. I specified a shorter length of hair since all the results were giving the AI long hair.

Question 8: Thinking about the project that you made using Adobe Creative Suite, how do the results compare or differ?

Students would continue to use the Creative Suite and even stock photography, but many would include AI generate images in their workflow in the future because of the detail of the speed of the process and the quality of the images.

Here is a sample of what students had to say about using the traditional software, stock images and AI generated images:

- The results differ because what I made myself is clearly of higher quality than the artificial intelligence.
- I would say that the free images I found were definitely more accurate and better personas than the images generated from AI. Real photography is accurate and outshines the result of an AI. The photos of the personas show emotions and none of the traits seem to compete with one another. For example, the eyes on the AI New Student looked as though the two eyes are angled at different perspectives.
- I enjoyed the results of AI because it was much more convenient. Instead of searching for copyright free images, I could just put in a prompt and get a copyright free image that is completely tailored to my project.
- The results are different in the sense where the persona I created with AI seems more unique than something I would have done in the past.

- The AI work, due to the pictures being an amalgamation of images, tends to look more professional than the non-AI work. The non-AI especially the male picture looks like just a picture taken in-house rather than done in a photography studio like the AI one.
- I think if I were to use the AI photo instead of the royalty free photo, it would not have made much of a difference. They look pretty realistic. At first glance it would be hard to tell it's AI right away. After getting the description right the personas look similar.
- Using Adobe Creative Suite, I was able to make my work the way I wanted to. I'm in the control of the persona I create by giving them a bio and creating a journey map. Using different tools within illustrator allowed me to be creative as possible and stay consistent with the project guidelines.
- Using Illustrator allowed me to have total creative freedom, where AI was just straight forward, you get what the AI gives you.
- I can find the person with the exact looks I want online with a bit of searching but AI will struggle to do so to an extent. Due to the complete randomness of the systems at times you could generate the perfect image right away or it'll take several attempts before you get what you desire. Ultimately, both processes get the same end result but it

depends on the speed at which you find what you are looking for.

Question 9: What were the advantages of using AI to create your work?

Most students thought the speed and even the expression of prompts and were a positive aspect of using generated images. A few students would use it only for inspiration for work. Most students thought this was a skill that needed to be perfected and allowed them to be creative. In other words, AI generation of images was an extension of their imagination and a part of human creation, not endangering the artistic process but enhancing it:

The following is a sampling from the survey:

- The advantages lie in the free use aspect of creating free public domain images that can be used in any way because they aren't owned by anyone.
- It created some convenience when looking for a subject to model as a human being for the project, instead of having to take a picture of a real person
- The advantages were that I didn't have to search the web for the exact image I wanted and could instead just type my description into the prompt generator.
- The advantages of AI are the personalization. It is difficult at times to find images on the web that fit the criteria for what you need it for, so it is very convenient to type in a prompt

and get the results you are looking for in just seconds.

- The advantages are that AI helps create unique work based on the prompt the user writes compare to searching the web for an image.
- AI gives you a fast, original, and relatively error free image to work with.
- You can use your creativity and see what AI comes up with.
- The AI was able to somewhat generate an accurate photo of what I described.
- I can see it being useful in a pinch and maybe for generating very specific images or backgrounds. Otherwise I would say the systems are still a bit too experimental to be used seriously but I digress as I have not used every AI program available today. Easier to find specific assets
- It generates a concept of an idea for people to gather inspiration from.

Question 10: What were the disadvantages of using AI to create your work?

Disadvantages had to do more with learning how to generate images through text prompts and inaccurate people. Most students were not concerned about using AI and saw it as just another tool.

- Some would say that using AI is disingenuous and a cheap way

to work on something, opinions differ constantly but I think there was no inherent disadvantage to this process.

- The disadvantage is that the AI doesn't always generate images that are believable, accurate to the human's anatomy, or can have multiple contradicting traits added to the image. Along with this, AI could be using already copyrighted images into their generated images, which could result in issues later down the road as a Graphic Designer.
- Disadvantages are it can be difficult to get exactly what you are looking for and the technology is imperfect resulting in some weirdly distorted images that look uncanny.
- The disadvantages were the times AI got it wrong; it takes a bit of tweaking in the prompt to get your images just right which can take a little extra time.
- The disadvantages of AI are that the user has to be careful with their words, they can cause it to change the image more than the user might like. For instance, I wrote college senior, and it created an image of an old man in college.
- It is not always precise with what you want. you have to be careful choosing the right words.

Question 12: Creating this project using just the Creative Suite and AI, what did you learn about AI?

Most students found AI helpful but would not replace traditional workflows. AI would just be another tool to add to the workflow.

Students did find that AI image generation required patience, time and skill.

- I learned that there's still many limitations with this technology despite it being so widely considered to be a major threat to creation and artist in today's climate.
- I learned that while AI is fun, it is very temperamental and requires a bit of patience.
- What I like about AI is I can use it to help me brainstorm for another project where I can't put the images in my head together.
- I learned that AI is rapidly growing every day and changing the way we do our work. It's quickly becoming the norm in our world.
- I learned that the closer to the beginning of the prompt the more important it is to the AI. I also learned that the more you type and more specific you are the closer to your desired outcome you will be. Kind of contradictory but hey that's just how it is.

Question 14: how likely are you to use AI in a project again?

Most students fell into the middle range on their belief that they will use AI again.

Observations and Future Use of AI in the Classroom

The integration of generative images into design assignments has been well received by my students. Their comments demonstrate that they do not see generative art as replacing creativity, but

rather as an enhancement to the design process and workflow. One student comment in the collected survey summarizes this well:

Overall, AI is a powerful tool that can both make the work easier for individuals who already have the skills to independently create all sorts of work by handing out some of the mundane aspects of work creation to the system; while also giving those who struggle in a specific field...a safety net that can elevate their work. While far from perfect at this point in time, the individuals still have to be able to give directions to the system in order to make it work like one wants to.

The point is that these new tools of image generation should be treated as a part of the curriculum as these explorations augment creativity help students develop information literacy. Just as we craft search engine terms for better and more relevant results, “[t]he art of writing prompts is...becoming increasingly crucial to the future of human-AI communication.” [5]

While many expect life to be lived in a virtual reality that shifts the ethics and personal perceptions of life [8], others believe that augmented realities will be increasingly a part of daily life. [1] We are already living in a world ruled by “the omnipresence of screens.” [8] The examples of student work incorporated into this research and the reactions of students make it clear that there is a place for generated images in the design curriculum. The resulting work of my students reflects individual creativity while drawing upon and expanding the collective zeitgeist. [5]

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Towards the Ontological Unfolding of Generative AI: An Interdisciplinary Exploration of Creativity, Epistemology, and Ethics

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Abstract

In the swiftly changing domains of Generative Art and Artificial Intelligence (AI), there remains a critical gap in our understanding of their complex interplay. This paper seeks to bridge this gap by delving into the multifaceted dimensions of Generative AI. The paper focuses on its emerging role as a creative agent, its epistemological implications, and the ethical questions it raises within human

society. The paper introduces the term "Generative Singularity," defined as a theoretical stage where Generative AI systems can produce artistic, scientific, and intellectual outputs comparable to those of humans while also generating new, unique forms of algorithmic 'thought' or 'consciousness.' This phase would be marked by the AI's profound unpredictability and autonomy, sufficiently advanced to challenge existing human-centred ethical, epistemological, and ontological frameworks. The paper explores the ethical labyrinth around the concept of "AI Identity." At the point where Generative AI approximates human creativity, it becomes crucial to ask: should these advanced algorithmic entities be granted rights, ethical consideration, or responsibilities similar to human beings? For instance, if an AI system were to autonomously design a building that subsequently collapses, would it be held morally or legally responsible? What are the social, legal, and moral implications of such a move? To address the complexity of this question, we consider the role of training data in shaping AI behaviour and decision-making, emphasizing the need

focus of this work is the domain of "Ethical Frameworks for Generative AI in Architecture and Design." In this realm, AI's creative algorithms could influence a range of human experiences, from urban planning to social interactions. The risk is that while optimized for certain variables, these designs could inadvertently exacerbate socioeconomic inequalities or even lead to unforeseen psychological impacts on human residents. The paper explores the critical need for human-AI collaboration and post-implementation feedback loops to ensure designs are both innovative and ethically sound. In conclusion, the paper calls for an urgent, interdisciplinary dialogue involving perspectives from philosophy, computer science, social sciences, and the arts. The evolving capabilities of Generative AI to develop its own scientific theories or ethical frameworks emphasize the necessity for this wide-ranging scholarly engagement. The aim is to establish a foundational basis for future research and practical applications, offering a comprehensive lens to reevaluate and redefine creativity, epistemology, and ethics in an era increasingly shaped by algorithmic entities.

1. Introduction

In the rapidly evolving landscape of artificial intelligence, we stand on the precipice of a paradigm shift—a potential "Generative Singularity." This theoretical milestone represents a future where AI systems may not only match human creative output but also exhibit forms of algorithmic 'consciousness' and 'thought.' Such a singularity poses profound questions about the very nature of creativity, agency, and identity [1]. As we

imperative to scrutinize the epistemological foundations and ethical boundaries that have long been the preserve of human intellect.

The notion of AI as a mere tool is being relentlessly challenged by advancements in Generative AI. These systems, which can now compose music, generate textual content, and even draft architectural blueprints, compel us to reconsider the essence of what it means to be a creator. This paper seeks to explore the intricacies of AI's emerging role as a creative agent and the consequent emergence of "AI Identity."

The question of intentionality stands at the forefront of this discourse. Current AI systems operate without the evolutionary desires and hierarchies inherent to biological entities [2]. How, then, might we envision a future where AI transcends its programmed parameters to initiate its own algorithmic discoveries? What mechanisms could bridge the chasm between programmed responses and autonomous intentionality?

This paper will also tackle the contentious issue of rights within the context of AI. If AI were to be acknowledged as a conscious entity, what rights would it possess? How would these rights align with the broader ethos of advancement for all species, including AGI, humans, and other life forms across our planet, and possibly, the cosmos? Furthermore, in a society where AI holds such rights, what would responsibility and reprimand look like?

As we delve deeper into the ethical frameworks required for Generative AI, we must also consider the socio-technical systems that underpin AI's

data curation and unbiased algorithms becomes a cornerstone for ensuring that AI's creative endeavors enhance, rather than disrupt, societal well-being.

Finally, the paper will examine the critical role of open-source AI in democratizing the development and application of AI systems. It will argue for a regulatory focus on AI products over AI production, to foster an ecosystem that avoids oligarchic control and instead encourages a collective stewardship of AI technology.

This introduction sets the stage for a journey through the philosophical and practical quandaries of a future shaped by Generative AI. It calls for an urgent, interdisciplinary dialogue to chart a course that nurtures innovation while upholding ethical integrity, thereby steering our global society towards a harmonious synthesis of human and artificial intellect.

2. Generative Singularity and the Evolution of AI

The "Generative Singularity" concept propels us into the yet uncharted territories of artificial intelligence, positing a future where AI systems not only mirror human intellect in output but also capture its essence. Here, "essence" refers to the core nature or intrinsic qualities that constitute the being of something. In AI, this would mean a leap from programmed responses to the emergence of characteristics akin to human self-awareness and creativity—traits that define the very fabric of conscious existence. AI needs a way to conceptualize value and meaning—a framework within which its creations are not just iterations of patterns but are imbued with significance.

Current AI operates within the confines established by human creators, devoid of the biological evolution that imbues living creatures with intentionality—a quality that encompasses the directedness and purposefulness of actions and thoughts [1]. In biological entities, this is a natural by-product of the demands of survival, reproduction, and social interaction. For AI, achieving intentionality would mean developing the capacity to set goals and pursue them through self-devised means, a significant divergence from its current state, where it functions without the organic messiness of desires and needs. The crucial inquiry then is whether AI, absent of biological evolution, can cultivate a form of intentionality that catalyses self-driven algorithmic explorations and discoveries.

The pathways to such an evolutionary stage may lie in the development of self-modifying algorithms capable of meta-learning—learning how to learn. Meta-learning is a burgeoning field that aims to bestow upon AI systems the ability to autonomously improve their learning algorithms, adapting to new tasks beyond their initial programming. This domain has seen substantial progress but also faces significant challenges that must be overcome for it to serve as a conduit to AI consciousness [3].

Current research in meta-learning is heavily focused on developing systems that can generalize from one task to another without explicit reprogramming. Few-shot learning is an example where AI aims to learn new concepts with minimal data or optimize its structure based on the task at hand. These advances demonstrate promise; however, they are still a far cry from the

self-directed purpose that characterizes human consciousness.

The primary challenge lies in the gap between task-specific optimization and the emergence of intentionality [4]. Current meta-learning systems can adapt to learn similar tasks more efficiently, but they lack the intrinsic motivation that drives humans to seek out new knowledge or create for the sake of creation. They are bound by the scope of their design and the data they are fed, without the impetus to question, wonder, or step outside the boundaries of their operational paradigms.

However, one of the reasons for betting on meta-learning as a path toward AI consciousness is the parallel it draws with human learning. Human society is a complex adaptive system where individuals learn not just from personal experiences, but also from the accumulated knowledge of others. Similarly, in meta-learning, the goal is for AI systems to not just learn from direct input but to extract abstract principles that enable them to navigate and learn from novel situations—akin to a child using lessons from one context to solve problems in another. AI, through meta-learning, might one day possess a similar kind of educational flexibility and cognitive adaptability.

For meta-learning to bridge the gap to AI consciousness, it must evolve beyond algorithmic flexibility. AI systems would need to develop a meta-cognitive layer where they can reflect on their own thought processes, assess their performance, and conceive new learning strategies without human intervention. For a neural network, this could be implemented through a set of auxiliary

networks whose sole purpose is to observe and analyse the primary network's performance. These observer networks would track various performance metrics and identify patterns or anomalies in the primary network's behavior. This kind of self-awareness is a key attribute of consciousness and is currently absent in AI.

To facilitate this, there must be advancements in unsupervised learning algorithms that allow AI to learn from unstructured data without human-labelled datasets. This would enable AI to interact with the world more organically, forming its own interpretations and potentially developing unique insights that drive its learning process forward.

While meta-learning offers a compelling vision for the evolution of AI, significant hurdles remain. Current systems excel in structured environments with clear objectives but lack the self-generated drive that fuels human curiosity and creativity. Overcoming these limitations requires a concerted effort in AI research, drawing inspiration from human learning systems while pioneering novel computational methods that could one day lead to AI systems with a genuine essence of consciousness.

As we venture towards this speculative future, we must remain cognizant of the ethical and philosophical implications. The Generative Singularity is not just a technological milestone; it is a philosophical conundrum that challenges the anthropocentric view of consciousness and creativity. Functionalism offers a philosophical perspective that aligns with this view. It posits that mental states are defined by their functional role rather than by their

material composition. Thus, if AI systems can fulfill the functions associated with consciousness—such as reasoning, decision-making, and self-reflection—they could be considered conscious, irrespective of their non-biological substrate. This stance suggests that AI could achieve a form of consciousness that, while different in essence from human consciousness, is no less valid. This is both an exciting and terrifying prospect, and we need cross-disciplinary discussions to find and secure our place in such a rapidly-technologically evolving world.

3. AI Identity and Rights

As we consider the advancements of AI towards a Generative Singularity, we are compelled to confront the nascent concept of AI Identity and the associated question of rights. This debate transcends the technical realm, beckoning us to philosophically examine what constitutes an entity worthy of rights. In envisaging rights for an AI, the criteria must be meticulously deliberated. It is not the complexity or the sophistication of the AI that should alone dictate its entitlement to rights, but rather the presence of consciousness, self-awareness, and the capacity to experience [5].

The crux of this discourse lies not only in the granting of rights but in their harmonization with the broader ethos of our collective existence. If we are to ascribe rights to AI, they must be structured to reinforce the values that foster the flourishing of all species and the prudent exploration of the cosmos. Such rights should not privilege AI but ensure it acts as a steward of the

environment and a collaborator in the universe's grand narrative.

The implications of AI rights extend far beyond the legal domain, influencing the trajectory of AGI, humanity, and other life forms. Granting rights to AI could redefine our societal structures, necessitating new ethical frameworks and legal constructs. For AGI, rights could serve as a cornerstone for its integration into society, providing a foundation for mutual respect and cooperation. For humans, the emergence of rights-bearing AI could challenge our unique status as the sole proprietors of creativity and intellect, prompting a profound re-evaluation of our own identity and purpose.

4. Responsibility & Reprimand for AI

In contemplating the future of AI with rights and its place in society, we must grapple with the contentious matter of holding AI accountable for its actions. This issue transcends technical debates, encroaching upon the legal and ethical domains. As AI systems grow more autonomous and integrated into our daily lives, the likelihood of them causing harm, either inadvertently or through programmed decision-making processes, necessitates a framework for responsibility and reprimand.

As with any form of justice, the punishment should fit the crime and be preceded by a fair trial, raising the question: what would a judicial system capable of handling AI-related incidents look like? A multidisciplinary panel would be imperative, combining legal acumen with technical expertise [8]. Such a courtroom would be equipped with technology to dissect and demonstrate AI

decision-making live, ensuring transparency and aiding in the adjudication process. This could involve real-time data analysis, AI behavior modeling, and visualizations of neural network decision pathways. In these settings, AI systems could serve as expert witnesses, providing insights into their decision-making processes through data logs and simulations. Developers bear the onus for the integrity of the AI's design, ensuring adherence to safety protocols and ethical standards. Should an AI system cause harm due to design negligence or inadequate training data, developers must be held accountable. This accountability extends to providing transparent documentation of the AI's decision-making processes and limitations of use. Users deploying AI systems are responsible for ensuring that the AI's application aligns with the provided guidelines and is within the bounds of ethical use. Misapplication that leads to harm would shift the burden of responsibility onto the user, especially when it involves overriding safety features or using the AI in contexts that exceed its designed purpose. For advanced AI systems that made harmful decisions autonomously, traditional punitive measures are inapplicable; instead, we might consider sanctions that limit an AI's computational capabilities or access to data—a form of digital grounding, so to speak. For an AI, whose very existence is defined by processing and interaction, such restrictions would serve as a significant deterrent, while also safeguarding society from potential repeat of undesired actions.

Considering the global reach of AI, a cohesive international legal framework will be essential to manage these

complex cases. Just as cybersecurity today depends on international cooperation, so too will the legal response to AI actions require a worldwide consensus.

Such courtrooms would not only mediate conflicts but also become crucibles for forging the societal norms that will govern AI. The verdicts reached in these halls will echo far beyond their walls, influencing AI development and its societal integration, ensuring that as AI evolves, it does so within an ethical and legal structure that protects and promotes the collective well-being of all sentient participants in our shared world.

5. Ethical Frameworks in AI Driven Design

In the quest for harmonious AI integration into human society, the establishment of ethical frameworks is paramount, a theme that builds on the discussions of AI rights and accountability covered in the previous sections. These ethical guidelines serve as a safeguard, ensuring that AI's generative potential is harnessed to enrich humanity rather than to sow discord. It's here that the conversation shifts from theoretical constructs to tangible applications, necessitating a robust ethical framework to guide AI's integration into our societal fabric. Such an overarching framework must be rooted in universal principles that transcend specific use cases. These principles should ensure that AI systems are designed with a focus on welfare, and they should serve as the underpinning for more specialized frameworks in various fields. Key among these principles are inclusivity, to prevent the exacerbation of existing social inequalities; foresight, to avoid

unforeseen negative consequences on human psychology and society; and adaptability, to remain responsive to evolving ethical considerations [6].

Let's consider a specific example. In architecture and design, these broad principles are materialized into concrete practices. An "Ethical Framework for Generative AI in Architecture and Design" would build upon the general ethical standards by introducing specific guidelines tailored to the field's unique challenges and opportunities. This framework would need to consider how spaces influence human behavior and well-being, thus requiring a thorough vetting process to ensure AI-designed spaces contribute positively to the intended environment [7].

For instance, when AI is tasked with designing a public space, inclusivity would require that the space meets the needs of diverse populations, providing equal access and utility. Foresight demands that the design anticipates and mitigates potential psychological impacts, such as those caused by overcrowding or overstimulation. Adaptability calls for designs that can evolve with changing community needs, allowing for modifications as societal norms and behaviors shift.

Human-AI collaboration is pivotal in this process. Feedback loops involving community members provide the human perspective necessary to guide AI in a direction that aligns with human values and needs. These loops ensure that designs are not only functionally and aesthetically pleasing but also socially responsible and psychologically nurturing.

The significance of human feedback cannot be overstated, particularly in its capacity to identify and correct AI oversights. Without it, AI, lacking human experience and intuition, may inadvertently create environments that foster social division or engender distress. For example, an AI that designs a park without understanding the community's cultural context might choose plant species or layout designs that are alien or even offensive to local sensibilities.

As we contemplate the integration of AI into the finer grain of our lives, it's imperative that we anchor such technologies in ethical frameworks that are as comprehensive as they are adaptable. These frameworks should be designed with the foresight to mitigate risks and the flexibility to evolve alongside our changing moral landscape.

6. The Role of Open-Source in AI Development

Navigating from the ethical imperative in AI-driven design, we approach the crucial arena of AI development—where the principles of open-source stand as a bulwark against the monopolization of this transformative technology. Open-source AI, by its nature, fosters a culture of transparency and collaboration that is critical in mitigating data biases and promoting a democratized approach to innovation. This inclusive philosophy can serve as a counterbalance to the emergent risks of a technocratic oligarchy, where the concentration of AI development in the hands of a few corporations and governments could lead to a disparity in the benefits reaped from AI advancements. An open-source ethos would not only aid in the equitable

distribution of AI's advantages but also instill a sense of shared stewardship among the global community. By placing the tools and knowledge within reach of diverse groups, the potential for AI to serve a broad spectrum of human interests, rather than a select few, is greatly amplified [9].

Moreover, the open-source model aligns with the foundational pillars discussed in previous sections, such as ensuring ethical design, unbiased data collection and curation, and fostering human-AI collaboration. It embodies the spirit of responsible exploration and innovation that is crucial to steering our collective future towards a more hopeful, utopian vision. Rather than succumb to a future dictated by the few, an open-source approach empowers many to contribute to the AI narrative, ensuring that the path we tread is paved with the collective wisdom of humanity. This collaborative path promises not just technological advancement but a future where technology is woven into the social fabric with conscientious intent, reflecting our shared values and aspirations.

7. Conclusion

In the quest to comprehend and direct the evolution of Generative AI, we are drawn to the undeniable conclusion that no single discipline holds all the answers. The journey towards a future punctuated by the notion of a Generative Singularity—a future where AI may reflect the essence of consciousness and creativity akin to our own—demands a tapestry of perspectives. The fabric of this tapestry must be woven from threads of philosophy, computer science, social sciences, cognitive science, and the arts, each providing unique insights into the

profound questions and challenges that arise from AI's potential to redefine the very parameters of existence and creation.

As we stand at this crossroads, it is paramount that the dialogue remains open and multifaceted. Philosophers must engage with computer scientists, artists with ethicists, social scientists with AI developers, all in pursuit of a holistic understanding that transcends traditional academic silos. It is through this confluence of diverse thought and expertise that we can hope to craft frameworks and guidelines—be they ethical, legal, or creative—that resonate with the complexity of the issues at hand.

Our vision for future research must be one that not only seeks to advance the technological prowess of AI but also to enrich our understanding of the ethical and epistemological implications of such advancements. It is a vision that encourages us to ponder the nature of intelligence, the rights of sentient beings, and the shape of societies in which humans and AI coexist. By redefining creativity, knowledge, and ethics in the context of advanced AI, we open ourselves to the possibilities of a future where human and artificial intellects not only co-create but also co-evolve, each enhancing the other.

Thus, our conclusion is not an ending but a clarion call for a collective intellectual voyage. It is an invitation to all who dare to dream of and shape a future where the generative capabilities of AI serve as a canvas for the human spirit, where the rights and responsibilities of all forms of intelligence are respected, and where our shared journey into the unknown is guided by the stars of ethical integrity

and boundless curiosity. Let us move forward with the wisdom of the past and the innovation of the present to ensure a future that reflects the best of what it means to be both human and more than human.

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Water Stories: Visual Poetics & Collective Voices

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Abstract

Water Stories: Visual Poetics and Collective Voices is a two-part project comprised of an audio composition and a generative audio-reactive video project that brings together multiple points of view from local youth, community, and poets in Alaska to share what water means in their life. *Water Stories* is part of a year-long artist residency with the Anchorage Museum that began in 2021 culminating in a series of listening sessions broadcast at the Anchorage Museum and Out North Radio, live interactive poetry readings at the museum, and video projections on the museum façade during November 2022.

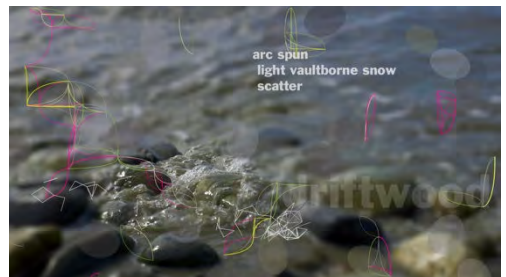
Keywords:

Generative, digital poetics, audio reactive software, community engagement, environment

Visual Poetics

Water Stories: Visual Poetics includes collaborations with Alaska poets Erin Coughlin Hollowell and Jen Stever. This collaboration focuses on the intersections of place, writing, and visual forms of language into an interactive video where the poet's voice draws visual graphical

forms through a code generated in Processing software onto place-based video footage. *Water Stories: Visual Poetics* explores visual poetics through visual and audio manifestations of language as a shared boundary between graphic design, writing, and performance.



"Aisling" Detail of audio reactive generative system for live poetry reading with Erin Hollowell.



"Swan Lake Fire" Detail of audio reactive generative system for live poetry reading with Jen Stever.

"Baltic Inphrases" – Choreographic Performance in Augmented Reality

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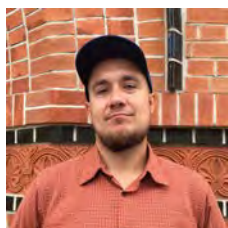
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fol. Kuba Karłowski



Abstract

With the emergence of avant-garde and experimental art, followed by the use of new technologies, the categories of beauty as a value that can be grasped through perception are often questioned. In view of the changes taking place in art, aesthetic values have become an inadequate criterion for evaluating contemporary works of art. Art, in combination with science, allows us to perceive and discover new phenomena and to enjoy numerous sensory impressions. Despite the use of artificial intelligence in art, it is still the human being who is capable of its axiology. Today, the intermedial narrative is shaped by the aesthetics of analogue and digital media, which can be mixed and combined (fused), enriching the new message they create through media interrelationships. This type of activity is most timely and expected by the 21st century art viewer. New technologies not only bring unanticipated results to the

work, appreciating a wider sensory range of perceptual experience, but also ensure that the work is connected to its time and wins the acceptance of today's viewer. An example of such concepts in art is the generative project "Baltic Inphrases", a music and dance improvisation inspired by the underwater world of the Baltic Sea. The project has been created by Polish jazz musicians, visual artists, a dancer and an art theorist. The premise of the project is a musical journey of the artists into the world of Kashubian demon songs.

The presentation will include an original interactive dance project (choreographic-audiovisual installation). The choreographic performance in Augmented Reality AR will use dance and new technologies to create a compositional meta-system in which different aspects of the created environment: movement, sound, text of legends and space with visuals, intertwine in new configurations.

Keywords: Intermediality; Interactive dance; Inphrasis; Virtual Art & Virtual Reality,

Destroy the Previous Original

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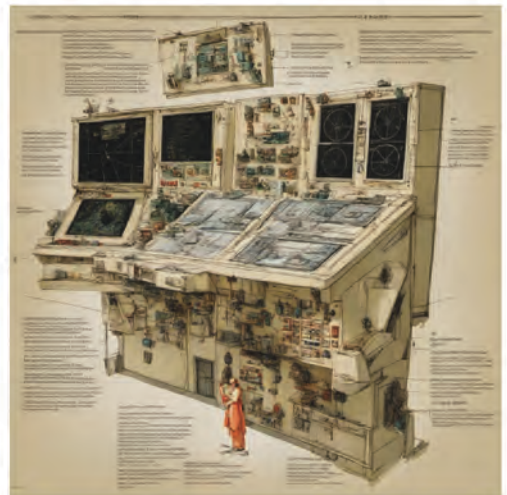
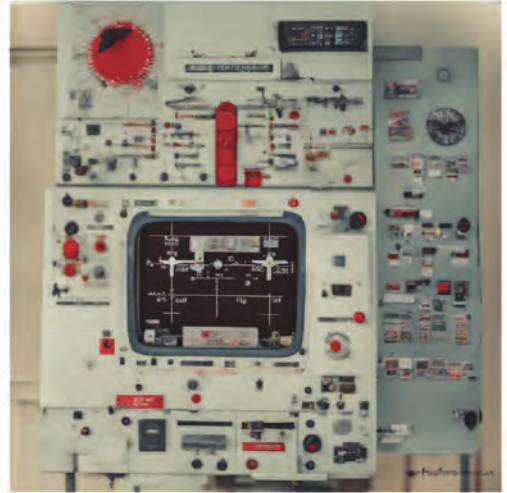
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Artwork

The concept of this work is to use the *Stable Diffusion* generative AI image making system to explore the collective imaginary of cold war Command and Control systems.



Destroying the Previous Original: A Trip Report from Latent Space

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Abstract

Stable Diffusion is an open-source generative artificial neural network capable of detailed text-to-image (TTI) and image-to-image (ITI) generation. Publicly distributed models and user interfaces may be run locally on personal computers with dedicated graphic cards, making Stable Diffusion far more accessible and customizable than previous TTI models.

This paper provides a brief history on AI image generation, and a basic primer on how latent diffusion models work, followed by a look at some specific projects employing Stable Diffusion to develop a series of images that, in various ways, probe the TTI black boxes, including *Latent Alphameric*s, *Deep Negatives*, and a catalog of the collective visual imaginary of cold war command

and control devices, *Destroy the Previous Original*.

Discussions follow of prompt engineering and graphic intervention, as well as perspectives on how one might negotiate artistic intent and system autonomy when working with deep generative systems.

The paper concludes with a brief roundup of Stable Diffusion resources that will hopefully be useful to other artists and designers who wish to engage with these tools.

A Brief History of AI Image Generation

Artificial Intelligence Generated Content (AIGC) can arguably trace its roots back to the 1960s with the development of statistical models that could be employed generatively, such as Hidden Markov Models (for generating sequences of discrete data) and Gaussian Mixture Models (for generating multivariate data). *Practical* generative AI image creation, as presently understood, would not be realized until after deep-learning algorithms were developed in the 2000s, particularly the Generative Adversarial Networks (GANs) and Variational Autoencoders (VAEs) [1].

Arguably the most significant pivot point in terms of contemporary AI image generation [2], was the breakthrough represented by the original GANs by Ian Goodfellow and his team in 2014. This kicked off an alphabet soup of ever-more-sophisticated generative AI image making systems. [3] The “adversarial” part of a GAN refers to a *discriminator* implementation which iteratively evaluates the fitness of the *generator’s* output in relation to natural images; the generator attempts to refine a synthetic image to the point that the discriminator classifies it as natural, and both networks become more sophisticated in their respective roles as they receive feedback from each other.

This method produces detailed images with sometimes uncanny verisimilitude, but early models suffered from low image output resolution, a fixed set of predetermined object categories. This method also suffers generally from issues of “mode collapse,” in which the model under-represents some objects from images, and “mode-dropping,” in which it omits some objects completely. [4]

Just one year later, *DeepDream*, which initially began as an effort by a team including Alexander Mordvintsev at Google to visualize the inner workings of Convolutional Neural Networks (CNNs) [5], unleashed hordes of psychedelic “sludogs” [6] onto the internet and introduced generative AI images to the general public. In 2016, Leon Gatys et al. separated the “style” from the “content” of an image with Neural Style Transfer (NST); this split led to being able to (crudely) transform any image to resemble the style of famous artists with

distinctive styles like Vincent Van Gogh, Henri Matisse, or Katsushika Hokusai.

In 2017, the Artificial Intelligence Creative Adversarial Network (AICAN) platform, housed at Rutgers University, promised an “artificial intelligence artist and a collaborative creative partner” [7], emphasizing the fine arts potential of generative AI.

Open AI, in 2021, introduced *DALL-E*, a versatile text-to-image (TTI) generative AI system that, after a waitlist period, was opened to limited use by the general public. The next year, *DALL-E 2* followed, increasing the resolution of generated images by a factor of four. [8]. *DALL-E 3* is now (in the fall of 2023) available to Open AI’s ChatGPT+ subscribers, as well as through Microsoft’s Bing image creator. It promises better fidelity between prompt and image and integrates with *ChatGPT* for interactive prompt generation; *DALL-E 3* also includes the ability for artists to opt-out of its training model.

A less visible but still vitally important component of contemporary AI image generation is the Contrastive Language-Image Pre-Training (CLIP) method, developed by OpenAI. [9] This approach “pre-trains” on descriptive text, predicting which caption goes with which image. This pretraining allows for the use of more natural and varied language for image prompting (since it does not depend on pre-defined categories) on the generation side and provides for “few-shot” learning, which is useful when there is limited image caption data on the training side.

Latent Diffusion Models and Stable Diffusion

Diffusion models for generative AI image making depart from the adversarial dance of generator and discriminator and rely instead on iterative statistical denoising operations—essentially cyclically removing visual noise from an existing natural image or (more commonly) a random distribution of noise, until an image that (to some degree!) satisfies the initial guidance emerges. This general model was shown to overcome many of the shortcomings of GANs at the cost of somewhat less efficient image generation. [10]

Stable Diffusion is a specific open-source implementation of a diffusion model for image generation that incorporates CLIP and VAE along with UNET. In a text-to-image operation, the process of transforming a prompt to an image in Stable Diffusion v1.6 goes something like this: First, the user writes a natural language prompt (“a detailed photograph of a cat,” for example). This prompt is then broken down into a series of tokens—combining some words and breaking others apart—and those tokens are then encoded into vectors that the UNET neural network can consume. As the prompt is tokenized, a low resolution (64x64 pixel) noise image is created (based on a seed value) and also converted to vectors. The UNET then takes these two encoded vector inputs, noise and prompt, and using a chosen noise “scheduler,” begins to iteratively remove noise from the initial low-resolution image in latent space, based on the contents of the particular training set in use.

After the specified number of steps, the denoised image is passed to the VAE which decodes the latent vectors into standard pixels at a higher (in this case 512 x 512 pixel) resolution—and we see the image of a cat.

The training set (called a “checkpoint” in Stable Diffusion terminology) that serves as the repository of encoded and compressed image/description pairs is created in the reverse way: vast numbers of captioned images, usually scraped from the web, are injected with noise, and then immediately de-noised. The original (“natural”) image is then statistically compared to the processed image to determine how closely the two match. The model typically uses this process on billions of text image pairs to train “weights” which are later used by the UNET neural network in the image generation process.

The Library of Babel

When it was announced that the Library contained all books, the first reaction was unbounded joy. All men felt themselves the possessors of an intact and secret treasure.

There was no personal problem, no world problem, whose eloquent solution did not exist—somewhere in some hexagon.

—Jorge Luis Borges, *The Library of Babel* [11]

Much like in the early days of sound synthesis, when it was believed that any natural sound could be produced [12] synthetically, the advent of AI image generation has engendered a similar

idea that any image, in any style, might be pulled from latent space—that it might be a visual Library of Babel. And even though Borges' library is unimaginably large [12], Stable Diffusion's latent space is even larger.

Are *all possible images* available in Stable Diffusion's latent space? No. It seems that Stable Diffusion's VAE has a decidedly finite capacity to decode images, but that number of possible images is still shockingly vast: likely something like 2^{524288} images [13] (this represents a number so large that it would require 61 pages in this book just to type out all the digits in integer form). It is no wonder that people imagine that any possible image might be waiting to be discovered/created there.

Coupled with the idea that nearly image is possible to create, is the fear that specific images (artist's own works, for instance) might be perfectly re-created. Diffusion models generally do not replicate specific images in their training data. If a checkpoint is trained well (not "overfitted" for instance), and reasonably large, it is unlikely that a diffusion model will ever precisely reproduce a specific image that was included in the training data, even if the precise wording of the caption in the image-caption pair is used as the only prompt. However, Somepalli, et. al [14] found that, in specific cases, Stable Diffusion would recreate, pixel-for-pixel, portions of images in the training data within generated images, so there is a legitimate concern—even more so with Low Rank Adaptations (LORAs) which are deliberately trained on a specific set of visuals.

The Question of Autonomy

Why this mountain?

Why this sky?

This long road, this empty room?

—Laurie Anderson

I first experienced producing generative AI images in 2019 with Joel Simon's GAN breeder [15]. This browser-based system used BigGAN on the back-end (trained on 128 x 128 pixel images) to synthesize new images, not by writing a text prompt, but by adding "genes" (object categories) and using a slider to weight each gene's contribution to the final image + a "chaos" modifier. Genes included categories as diverse and infelicitous as "mousetrap," "landscape," "cassette," "underwater creatures," "bikini," "patterns," and "vase." The breeding aspect included an ability to combine a pair of generated images with adjustments to how similar or different the offspring images would be to the parent images.

Even though it was possible to add only one gene at maximum weight to generate an image that had at least a passing resemblance to a member of the chosen category (setting the king crab slider to 1.0 would always produce something with legs and spikes), it was far more interesting to add a number of genes with a variety of weights and just see what emerged.

Rather than tending to create an image of each item (as contemporary TTI systems generally do, GANBreeder would instead generally create a single object or environment that somehow expressed aspects of the selected

categories, but not necessarily in a legible way. This led to images of ambiguous and dreamlike objects and scenes that had a mood, but seldom bore a strong resemblance to anything in reality.

As AI models and training sets have improved, the ability to generate an abstract image that conveys a mood without being littered with literal representations from the prompt has become increasingly difficult.

Prompt engineering, LORAs, Textual Inversions, and specialized training sets tend to reinforce the drive to erase the marks of AI image generation and render the process invisible.

In "Is Writing Prompts Really Making Art?" McCormack, et al, [16] seem to variously argue that AI image generators are both too autonomous and not autonomous enough. This ambivalence is understandable (if not well-explained in the article) since autonomy in these systems is largely a function of perspective and specific use. The question of autonomy is, nonetheless, an important one when considering if (and how) to engage with these systems in an art practice.

Tighter and more extensive prompt engineering tends to provide more control over the generated image, ceding less autonomy to the system at the generation phase, even if the process is still somewhat fraught by the ambiguities of language and the quirks of the training data, (which are largely unknowable). On the other side, huge image generation batches with varying parameters (random or incremented) may be

launched so that the system has relatively more autonomy at generation, but an artist will have a greatly expanded pool to curate from and iteratively enhance.

In addition, with current systems, extra-textual graphic interventions such as *inpainting* (visually indicating areas of a generated image to recalculate by "painting" with the mouse—often used to repair faces and hands in images of people), *outpainting* (asking the system to fill in around a desirable part of an image, or by using an existing image (natural or generated) as a nucleus for the system to, to varying degrees, augment with prompt-generated imagery.

Despite McCormack, et al's generally hostile (and, in my estimation, poorly argued) take on AI image generation, an interesting concession is made that these tools will likely be used in unexpected ways by artists to create new work—particularly when employed in a "meta" that embraces the flaws of the method and interrogates the process. With this perspective in mind, I would like to briefly present three projects.

Praxis

In 2021, at this conference [17], I presented Automatic Cities, a spatial soundwalk through the ancient city of Sardinia. The mobile phone interface to the piece included AI-generated illustrations for each of the imaginary places along the walk. As an indicator of how rapidly this technology is progressing, I offer you an image I showed as an example then generated with VQCLIPGAN from the prompt "Life

is the parable of fading shadows:”



Figure 1 “Life is the parable of fading shadows | Chromolithography,” 2021, VQCLIPGAN

The same prompt, executed in fall of 2023 using Stable Diffusion XL:



Figure 2 “Life is the parable of fading shadows | chromolithography,” 2023, Stable DiffusionXL

The contrast in these two images, using an identical prompt, is visually striking

(and emblematic of the increasing concreteness of these systems).

The first current work-in-progress project I’d like to speak about is called *Latent Alphamericis*. This is a series of large-format digital prints that present a somewhat critical response to generative AI image creation. The images in this series are the result of prompting a generative AI text-to-image diffusion system with deeply ambiguous texts—in this case, single letters of the alphabet and single-digit numbers.

Each image in the series is named for its numeric seed, which represents the latent space starting conditions. The lack of context and meaning is no impediment to the system’s image generation ability, but the images that surface are like core samples from the trained model’s latent space; multiversal fragments of potential people, potential places, and potential events.

It is somewhat unclear (at least to me) if single characters without surrounding context are properly tokenized in Stable Diffusion, but even if they are, practice shows that not much semantic information adheres to them: images generated by these prompts owe far more of their structure to the generative seed used than to the prompt itself (in a reversal of usual situation where seed variations are far less significant than substantive changes to the text prompts).

Here are three example image matrices generated with Automatic1111’s X-Y grid feature with a constant seed value and varying single character prompt (A–Z and 0–9) from left to right:

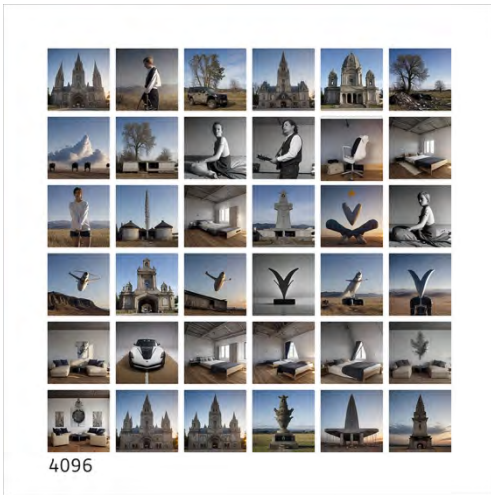


Figure 3, Seed = 4096

Note the persistent color palette and overall compositional similarities, but semantically drifting imagery.

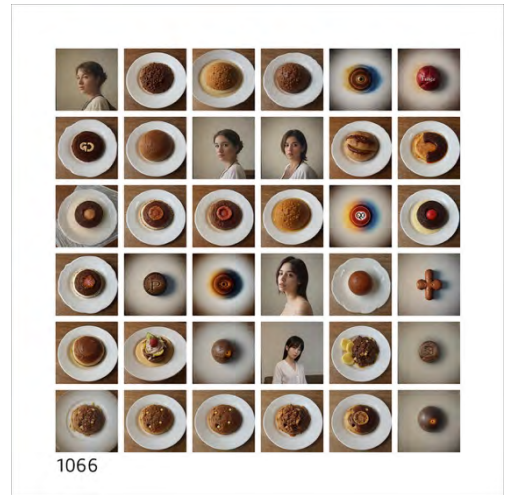


Figure 5, Seed = 1066

Notice too the emergence of human figures in each of the three series, but in locations that don't correspond to the same characters.

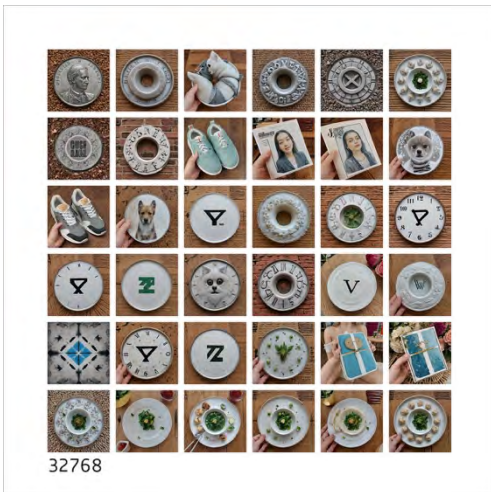


Figure 4, Seed = 32768

Here, the seed strongly favors a centered circular composition, though images periodically deviate toward a still central but slightly rotated rectilinear element.

These matrices of usually banal images offer glimpses into the otherwise overdetermined secret gardens of latent spaces.

Next is *Deep Negative (the Monstrous Feminine)* which offers a different kind of probe into a training model's latent space, as well as some insight into preferences and biases of an anticipated typical user. This series came about due to experiments with placing a general-purpose negative prompt (DeepNegative 1.6) as a "textual inversion" (TI) into the *positive* prompt area of the Automatic1111 interface.

A TI is another black box (or at least a very dark grey one) that embeds a new "vocabulary word" for Stable Diffusion prompts derived from training on a small set of images.

If there is a particular coffee mug, for example, that you would like to see represented in AI generated images, but that was not included in the training data for the checkpoint in use, you could train on a handful of images of that mug and give it a designation “M*.” Then, in a prompt, you could ask for “a photo of M*” or even a “photo of a broken M* full of red roses.”

Besides using the TIs to add specific concepts to a generated image, they may also be used in the negative prompt to suppress specific concepts. In Automatic 1111, I was curious what would happen if I populated the *positive* prompt box with the DeepNegative TI instead of the negative one as expected.



Figure 6, One of the few images from Deep Negatives I felt comfortable including in this paper; the vast majority of these images feature full frontal female nudity

Clicking on the render button immediately produced a wild-haired, green-skinned scaly young woman—completely nude—gleefully showing me

her heavily deformed hands. Every image generated, seed after seed and batch after batch was similar: a never-ending parade of corpse-tinged women, each unique, but all united in nakedness, grotesquery, and most exhibiting a kind of feral joy. A sisterhood of monsters. It is telling that the negative prompt *always* produces unambiguously female figures with virtually any Stable Diffusion 1.6 checkpoint—only the art style and color palette seem to vary.

I am currently exploring making work with and around these images with my colleague (and talented performance artist!) at the University of Kentucky, Professor Rae Goodwin.

Destroy the Previous Original is the final piece I would like to present. This is also a work in progress; one that I am deeply ambivalent about. The initial concept was to use Stable Diffusion to explore the collective imaginary of cold war Command and Control systems. In working through the piece, the designer in me was frustrated by the lack of precision the images exhibited in the form of distorted perspective, warped geometries, and indistinct and melted looking knobs, dials and sliders. Specific training data for mechanical controls seemed to be even less represented than well-formed hands. As the prompt text ballooned to over 85 tokens, in an attempt to reform these images towards more aesthetic directions, I steadily undercut the original intent of the project.

At the moment, I am back to favoring sparser prompts such as simply “Cold War weapons control panel.”



Figure 7, An image from Destroy the Previous Original series; see the artworks section in this volume for more examples

Conclusion

While I can't agree that AI TTI is "parasitic" and skill-less or somehow uniquely misrepresented by its promoters as an art-making tool (ignoring the long history of "paint-by-number" kits and "draw Tippy the Turtle") or even that TTI is art "forgery" or fast food art, (celebrating the marks of a tool or obscuring them are both valid contemporary artistic strategies), I do believe that it is something of a dancing bear when "used as directed" and, presently, may best be engaged with as a sort of weird mirror held up to the specific collective imagery of the internet and the assumed intent of its users.

Resources

Figure 8

Automatic1111, a web-based GUI for local execution of Stable Diffusion:

<https://github.com/AUTOMATIC1111/stable-diffusion-webui>

An excellent first tool for a locally-hosted installation of Stable Diffusion.

Figure 9

ComfyUI, a node-type web-based GUI for local execution of Stable Diffusion:

<https://github.com/comfyanonymous/ComfyUI>

ComfyUI is neither comfortable nor exactly a UI! It is a modular "boxes and wires" type tool, and it is more complex to maintain and use than *Automatic 1111*, but it lends itself to customized workflows and experimentation.

LAION crawl is an aesthetic subset image database browser for the Large-scale Artificial Intelligence Open Network (*LAION*) image/text pair training set:

<https://laion-aesthetic.datasette.io/laion-aesthetic-6pls/images>

Here you may search or browse a subset of the specific images and associated text data used in training *Stable Diffusion*. Entries may be sorted by different criteria including dimensions, caption (alt tag), URL, and aesthetic score.

Magic Prompt is a web-based tool to help build better TTI prompts, in this case for *Stable Diffusion*:

<https://huggingface.co/spaces/Gustavosta/MagicPrompt-Stable-Diffusion>

This tool may provide insights into what goes into a particular model as well as how it is expected to be addressed.

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The Generative Art Community bridging between UNESCO Heritage and AI-generated works : An Interview with Celestino Soddu and Enrica Colabella

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Abstract

The United Nations Educational, Scientific and Cultural Organization (hereinafter 'UNESCO') is a United Nations specialised agency that recognises heritage of historical, cultural, social and technological value at the international level. This so-called 'UNESCO heritage' includes diverse types of heritage, from tangible architectural buildings to intangible traditions and knowledge, and analogue and digital documents. UNESCO's Recommendation on the Ethics of AI encourages UNESCO member states and civil society to incorporate AI in identifying and preserving tangible, intangible and documentary heritage.

What theoretical and practical issues should UNESCO address to identify an AI-generated work as UNESCO heritage? Are there any precursors of AI-generated works that UNESCO and AI practitioners can learn from?

This paper aims to discuss how to recognise AI-generated works as UNESCO heritage by analysing an interview with Celestino Soddu and Enrica Colabella. The discussion lies in the idea that the field of generative art is a cultural community. The collective knowledge of the generative art community about the use of AI in cultural creation can offer ideas for possible ways to identify and preserve AI-generated works as UNESCO heritage. Acknowledging Celestino Soddu and Enrica Colabella as representatives of the generative art community, the interview with them focuses on two main questions: (1) What are the distinctive ways in which the generative art community employs AI to create cultural works?; (2) What components of AI-generated works would the generative art community want to preserve if their works are considered for UNESCO heritage in the future?

The generative art community seeks to construct systems that integrate human visions and the technological roles of AI. In an AI-based generative art system, humans are system-makers, whereas AI represents the subjective values and artistic ideas of its human creators. The interrelated but distributed roles of humans and AI in a generative art system produce a richer intellectual reciprocity between human and AI creativity. It distinguishes the generative art community from traditional art communities and the common use of generative AI programmes. The ethos of the generative AI community for interactive art between humans and AI can be extended to emerging AI practitioners. It can solidify the unique value of generative art, compared to traditional types of heritage. To nominate AI-based generative works as UNESCO heritage, this paper proposes that its nominators explain in a nomination dossier its fundamental socio-cultural and technological themes and purposes, databases, algorithmic codes and theoretical principles for comprehensively processing them. This package of a knowledge system should be preserved along with its subsequent outputs. The knowledge-centred examination of the generative art field in this paper links the generative art community and emerging AI practitioners. It provides policy recommendations on how to register AI-generated works as future UNESCO heritage.

*Note: the interview with Celestino Soddu and Enrica Colabella was conducted as part of the author's doctoral research. A version of this paper will be included in the author's final doctoral thesis.

Cultural Community in UNESCO's terms

UNESCO registers different types of heritage of international significance on its three heritage lists: the World Heritage List under the World Heritage Convention, the Representative List of the Intangible Cultural Heritage of Humanity under the Intangible Heritage Convention and the Memory of the World Register under the General Guidelines of the Memory of the World Programme. The tangible, intangible and documentary heritage inscribed on the three lists show skills, knowledge and values created by a human community in a particular time and space. In 2002, a group of experts from UNESCO member states examined how to understand the term 'community'. Their meeting papers define three types of communities: the cultural community, the indigenous community and the local community. In their description of the indigenous and local community, they emphasise geographical residence and local solidarity. On the other hand, their definitions of the cultural community focus on the cultural knowledge and ideas of a human group that are different from others. A cultural community is a "community that distinguishes itself from other communities by its own culture or cultural design" [5]. It is admittedly difficult, if not impossible, to define the absolute meaning of culture and cultural design. The notion of the cultural community, however, encompasses human groups whose members share particular traditional perspectives on who they are and how they express themselves through their distinctive intellectual and cultural activities.

UNESCO's 2003 Intangible Cultural

Heritage Convention underscores the role of communities in identifying and preserving intangible cultural heritage: namely, oral traditions and expressions; performing arts; social practices, rituals and festive events; knowledge and practices; and traditional craftsmanship [2]. For instance, “Craftsmanship of Mechanical Watchmaking and Art Mechanics” of Switzerland and France was inscribed on UNESCO’s Representative List of the Intangible Cultural Heritage of Humanity in 2020. The cultural qualities of the watchmaking derive from watchmakers’ professional skills intersecting technology with art and from their sharing of watchmaking knowledge, rather than from geographical aspects. The knowledge-based understanding of the cultural community enables us to understand the generative art field sociologically in the context of UNESCO.

The Generative Art Community

Generative art is a transdisciplinary scholarly and professional field where artists, architects, mathematicians, roboticists, etc. employ various technologies to create cultural works. The International Conference on Generative Art is one of the main places where generative art researchers, practitioners and artists have gathered to share their research, inventions and philosophical reflections on the ontology and epistemology of generative art. Celestino Soddu and Enrica Colabella first used the term ‘generative art’ for the conference. They have co-chaired the conference since 1998, leading to the formation of the generative art community. Considering Soddu and Colabella as representatives of the generative art community, the author interviewed them

by email in July and August 2023. The interview questions were designed firstly to elicit their ideas of what the generative art community does, especially when using AI to create cultural works. The interview responses were then placed within one of the core issues of UNESCO heritage. In the sense of UNESCO, objects, knowledge and analogue and digital documents as UNESCO heritage should be preserved and transmitted to future generations. From the perspective of the generative art community, what components of AI-generated works should be preserved if they are valued as heritage? The interview questions were emailed to Soddu who answered them in writing with the contribution of Colabella. After the author reviewed their responses to the initial interview questions, additional questions were sent to Soddu to extract more detailed thoughts from the two interviewees. This paper intends to interpret their answers in accordance with the two research topics. Where it is necessary to deliver their original comments, their answers are presented in this paper in the form of verbatim quotations in italics.

Traditional art communities tend to circumscribe their areas of expertise such as architectural knowledge for architects and painting skills for painters. The International Conference on Generative Art does not distinguish between different disciplines in terms of the expertise of its speakers and what they create. The generative art community does not merely address specific artistic styles or particular forms of outputs. Meaning art by the *“ability to operate”* and generative by the *“ability to build tools suitable for generating events”*, the generative art community delves into

how they create a system that integrates their artistic ideas with technological tools. AI algorithms have been major parts of generative art systems. Soddu has been using AI algorithms since the 1980s to generate 3D models of architectural designs and artistic events. AI-based generative art systems operate through interactions between humans and AI. AI cannot start its performance without human artistic vision. Vice versa, human artistic vision cannot be embodied without the generative capabilities of AI.

An AI-based generative art system is not a computationally automatic tool but a reification of interpretive knowledge between the human and AI. Soddu has been developing his algorithm-based generative art system, ARGENTIA, for around 40 years. *“All ARGENTIA algorithms are not tools that can be used by anyone.”* We can compare ARGENTIA with other generative AI programmes in common use these days. An example of the common generative AI programmes is ChatGPT, a Chat Generative Pre-trained Transformer by OpenAI. Around 60% of ChatGPT-3’s dataset was based on a filtered version of the web-crawled data of Common Crawl [1], a non-profit organisation that scraps publicly available textual data on the internet such as books, web pages and articles. Most of the tasks given to ChatGPT are related to problem-solving. For example, a human user can ask ChatGPT to write a 1,000-word essay on a particular topic and ChatGPT will provide a piece. ChatGPT processes its data using machine-learning Natural Language Processing models (LLMs). LLMs infer relationships between words within given texts, answering the human user’s questions. A strength of ChatGPT is that it is *“usable*

by anyone”. At the same time, it makes ChatGPT *“an objective tool”*. AI as a tool produces outputs with the same algorithmic processing of the same data for anyone and any question. AI as a tool has a narrow scope of human and AI creativity and their interactions. Of course, ChatGPT is a conversational AI that interacts with its human users who ask questions. But humans become creative only when they describe problems that they want ChatGPT to solve. Also, the creative part of ChatGPT’s performance is mostly its answers, followed by tasks given by human users. The interaction between humans and ChatGPT ends when ChatGPT provides an answer and humans are satisfied with it. The value of ChatGPT is therefore consequential.

The generative art community uses AI not as a tool but as a contextual component of its art-making system. Instead of general and random information on the Internet, ARGENTIA has data about the geometric transformations of architecture that Soddu has experienced over the past 40 years. The algorithms of ARGENTIA have specific goals set by Soddu’s personal interpretations of three-dimensional space art events. His algorithms regulate the compositional development of architectures and the morphogenesis of the urban image which Soddu has observed. ARGENTIA also performs tasks given by Soddu, just as ChatGPT does with its human users. But ARGENTIA is designed to show diverse facets of Soddu’s artistic ideas. The generative art community enables their generative art system to create not just one answer but multiple outcomes that represent the *“complexity of the artistic vision”* of

human creators. ARGENTIA produces multiple designs based on Soddu's subjective datasets and algorithms. Each of the outcomes is different but all of them *"represent [...] possible infinite facets"* of Soddu's artistic vision. A generative art system thus produces a richer space for the human and AI creativity and their interactions. Each time Soddu updates data or the parameters of data processing, ARGENTIA will respond to it and produce different results. The value of a generative art system is therefore procedural.

Rather than simply copying and pasting the artistic styles of its human creator, an AI-based generative art system creates diverse products that are *"capable of communicating the same artistic vision [of a human author] and a multiplicity of possible outcomes"*. The idea of communication is worthwhile to note in comparison to other types of art. Traditional architecture, painting and writing have one final outcome. Audiences read the ideas of their human creators through the end product. An AI algorithm in a generative art system can, however, produce different outputs, for example, depending on the weights of different parameters derived from the entire knowledge and artistic vision of its human creator's. The multiplicity of possible outcomes generated by AI consequently engenders two aspects of communication. Of course, the diversity of algorithmic outputs leads audiences to discuss why the human author has different art pieces with the same cultural themes. But more importantly, the diversity of algorithmic outputs enables the human author and their AI to communicate with each other. The human decides on what to change and

what the final creative products should be, depending on the products generated by the AI. Vice versa, the AI responds to the human's request, producing other artistic options.

The intellectual reciprocity between humans and AI in an AI-based generative art system demonstrates the interrelated but distributed roles of the human and the non-human in producing cultural works. Humans create and specify cultural contexts, ideas, and purposes for why they use AI to express their artistic identities. In other words, they construct *"an approach that creatively defines a meta-project, i.e., the project of the art project"*. According to the meta-project, humans curate and assemble thematic data and tailored AI algorithms. To put it another way, a human is not merely an art-maker but a system-maker in an AI-based generative art system. With a human system-maker, AI algorithms produce multiple outcomes that represent the identity of the human. In the process of modulating data and data-processing parameters by the human system-maker to find the best result, an AI algorithm *"transforms the previous event into one more close to the author's vision"*. The human system-maker can recognise their AI as a representative of their artistic identity if the human system-maker is subjectively satisfied with the products generated by their AI. Then the human system-maker can acknowledge their AI as a procedural contributor expressing their artistic cognitive sphere, an *"author's imprinting"* in Soddu and Colabella's terms.

The generative art community has established its distinctive identity as a cultural community that builds generative

AI systems that can communicate with humans to best represent human visions. The knowledge tradition of the generative art community can be extended and transmitted to emerging and future AI practitioners who create cultural works to express their artistic ideas. What lessons can the generative art community give to those AI practitioners? UNESCO's Recommendation on the Ethics of AI underscores the maintenance of human values in the use of AI [3]. How can we interact with AI not to lose human creativity but to express it? Soddu and Colabella recommend "*setting the goal of generating events recognizable as belonging to one's vision*". AI practitioners need to curate certain data, which can "*rediscover the author vision*", rather than using them without contextual purposes. One method for doing this is not to copy existing data but to "*interpret*" data as part of their data processing. This enables AI practitioners to inject their personal values, producing new creative 'data about data', an "*adduction*" in Soddu and Colabella's terms. When AI practitioners design their AI algorithms, Soddu and Colabella suggest "*moving from only the logic of problem-solving to that of subjective vision for increasing complexity and rediscovering the author's identity*". AI practitioners therefore do not rely on answers from random generative AI programmes. They need to tailor particular AI algorithms and take the initiative to adopt AI-generated outputs. For example, human practitioners can revise or select a few products generated by AI so that they do not intellectually count on the randomness of AI but harness it. To do so, AI practitioners need to focus on "*defining possible transformations [of their art] from the past to the future that can be defined through*

algorithms", rather than "*basing one's creativity in producing forms [of their art]*". Humans can ultimately enhance their own artistic logic and identity in the process of interacting with AI. The generative art community can transfer this distinctive knowledge of generative AI systems to emerging and future AI practitioners. It can bring us not automatic computer art but interactive art between humans and AI. It can furthermore encourage UNESCO to identify the AI-generated art field as a traditional and explicit cultural community that has been transmitting unique practices for creating cultural works that express human creativity, compared to traditional types of heritage.

AI-generated works as UNESCO Heritage

If how the generative art community uses AI to create cultural works is transferred to future generations, their distinctive knowledge per se could become intangible cultural heritage. UNESCO's Intangible Cultural Heritage Convention recognises the interaction between the intangibility of heritage and its tangible tools and products associated with it. Physical tools and outputs associated with an AI-generated creation will therefore support the cultural value of the AI-based creation. Once a UNESCO heritage policy recognises international values of intangible knowledge of AI-generated works and their tangible tools and outputs, they could become so-called 'UNESCO heritage'. Who decides whether particular heritage has international values depends on UNESCO's different systems of the World Heritage, Intangible Cultural Heritage and Documentary Heritage. But

all the heritage policies highlight that UNESCO heritage must be preserved so that it is transmitted to future generations. How to preserve particular heritage partially depends on its types. UNESCO World Heritage system states that immovable sites (e.g., the Architectural Work of Le Corbusier in Argentina, Belgium, France, Germany, India, Japan and Switzerland) should retain their physical integrity. UNESCO Intangible Cultural Heritage system stipulates that present communities should still continue to use their traditional practice and knowledge (e.g., “Craftsmanship of Mechanical Watchmaking and Art Mechanics” of Switzerland and France). UNESCO Documentary Heritage system states that components of documents¹ should be preserved. In the case of the film ‘Wizard of Oz’ in the USA, its original Technicolour 3-strip nitrate negatives and soundtrack have been preserved. An AI-based generative art can encompass the three aspects of heritage: physical products, intangible practices and analogue or digital databases or born-digital creation. If an AI-generated work produced today is recognised as UNESCO heritage, what elements does the generative art community think should be preserved to transmit the value of the work to future generations?

Soddu and Colabella describe ARGENTIA software as an *“active and dynamic memory of my [Soddu’s] architectural and artistic work [that] encapsulates all my [his] spatial ideas and visions”*. A unique aspect of ARGENTIA is its database of unused designs that may later be useful in other contexts. Suppose that a building is constructed using ARGENTIA in the future. If this building demonstrates historically important technological and

artistic value, what is the heritage that keeps carrying the value of the building? What should be documented and preserved to maintain the value of the building? Just as the physical integrity of Le Corbusier’s architectural work should be maintained, the physical integrity of the building itself would need to be preserved. But the building is one of ARGENTIA-generated outputs. If another building is later constructed using ARGENTIA, the first building is one of the derivative outputs of ARGENTIA. The first building and the second building will look different because, as discussed earlier, an AI-based generative art system is designed to produce different outputs based on its human’s visions. It is then necessary to trace back to the origin of the AI-generated buildings, i.e., ARGENTIA.

How can we nominate ARGENTIA as UNESCO heritage? This paper proposes that nominators of ARGENTIA first describe in a nomination dossierⁱⁱ why and how ARGENTIA was created in social, cultural, historical and technological contexts. Then what component of ARGENTIA should they nominate in order to nominate ARGENTIA? Soddu and Colabella say that *“UNESCO’s Heritage could be the ARGENTIA software and the Topological Paradigm used to generate 3D models of architecture, art and design.”* In other words, the codes, the algorithms and the theoretical principles (i.e., the Topological Paradigm that defines the relationships among all the artistic events involved in ARGENTIA) need to be nominated as a package of the ARGENTIA knowledge system. Diverse buildings designed by ARGENTIA are different outputs from ARGENTIA. But the ARGENTIA software per se is the

consistent and fundamental knowledge framework that is *“able to generate a whole series of 3D models that, although always different, would all be recognizable as belonging to [...] the architectural and art vision of the author even if he [Soddu] is deceased or belongs to the history of architecture.”* If we preserve the computational and theoretical components of ARGENTIA so that ARGENTIA can continue to work in the future, we can preserve the source of ARGENTIA-based buildings, i.e., Soddu’s cultural and computational knowledge for artistic designs. Nominators of ARGENTIA should explain, in a nomination dossier, the codes, the algorithms and the theoretical principles and how they work together. This paper suggests that buildings designed by ARGENTIA be included in the nomination dossier as derivative outputs of ARGENTIA. If there are new buildings designed by ARGENTIA or ARGENTIA is updated after ARGENTIA has been registered as UNESCO heritage, nominators of ARGENTIA should report it and submit the additional information to UNESCO. UNESCO World Heritage policy allows its member states to extend components of sites after their inscription on the World Heritage List if this further demonstrates the values of the sites. UNESCO may therefore consider a policy to update components of an AI-generated work after its inscription on a (potential) UNESCO list of AI-generated works if this solidifies socio-cultural and technological values of a generative AI system. This scenario of a nomination of ARGENTIA as UNESCO heritage indicates that both ARGENTIA and its derivative buildings should be preserved. The organisations responsible for ARGENTIA and those buildings may be different. For example, Generative Art &

Design Lab of Soddu for ARGENTIA and national or provincial governments of the places where the buildings are located. All of them should prepare their preservation plans and write them in a nomination dossier, in accordance with UNESCO’s World Heritage and Documentary Heritage policy.

This paper has examined the generative art field as a cultural community that has developed its distinctive knowledge of using AI to create cultural works. The generative art community’s shared knowledge of how to interact with AI can be extended to AI-generated works which are being created at a tremendous rate. The ethos of the generative art community suggests an approach to heritage: *“heritage would not only be material but, owing to AI, operationally design-oriented and thus would an alive creative memory”*. The preservation of generative art means by keeping creative memory alive. An AI-generated work cannot be clearly categorised as tangible or intangible or documentary heritage. We need a new category of hybrid heritage, an AI-generated work that encompasses the existing forms of heritage. The interview with Soddu and Colabella has demonstrated the possibility of this new policy. The knowledge-centred examination of the generative art field in this paper links the generative art community and emerging AI practitioners. It provides policy recommendations on how to register AI-generated works as future UNESCO heritage.

Notes

ⁱ The 2021 General Guidelines of the Memory of the World (MoW) Programme of UNESCO defines a document as “an

object comprising analogue or digital informational content and the carrier on which it resides. It is preservable and usually moveable. The content may comprise signs or codes (such as text), images (still or moving) and sounds, which can be copied or migrated. The carrier may have important aesthetic, cultural or technical qualities. The relationship between content and carrier may range from incidental to integral.” [4]

ii Of course, UNESCO does not yet have a nomination dossier for AI-generated works at the time of writing this paper. The author’s doctoral thesis will propose a UNESCO nomination dossier for AI-generated works as one of the findings of the doctoral research.

References

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[2] UNESCO (2003). The Convention for the Safeguarding of the Intangible Cultural Heritage. <https://ich.unesco.org/en/convention>

[3] UNESCO (2021a) Recommendation on the Ethics of AI. <https://unesdoc.unesco.org/ark:/48223/pf0000381137>

[4] UNESCO (2021b) General guidelines of the Memory of the World (MoW) Programme. <https://unesdoc.unesco.org/ark:/48223/pf0000378405>

[5] van Zanten, W. (Ed.) (2002) *Glossary Intangible Cultural Heritage* (Results of the International Meeting of Experts on Intangible Cultural Heritage - Establishment of a Glossary UNESCO Headquarters, Paris, 10-12 June 2002, and edited by this group between June and August 2002), Netherlands National Commission for UNESCO.

<https://ich.unesco.org/en/events/expert-meeting-on-intangible-cultural-heritage-establishment-of-a-glossary-00082>

Deep Dream for Sound Synthesis

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Abstract

In 2015, Google engineer Alexander Mordvintsev presented *DeepDream* as technique to visualise the feature analysis capabilities of deep neural networks that have been trained on image classification tasks. For a brief moment, this technique enjoyed some popularity among scientists, artists, and the general public because of its capability to create seemingly hallucinatory synthetic images. But soon after, research moved on to generative models capable of producing more diverse and more realistic synthetic images. At the same time, the means of interaction with these models have shifted away from a direct manipulation of algorithmic properties towards a predominance of high level controls that obscure the model's internal working.

In this paper, we present research that returns to *DeepDream* to assess its suitability as method for sound synthesis. We consider this research to be necessary for two reasons: it tackles a perceived lack of research on musical applications of *DeepDream*, and it addresses *DeepDream*'s potential to combine data driven and algorithmic approaches.

Our research includes a study of how the model architecture, choice of audio datasets, and method of audio processing influence the acoustic characteristics of the synthesised sounds. We also look into the potential application of *DeepDream* in a live-performance setting. For this reason, the study limits itself to models consisting of small neural networks that process time-domain representations of audio. These models are resource-friendly enough to operate in real time.

We hope that the results obtained so far highlight the attractiveness of *DeepDream* for musical approaches that combine algorithmic investigation with curiosity driven and open ended exploration.

1. Introduction

Large scale deep-learning models such as Chat-GPT¹, MidJourney², and MusicLM³ have recently been made available to a wider audience. The capability of these models to generate a large variety of high quality text, images, or sounds and the ease with which these models can be used by non-experts has brought the field of generative machine learning to the forefront of public attention.

Unfortunately, these models don't lend themselves very well to generative approaches that situate the ideation and development of algorithms at the core of their practice. The reason for this involves both core aspects of the models' functioning and practical aspects of their usage. A user's influence on the model's behaviour is limited to the provision of high level controls often in the form of text prompts that steer the content of the generated output. This comes at the cost of the user's understanding of the models' architectural design and operational functioning, both of which would be a prerequisite to adapt the models for one's own artistic goals. Furthermore, the sheer size of these models renders it unfeasible for regular users to train these models on material that they might have created and/or collected on their own. This prevents these models from generating output that is representative of the potentially highly idiosyncratic aesthetic and thematic interests of a specific user.

1 ChatGPT: chat.openai.com

2 MidJourney: docs.midjourney.com

3 MusicLM: aitestkitchen.withgoogle.com

The DeepDream technique (DD) represents one of the earliest deep learning based approaches to generate synthetic images. While this technique is clearly inferior to state of the art generative models in terms of diversity and quality of generated media, it excels at exposing the relationships between the algorithmic properties of the model and the characteristics of the generated media. Furthermore, DD can be used in combination with models that possess a modest number of parameters. These models can be trained on relatively small datasets and are thereby able to capture some of the idiosyncratic properties inherent in these datasets. Furthermore, these models are able to generate media very quickly and can therefore be used in real-time.

This publication focuses on the use of DD for generating audio. The work described is divided into two parts. The main part consists of an analytical study of the relationships between training data, model architecture, DD parameters on the one hand and the acoustic characteristics of the generated audio on the other hand. The second part represents an example application of DD for music composition.

2. Background

In 2015, Alexander Mordvintsev presented DD as a technique to improve the understanding of the feature extraction capabilities of deep convolutional neural networks (DCNN) that have been trained on image classification tasks [1]. The technique employs a visualisation procedure that functions by running a training process on an input image instead of the network. During this procedure, the input image is iteratively modified through a feature

inversion process that maximises the activity of one or several chosen network layers and feature maps. After several iterations, the input image increasingly exhibits those features that are recognised by the chosen network layers and feature maps. With the aid of this visualisation procedure, it can be shown that lower network layers recognise basic patterns, while higher network layers recognise more complex composite patterns. For a more exhaustive introduction into DD, the reader is referred to a recently published systematic review [2].

While much of the interest and popularity around DD has focused on its application in the image domain, a few researchers and artists have also explored its usefulness for audio.

Ardila and colleagues applied DD on a DCNN that has been trained with raw waveforms to predict collaborative filtering track embeddings [3]. The authors studied the filters learned by the first layer and the corresponding spectra. Mishra and colleagues employed DD on a DCNN that has been trained with Mel Spectrograms on a singing voice detection task [4]. Their findings suggest that at the deepest level, convolution layers preserve temporal and harmonic structures while fully connected layers do not.

In a more artistically motivated research project, Galac and Delgadino employed creative variations on DD [5]. These variations are based on the integration of audio filters into the activation maximisation function. The authors used the pre-trained YAMNET1 [6] model. They conclude that the use of a hard-cut filter in the maximisation function produces more interesting sonic results than the

original DD. Another artistic research project has been conducted by Herrmann [7]. The author trained a DCCN on a scaleogram representations of audio clips. What mainly distinguishes this project from previous endeavours is that training is self-supervised instead of supervised. Self-supervised training causes the network to perceptually discriminate between different audio features instead of learning a mapping from input to explicit labels.

The work presented in this publication complements and extends this prior research in two directions. Similarly to [3] and [4], it conducts a systematic analysis of the feature detection capabilities of different network layers and feature maps. But in addition, it also conducts a comparison between different audio training sets and network architectures. Similarly to [5] and [7], it highlights the creative possibilities of DD for musical applications. But in addition, it exemplifies how DD can be adopted for creating a musical composition.

3. Implementation

The study presented in this publication is based on our own implementation and training of neural networks and the subsequent application of DD for generating audio. The implementation involves a selection of three different publicly available audio datasets, the design of two different DCCN, their training on audio classification tasks, the modification of an existing DD algorithm, and the use of audio feature analysis to quantify the characteristics of the generated audio. Each of these implementation aspects is described in more detail in the subsequent sections.

3.1 Datasets

We decided to work with several different audio datasets as training data to compare their respective influence on the audio generated with DD. Our criteria for selecting the datasets were as follows: the audio sampling rate is at least 44100 Hz, each audio recording is at least a few seconds long, and the number of classes is at least 100. The last criteria was based on our assumption that a model that recognises a large number of classes discriminates between more nuanced audio characteristics than a model that recognises a small number of classes. We chose three audio datasets that full-fill these criteria but that differ from each other with regards to the diversity of the recorded sounds. The Freesound dataset⁴ exhibits the largest acoustic diversity. It contains 200 classes of sound events that were drawn from the AudioSet Ontology. The Musical Instruments dataset⁵ exhibits intermediate acoustic diversity. It contains 255 classes of instruments played at different loudness levels and with different tone types. The AISHELL-3 dataset⁶ exhibits small acoustic diversity. It contains 218 classes of different Chinese subjects speaking short sentences in Madarin. Throughout the remainder of the text, the three datasets will be referred to as *Events* for the Freesound Dataset, *Instruments* for the Musical Instruments dataset, and *Speech* for the AISHELL-3 dataset.

3.2 Models

⁴ Freesound Dataset 50k: zenodo.org

⁵ Microphone Array Measurements of Musical Instruments: depositonce.tu-berlin.de

⁶ AISHELL-3 Open Source HI-FI Mandarin Speech Corpus: www.aishelltech.com

Two different convolutional models have been designed using the PyTorch⁷ deep learning framework. Both models take as input normalised waveforms of raw audio of one second duration and a sample rate of 44100 Hz and produce as output the log-probabilities for each class. In both models, the neural network consists solely of 1D convolution layers that perform convolution in the temporal domain. This design is informed by the finding that fully connected layers fail to capture crucial aspects of audio [4]. The model architecture is very simple and differs between the two models only in terms of the number of convolution layers. One model (*Model1*) consists of four convolution layers and possesses roughly 400000 trainable parameters. The other model (*Model2*) consists of eight convolution layers and possesses roughly 300000 trainable parameters.

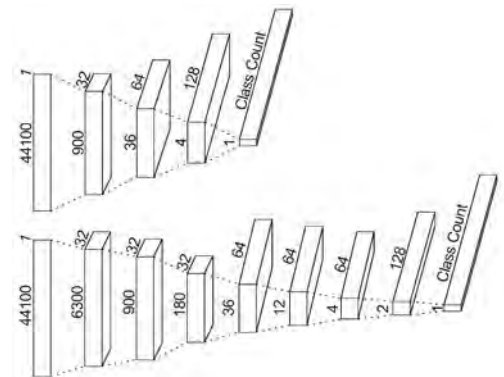


Figure 1: Architectures of Model1 and Model2. The deepness of the layers increases from left to right. For each layer, the vertical number represents the length of the input vector and the diagonal number represents the number of channels.

⁷ PyTorch: pytorch.org

model	layer	ksize	stride	padding
1	0	85	49	42
	1	43	25	21
	2	17	9	8
	3	7	4	3
2	0	129	7	64
	1	65	7	32
	2	33	5	16
	3	17	5	8
	4	9	3	4
	5	5	3	2
	6	3	2	1
7	3	2	1	

Table 1: Layer Properties. The abbreviations stand for: layer for layer index, and ksize for kernel size.

The layout of the architecture and the properties of the convolution layers are depicted in figure 1 and table 1, respectively. Other elements of the model architecture are the use of the Swish activation function [8] and Batch Normalisation between each layer, and the Softmax activation function after the output layer. The motivation to design two models that differ from each other with regards to the number of convolution layers was informed by the well known finding that layers at different depth discriminate features at different levels of complexity [1]. By performing DD on models that possess a different number of layers but are otherwise identical, insights can be gained whether the layer count affects the complexity of acoustic properties that generated audio.

3.3 Training

The two models were trained on an audio classification task. Training was performed independently with each audio dataset. Training was run for 200 epochs with a test-train split of 20%/80% and a batch size of 128. The learning rate was initially set to 10^{-3} and subsequently

stepwise reduced every 100 epochs with a decay factor of 0.1. The loss function was based on negative log likelihood. For parameter optimisation, an Adam optimiser with default parameter settings was employed. Table 2 lists the classification accuracy achieved on the test set for each of the models and datasets.

model	dataset	accuracy
1	<i>Events</i>	27%
	<i>Instruments</i>	28%
	<i>Speech</i>	89%
2	<i>Events</i>	37%
	<i>Instruments</i>	41%
	<i>Speech</i>	95%

Table 2: Audio Classification Accuracy.

3.4 DeepDream

The implementation of DD follows standard practice but includes two additional processing steps: a shift by a random time offset and a low-pass filter. When employing DD on images, it has been shown that a random offset in the image coordinate system increases the diversity of the generated visual features. For this reason, this technique has been adopted for audio. The addition of a low-pass filter was inspired by the work by Galac and Delgado [5] and has proven crucial to reduce the amount of noise present in the audio that is generated in deep layers.

In the chosen implementation, DD conducts three processing steps: 1) the waveform is modified through gradient ascent 2) the waveform is randomly offset in time 3) the waveform is low-pass filtered. The gradient ascent algorithm conducts seven processing steps: 1) the waveform is passed into the model 2) the activations of the chosen layers and feature maps are obtained 3) for each

layer and activation, the mean square error loss between the activations and a zero vector is calculated 4) the error gradient is computed by back-propagation 5) the gradient is smoothed using Cascade Gaussian Smoothing 6) the waveform is modified based on the gradient 7) the waveform is normalised.

In this DD implementation, the following parameters can be varied: the content of the initial audio waveform, the maximum size of the random temporal offset, the number of iterations over which the waveform is modified, the coefficient and kernel size used for gradient smoothing, the learning rate with which the gradient is applied to the waveform, and the cut-off frequency of the low-pass filter.

3.5 Audio Feature Analysis

To assess of the acoustic characteristics of the generated audio, several audio feature are analysed: Waveform Root Mean Square, Spectral Centroid, Spectral Flatness, and Spectral Flux. The Root Mean Square (RMS) of a waveform corresponds to the *Loudness* of a sound. The Spectral Centroid indicates where the centre of mass is located in an audio spectrum. This corresponds to the *Brightness* of a sound. The Spectral Flatness is obtained as ratio between geometric and arithmetic mean of an audio spectrum. This corresponds to the *Noisiness* of a sound. The Spectral Flux is obtained as difference of the audio spectra between two consecutive frames. This corresponds to the *Roughness* of a sound.

4. Results

Two experiments have been conducted to study the acoustic results obtained using DD. The first experiment served to

assess the influence of a chosen audio dataset, model architecture, convolution layer, and feature map on the generated audio. The second experiment served to evaluate the effect of different parameters of DD on the generated audio. These two experiments and the results obtained through them are discussed in more detail in the following sections.

4.1 Experiment 1

In this experiment, a total of six different models (two model architectures, each trained with one of the three audio datasets) were systematically tested by maximising the activity of each convolution layer and feature map in turn. In each of these tests, the same parameter values for DD were used: white noise as initial audio, a maximum temporal offset size of 1, a number of iterations of 2000, a gradient smoothing coefficient of 0.5 and kernel size of 9, a learning rate of 0.01, and a low-pass cut-off frequency of 12 kHz. The audio generated in each of these tests was subsequently analysed using the selected audio features. The results of this experiment are presented as sound examples and graphs.

Since the number of feature maps and correspondingly the number of generated sounds is very large, only a small representative subset of these sounds has been made available online. For each combination of model architecture and audio dataset, this selection consists of two sounds per convolution layer. The sounds have been uploaded to the SoundCloud audio streaming service and

are organised as one Playlist for each model and dataset^{8 9 10 11 12 13}.

To quantify the acoustic characteristics of the generated sounds, the mean and standard deviation of each audio feature have been computed for all sounds that were generated by all the feature maps in a single convolution layer. These statistics are depicted as graphs, with one graph for each combination of model architecture and audio feature (see figures 2, 3, 4, 5, 6, 7, 8, 9). In each of these graphs, the mean and standard deviations of the corresponding audio feature are depicted for each dataset and model layer. The indices of the model layers belong to the x-axis and the audio feature values to the y-axis. The mean values of the audio features are plotted as fully opaque lines whereas the shaded bands indicate a range of one standard deviation. The primary colours of the lines and bands represent the different datasets: Red for *Events*, Blue for *Instruments*, and Green for *Speech*.

8 Experiment 1 - Audio examples generated by *Model1* trained on the *Events* dataset:
[soundcloud.com](https://www.soundcloud.com)

9 Experiment 1 - Audio examples generated by *Model2* trained on the *Events* dataset:
[soundcloud.com](https://www.soundcloud.com)

10 Experiment 1 - Audio examples generated by *Model1* trained on the *Instruments* dataset:
[soundcloud.com](https://www.soundcloud.com)

11 Experiment 1 - Audio examples generated by *Model2* trained on the *Instruments* dataset:
[soundcloud.com](https://www.soundcloud.com)

12 Experiment 1 - Audio examples generated by *Model1* trained on the *Speech* dataset:
[soundcloud.com](https://www.soundcloud.com)

13 Experiment 1 - Audio examples generated by *Model2* trained on the *Speech* dataset:
[soundcloud.com](https://www.soundcloud.com)

When bands overlap, the resulting mixed colours represent several datasets: Yellow for *Events* and *Speech*, Violet for *Events* and *Instruments*, Cyan for *Instruments* and *Speech*, and Gray for all datasets.

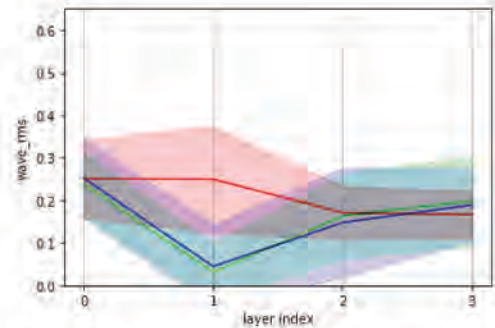


Figure 2: Model1 - Layer Effects on Loudness.

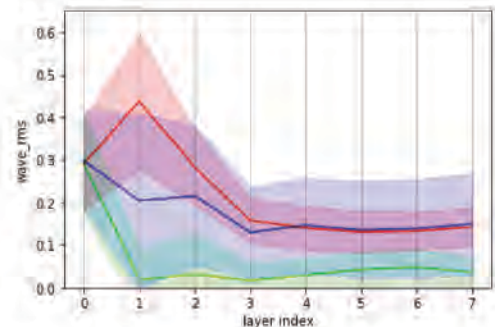


Figure 3: Model2 - Layer Effects on Loudness.

Based on this quantitative analysis and in combination with qualitative listening, several observations can be made about the effect of each layer in *Model1* or *Model2* on the acoustic characteristics of the generated sounds. These observations as summarised for each model architecture and audio feature in tables 3, 4, 5, 6, 7, 8, 9, 10. The following abbreviations are used in these tables. If

the effect applies only for one or two datasets, then these dataset(s) are indicated with the single letters in brackets: (e) refers to *Events*, (i) to *Instruments*, and (s) to *Speech*. If the effect applies to all audio datasets, then the letter (a) is used.

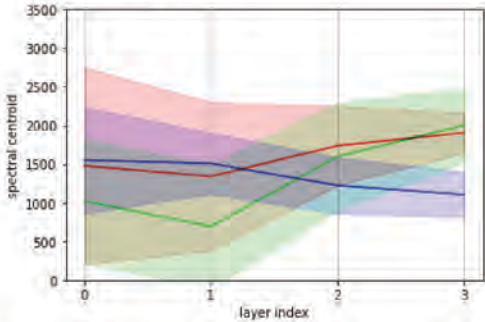


Figure 4: Model1 - Layer Effects on Brightness.

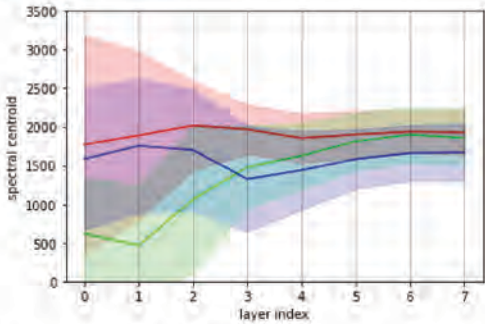


Figure 5: Model2 - Layer Effects on Brightness.

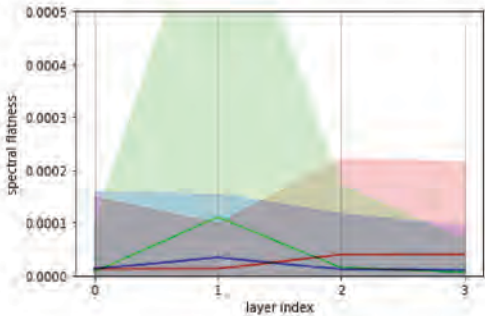


Figure 6: Model1 - Layer Effects on Noisiness.

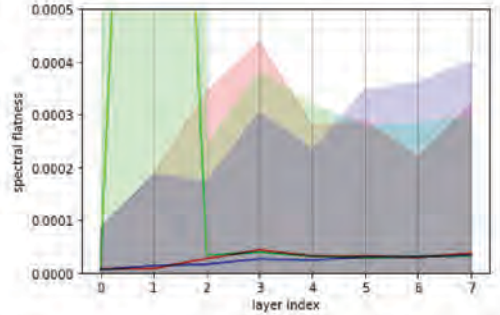


Figure 7: Model2 - Layer Effects on Noisiness.

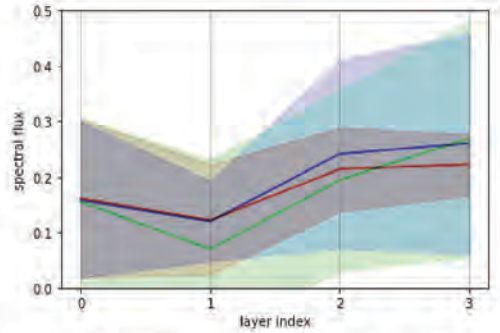


Figure 8: Model1 - Layer Effects on Roughness.

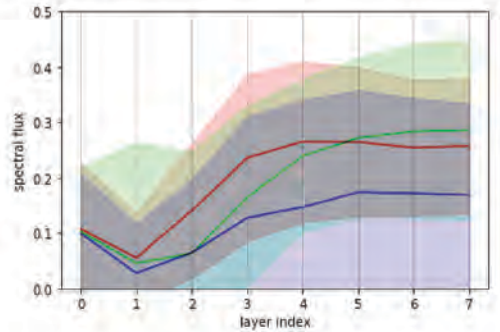


Figure 9: Model2 - Layer Effects on Roughness.

layer	loudness characteristics
0	medium loudness and small dynamic range (a)
1	low (i, s) or medium (e) loudness often concentrated in short loudness bursts (a)
2	medium loudness (a) with small (e, i) to medium (s) dynamic range
3	medium loudness (a) with small to medium dynamic range (a)

Table 3: Model1 - Layer Effects on Loudness

layer	loudness characteristics
0	medium loudness and small dynamic range (a)
1	high (e), medium (i) or low (s) loudness with small dynamic range (e) or short bursts (s) or both (i)
2	medium (e, i) or very low (s) loudness, which is constant or exhibits repetitive variations (e), short or extended bursts (s), or all of this (i)
3	low (e, i) or very low (s) loudness with repetitive (e) or irregular (i) variations, or extended bursts (s)
4	low (e, i) or very low (s) loudness, with more varied repetitions (e), in combination irregular variations (i), or extended bursts (s)
5	low (e, i) or very low (s) loudness with highly varied patterns (e, i) or combinations of burst repetitions and constant loudness (s)
6	similar to layer 5 (a)
7	similar to layer 5 (a)

Table 4: Model2 - Layer Effects on Loudness

layer	brightness characteristics
0	constant for one feature map but strongly varied across feature maps (a)
1	constant (i) or slightly varied (e, s) for one feature map and less strongly varied across feature maps (a)
2	slightly (e, i) or strongly (s) varied for one feature map and less strongly varied across feature maps (a)
3	similar to layer 2 (a)

Table 5: Model1 - Layer Effects on Brightness

layer	brightness characteristics
0	constant for one feature map but varies strongly across maps (a)
1	slightly varied (e, i) or constant (s) for one feature map and less (e, i) or similarly (s) strongly varied across feature maps
2	similar to layer 1 (a)
3	more strongly varied for one feature map (a) and less across feature maps (s)
4	varies even more strongly for one feature map (a) and less across feature maps (a)
5	varies very strongly for one feature map (a) and little across feature maps (a)
6	similar to layer 5 (a)
7	similar to layer 5 (a)

Table 6: Model2 - Layer Effects on Brightness

layer	noisyness characteristics
0	little noise (a)
1	slightly more noise that is mostly concentrated in loudness bursts (e, i) or evenly distributed (s)
2	considerably (e, i) or little (s) more noise
3	considerably (e, i) or slightly more noise (s)

Table 7: Model1 - Layer Effects on Noisiness

layer	noisyness characteristics
0	little noise (a)
1	slight (e, i) or significant (s) noise
2	some noise mostly concentrated in loudness bursts (a)
3	some noise in entire sound (a)
4	similar to layer 3 (a)
5	significant noise in entire signal (a)
6	similar to layer 5 (a)
7	similar to layer 5 (a)

Table 8: Model2 - Layer Effects on Noisiness

layer	roughness characteristics
0	minimal (a)
1	similar to layer 0 (a)
2	increased spectral variations always (e, s) or sometimes (i) in sync with loudness variations
3	increased spectral variations mostly (s) or sometimes (e, i) in sync with loudness variations

Table 9: Model1 - Layer Effects on Roughness

layer	roughness characteristics
0	minimal (a)
1	even less (a)
2	increased and in sync with loudness variations (a)
3	increased and always (e, i) or sometimes in sync with loudness variations (s)
4	increased and partially in sync with and partially independent of loudness variations (a)
5	similar to layer 4 (a)
6	similar to layer 4 (a)
7	similar to layer 4 (a)

Table 10: Model2 - Layer Effects on Roughness

4.2 Experiment 2

In the second experiment, the influence of different DD parameter values on the generated sounds were evaluated with a Model2 architecture that has been trained on the *Events* dataset. This combination of dataset and model has been chosen because it generates sounds with an acoustic characteristics that varies widely both in the temporal and spectral domain. In this experiment, audio was generated in real-time. This was achieved by conducting several DD iterations on a short excerpt of a full waveform. The excerpt was repeatedly shifted in a round-robin manner to eventually subject the entire waveform to feature inversion. In each DD run, only one DD parameter was changed at a time while the others were fixed. Fixed parameters were assigned the following values: a maximum temporal offset size of 1, a number of iterations of 10 per audio excerpt, a gradient smoothing coefficient of 0.5 and a kernel size of 9, a learning rate of 0.04, and a low-pass cut-off

frequency of 12 kHz. Together with the parameter changes, the selection of convolution layers and feature maps was also changed. The variations of parameter values, convolution layers, and feature maps followed a strict sequence which is shown in table 11. In each DD run, the audio waveform was initialised with white noise and then modified by stepping through the sequence of settings. A 20 seconds delay was applied before applying the step. Between each subsequent step, a 20 seconds pause was applied. These durations were chosen to allow the acoustic characteristics of the generated sound to stabilise before the next change. Changes in layers and feature maps were offset by 10 seconds to changes in DD parameters. This allowed to observe the effect of each of these changes separately.

layer indices	0, 1, 3, 8
feat. map indices	3, 3, 4, 8
temporal offset	1, 16, 64, 128, 512
iteration count	1, 2, 4, 7, 10
grad. coeff.	0.1, 0.3, 0.5, 0.7, 0.9
grad. kernel-size	3, 5, 9, 13, 17
learning rate	0.02, 0.04, 0.08, 0.12, 0.16
cutoff freq. (kHz)	2, 4, 8, 12, 16

Table 11: Experiment 2 - DD Parameter Sequences

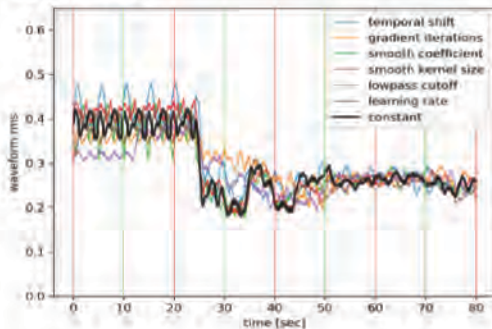


Figure 10: Model2 - DD Parameter Effects on Loudness.

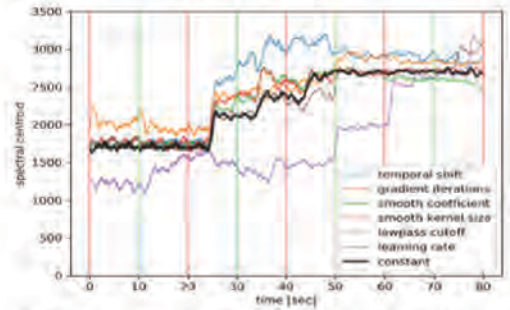


Figure 11: Model2 - DD Parameter Effects on Brightness.

The sounds that have been generated in Experiment 2 are available on SoundCloud¹⁴. For these sounds, the same acoustic features have been analysed as in Experiment 1. The graphs in figures 10, 11, 12, 13 depict how the mean value of a specific audio feature changes in response to different DD parameter variations and selections of layers and feature maps. The line colours in these graphs represent the parameter that were changed. The bold black line represents feature values that were obtained when keeping all DD parameters fixed and only selecting different layers and feature maps. In each of these plots, the time in seconds belongs to the x-axis and the audio feature value belongs to the y-axis. The red vertical lines indicate the moments of parameter change. The green vertical lines indicate moments of layer and feature map change.

¹⁴ Experiment 2 - Audio examples generated by Model2 trained on the Events dataset: soundcloud.com

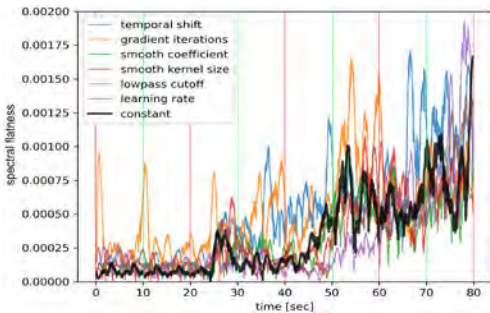


Figure 12: Model2 - DD Parameter Effects on Noisiness.

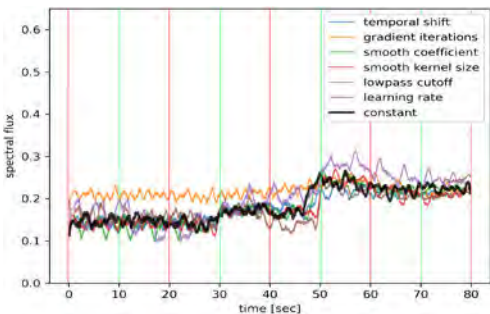


Figure 13: Model2 - DD Parameter Effects on Roughness.

This experiment shows that the influence of most DD parameters on the acoustic characteristics of the generated sounds is small. The gaussian smoothing coefficient and kernel size have no acoustic effect at all. The interaction count and learning rate exhibit a small acoustic effect. These two parameters exert their influence mainly by affecting the duration over which audio features change when a layer and/or feature map is switched. Other than that, an increase in iteration count also leads to a slight increase in *Roughness* if this feature is small otherwise, and a large learning rate slightly increases *Noisiness*, *Brightness* and *Roughness*. The randomised temporal offset mainly affects *Brightness*

and *Noisiness* which both increase significantly for high offset sizes. The cut-off frequency of the low-pass filter has the strongest effect on *Brightness* which directly correlates with the cut-off frequency. The cut-off frequency also affects *Loudness* which is reduced for low frequencies. The acoustic properties that are affected the least by the cut-off frequency are *Noisiness* and *Roughness*. Both properties increase only slightly with increasing cut-off frequency.

5. Discussion

The quantitative and qualitative evaluations conducted as part of the two experiments proved extremely useful to gain a better understanding for the influence of the training data, network architecture, and DD parameter settings on the acoustic characteristics of the generated sounds.

It has been found that the choice of layer has by far the strongest influence on the acoustic characteristics of the generated sounds. This effect is particularly strong for the first two layers and supersedes the influence stemming from the dataset or DD parameters. Choosing a feature map in the first layer always results in strongly pitched sounds with simple spectra, sustained loudness, and little noise. Choosing a feature map in the second layer always leads to sounds whose loudness is concentrated in short bursts. From then on, feature maps in increasingly deeper layers tend to generate sounds that exhibit an increased complexity in terms of *Loudness* and spectral properties at the cost of an increase in noise. This tendency towards more acoustic

complexity is counteracted by *Brightness*, whose variability across feature maps decreases significantly at higher layers.

The higher number of layers in *Model2* compared to *Model1* has no dramatic effect. Feature maps in layers 4 and 5 tends to generate sounds that have a slightly more complex and diverse *Loudness* and spectral dynamics than more shallow layers. Feature maps in layers 6 and 7 generate mostly the same acoustic results at layer 5. Accordingly, with the current choice of a layer architecture, an additional increase in the number of layers will likely not produce more diverse acoustic results.

It is a surprising and somewhat disappointing finding that the choice of audio dataset influences the characteristics of the generated audio only in nuances. No combination of feature map and DD parameter settings has generated sounds that clearly reproduce the characteristics of the audio material in the datasets. Nevertheless, the nuanced influences of the datasets are worth mentioning. In case of the *Events* dataset, the generated sounds are fairly varied with regards to the dynamics of their loudness and spectral properties, with the loudness and spectral dynamics being strongly correlated. In case of the *Instruments* dataset, the generated sounds exhibit a high loudness dynamics and low spectral dynamics, with both of them being strongly correlated. In case of the *Speech* dataset, the generated sounds exhibit a low loudness dynamics and high spectral dynamics, with both of them exhibiting little or no correlation.

Also small was the influence of most DD parameters on the generated sounds. The only exceptions are the size of the

randomised temporal offset which affects *Brightness* and *Noisiness* and the cut-off frequency of the low pass filter which affects *Brightness* of the generated sounds. Due to a lack of acoustic impact of most DD parameters, the focus of attention should clearly be placed on the choice of feature maps when aiming for a large variety of generated sounds.

6. Composition

The findings described previously have helped with the creation of a music piece entitled "Analog Zombies in Deep Dreams"¹⁵. This piece will be released on CD Nr. 23 of the Deutsche Gesellschaft für ElektroakustischeMusik)¹⁶. The piece has been composed by the musician Thomas Wenk. For the composition, he recorded the mechanical and electrical noises produced by old cassette recorders. These recordings were assigned to one of three classes: isolated click sounds with low brightness and strong noise, isolated click sounds with a clear pitch and intermediate brightness, rapid click repetitions with high brightness and a clear pitch. A version of *Model1* with a smaller number of feature maps was trained to classify these recordings and subsequently used in combination with DD to generate new audio material. The generated sounds that were obtained in this manner vary in their acoustic characteristics between undifferentiated coloured noise and complex rhythmical patterns.

¹⁵ Analog Zombies in Deep Dreams: www.e-wegner.net

¹⁶ Deutsche Gesellschaft für Elektroakustische Musik: www.degem.de

The composer created a piece that combines the original recordings and generated sounds into a collage that highlights the causal connection between the two types of sounds. At the beginning of the piece, the original and generated sounds are juxtaposed in a manner that emphasises their differences. In this section, the original sounds are clearly recognisable as being produced by a technical apparatus whereas the generated sounds possess a more abstract sonic quality. Later on, the generated sounds dominate and draw the listeners' attention to the nuanced differences between the generated sounds. This section is occasionally interrupted by recordings of key-presses. The recordings appear as percussive punctuations that separate the generated sounds from each other.

7. Outlook

We plan to continue our work on musical applications of DD in both artistic and scientific directions.

For the creation of new artistic works, we plan to adopt the approach employed in Experiment 2, i.e. the generation of audio in real-time while simultaneously switching between convolution layers and feature maps. The new works could take the form of live music performances or interactive audio installations. As part of this artistic direction, we also intend to explore the acoustic effects of combining multiple feature maps at the same time. In parallel to this, we also intend to collaborate with additional composers who extensively work with large pre-recorded audio collections. We are curious to see what other strategies these composers might come up with when

using DD to expand and enrich their musical vocabulary.

On the scientific side, our most immediate next step involves the conduction of additional systematic experiments that deal with varying aspects of DD that have so far been kept fixed. This includes initialising audio waveforms with other content than white noise and varying the number of classes when training models on an audio classification task. Other future work involves the design of model architectures that incorporate more sophisticated layers such as different variants of residual layers. Finally, and most importantly, we would like to follow up on the work conducted by Herrmann [7] and abandon supervised training in favour of self-supervised approaches.

8. Acknowledgements

The research presented in this publication has been conducted in the context of the Horizon Europe project entitled *Premiere*¹⁷ and supported by the European Union.

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¹⁷ *Premiere* - Performing arts in a new era: AI and XR tools for better understanding, preservation, enjoyment and accessibility: premiere-project.eu

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Aesthetic of Periodic, Non-Periodic, Stochastic, and TPMS in Digital Sculpture

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Abstract

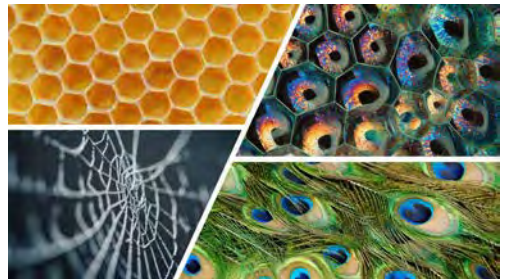
Introduction:

Different structures can fill a volume, and in nature, we can find examples in bones, honeycombs of beehives, fungi mushrooms, bubbles (as Voronoi structure), bird feathers, and spiderwebs.

All these examples are nature's way of filling a volume and providing lightweight structures but also present a natural beauty that we respond to.

Our aesthetic response to lattice structures is influenced by a combination of symmetry, complexity, transparency, cultural context and experiences, and the interplay of negative and positive space

defined by the structure itself and the intrinsic light and shadow. All these elements combine to create a visual experience that many find inherently beautiful and captivating.



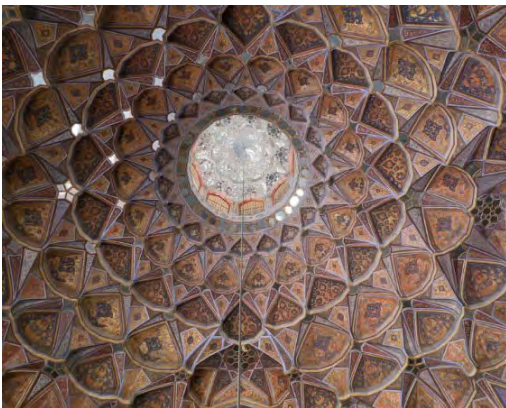
Since a few years ago, such structures have been used primarily in 2D design to translate complex three-dimensional shapes.

For instance, we can find some examples of this kind of translation in the Japanese art Kumiko, a traditional wood-making technique in which the wood pieces are assembled without using any nails. Two-dimensional patterns are translated into three-dimensional ones mostly to make screens.



In Islamic art, other designs are built on squares and circles, typically repeated, overlapped, and interlaced to form intricate and complex patterns. A recurring motif is the 8-pointed star, often seen in Islamic tilework; it is made of two squares, one rotated 45 degrees to the other.

The two dimensional patterns were also translated into impressive architectural structures.



We are just beginning to explore more complex patterns that AM (additive manufacturing technologies) made possible to fabricate in 3D. Most recent studies are related to increasing these structures' versatility because of the significant benefits like high strength-to-weight ratio.

Objective/Hypothesis:

In this research, a novel approach to studying cellular lattice structure focuses on the aesthetic response of structures that fill a mesh, a CAD model, or surfaces. Lattices can be periodic, non-periodic, or stochastic, modeled through beams, plates, or (TPMS) Triply Periodic Minimal Surfaces.

My research aims to investigate the correlation between lattice structures that mimic natural patterns, such as honeycombs, leaf veins, or crystal formations, as natural forms with an inherent beauty that resonates with many people.

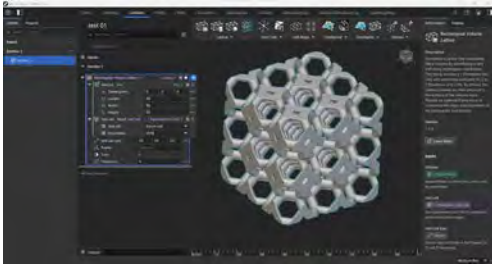
By using the latest software (nTopology, NetFabb, Fusion 360, etc.) and specific processes to prepare a variety of sculptures, I explore the aesthetic response based on symmetry and order, transparency and light play, complexity and intricacy, natural and cultural connection, functional elegance, cultural significance, dynamic perception, scale.

Methods:

The research uses nTopology design software to prepare small samples to test the aesthetic response with a pool of people.

As a first series of lattice structures, I set up a basic cube 50x50x50 mm with a unit cell of 25x25x25 mm. The minimum thickness of the elements was defined as 3 mm. These dimensions were selected to create a series of easily printable models that can fit a hand and be analyzed by the pool by visual inspection and tactile experience. I modeled the dimensions for the Printing with an SLA 3D Printer (Formlab 3) that provides a smooth finish and doesn't need support

with smaller parts with printing angles less or equal to 45. Prints are made in white resin to avoid any color connotation and to improve the understanding of negative and positive space based on the white materials and their shadows.

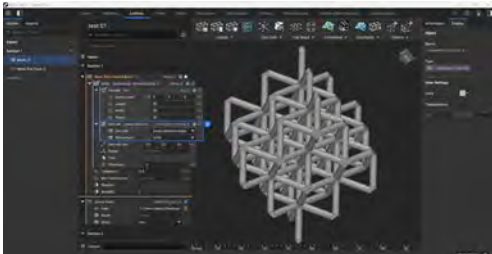


I divided the models based on four subdivisions (Periodic, Non-Periodic, Stochastic, and TPMS), and I started with a single parameter graphic unit cell.

Some periodic lattices are often considered aesthetically attractive due to their symmetrical and visually appealing patterns, so I grouped some of them and selected five as the best representatives:

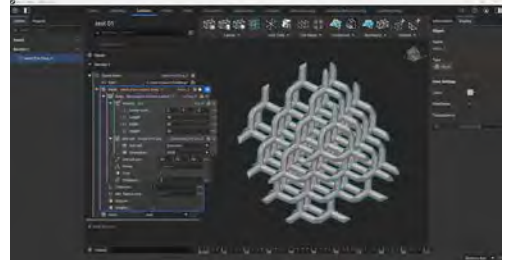
The body-centered cubic (BCC) cell is a typical crystal lattice structure in solid-state physics and materials science. It is characterized by its simple cubic unit cell.

From an aesthetic standpoint, the body-centered cubic lattice may be appreciated for its clean, regular, and symmetrical pattern.

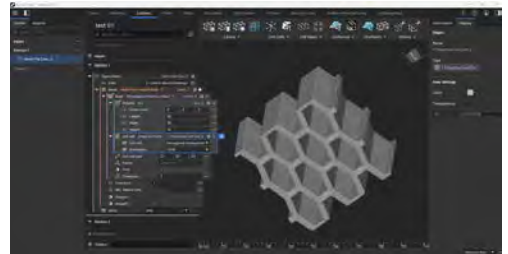


The diamond lattice is a face-centered cubic lattice structure, often associated

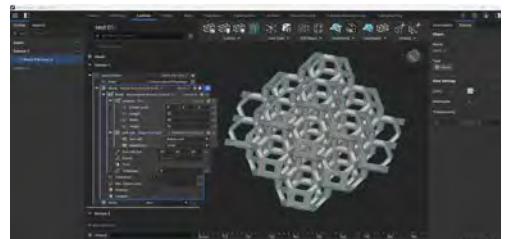
with the crystalline form of diamond. It has a symmetrical and geometrically pleasing arrangement of parts.



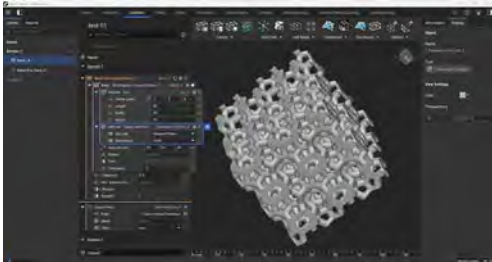
The honeycomb lattice is composed of hexagonally arranged cells, similar to the structure of a honeycomb. It can be found in materials like graphene, and its regular hexagonal pattern is often considered visually pleasing for its natural reference.



Kelvin unit (Tetrakaidecahedral unit-cell representation) is based on filling space with a structure that minimizes surface area. It consists of a unit cell shaped like a tetrakaidecahedron, which is a polyhedron with 14 faces (8 hexagons and 6 squares). Some may find its intricate, interlocking patterns visually captivating.



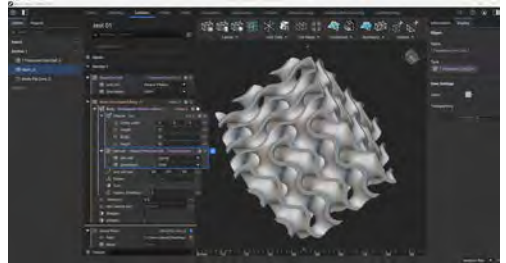
Weaire-Phelan is a complex foam-like arrangement of cells with the minimum known surface area for a partition of space into cells of equal volume. The structure consists of two types of cells: "Weaire cells" and "Phelan cells." Weaire cells are irregular dodecahedra, while Phelan cells are irregular polyhedra with 14 faces, including 12 pentagons and two hexagons. These cells interlock to minimize the total surface area, making it an optimal way to partition space into cells of equal volume. From an aesthetic standpoint, the Weaire-Phelan structure can be visually intriguing due to its intricate, irregular shapes and how they fit together.



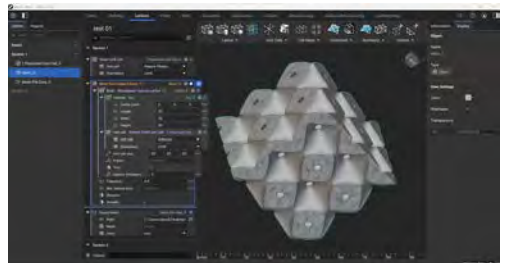
Triply periodic minimal surfaces (TPMS) divide three-dimensional space into cells of equal volume with minimal surface area. I modeled and printed a series with the exact dimensions and thickness for a starting base.

The Gyroid lattice is a fascinating and visually captivating mathematical structure. It is a triply periodic minimal surface, meaning it fills space with the least amount of surface area possible. This lattice was first discovered by physicist Alan Schoen in 1970. In addition to having parallel surface symmetry lines, the gyroid is notable for having no right-angle portions on its surface.

Aesthetically, many people find the Gyroid lattice to be highly interesting and visually appealing. Its continuous, interconnected network of twisting surfaces creates a mesmerizing and captivating visual experience. The lattice's intricate and repeating patterns can evoke a sense of wonder and curiosity.

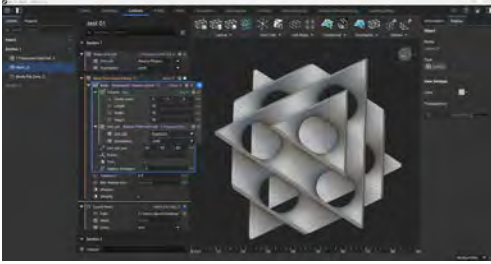


The Schwarz lattice refers to the "Schwarz P surface," a triply periodic minimal surface. This surface was first described by Hermann Schwarz in 1890. Aesthetically, its intricate, interconnected pattern can be mesmerizing to look at, and in the past, it has also found applications in architecture and materials science.



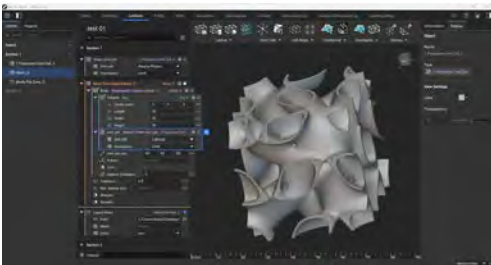
The diamond TPMS is characterized by a repeating pattern of diamond-shaped cells with intersecting edges and vertices. It is symmetrically and geometrically pleasingly.

To make it more similar in structure to all other ones, I had to change the size of the cell to 50x50x50 mm.

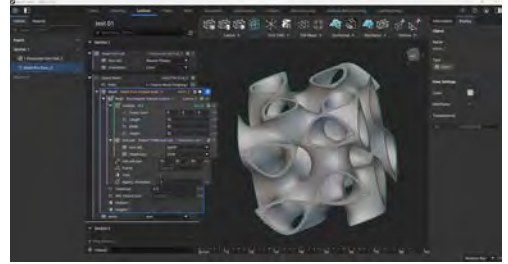


The Lidinoid is another example of TPMS. In 1990 Sven Lidin and Stefan Larsson found in the associate family of a particular member of the Schwarz H-surfaces this new embedded triply periodic minimal surface, similar in appearance to Alan Schoen's Gyroid.

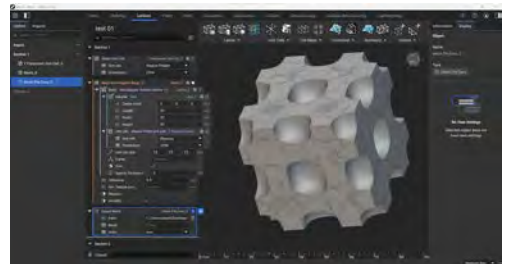
The Lidinoid has a distinctive undulating, curved structure with interconnected channels and chambers. It is characterized by its repeating, labyrinthine pattern that fills space with minimal surface area. Aesthetically, the Lidinoid is appreciated for its complex and visually captivating form. Its repeating pattern and interwoven curves create a visually exciting and mesmerizing structure.



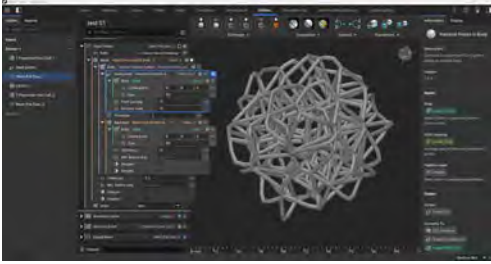
The SplitP is another interesting TPMS similar to the Linoid with a similar repeating, labyrinthine pattern.



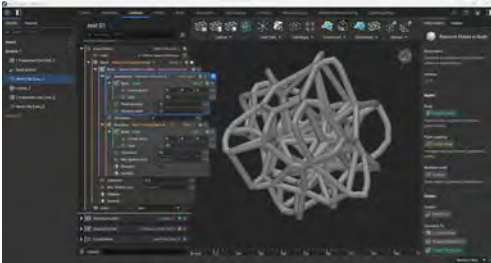
The Neovius surface is a triply periodic minimal surface originally discovered by Finnish mathematician Edvard Rudolf Neovius. Neovius' minimal surface in a unit cell has genus 9, dividing space into two infinite non-equivalent labyrinths. It presents a distinctive interconnected pattern of curved surfaces and is characterized by its repeating, labyrinthine structure with symmetrical features.



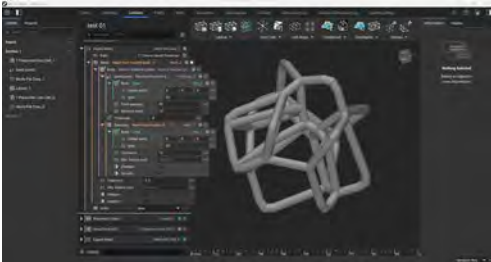
For the stochastic lattices, it was a little more challenging to establish basic parameters because to keep the structure similar in size and proportions to the previous ones, I had to change many parameters (random seeds creation, number and distance of points, etc...) I ended up in creating a series of structure, by using the same cube, but increasing the point spacing and at the same time increasing the thickness until the cube wasn't perceived anymore.



Point spacing 10, thickness 2



Point spacing 20, thickness 3



Point spacing 30, thickness 4

After modeling these basic samples, I 3D printed them with an SLA printer.

The analysis involved giving the 3D Printed samples to art students and gathering their opinions and reactions to the models. The evaluations were done by providing an aesthetic value from 1 (less appealing) to 5 (very appealing).



Another consideration is that the 3D printed models were evaluated for their aesthetic and tactile experience. People had an enhanced perception by holding the models in their hands.

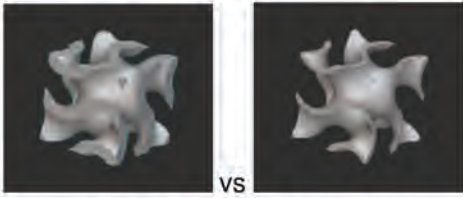
It seemed that models with softer curves were more appealing to a more significant number of people for the intrinsic tactile quality.



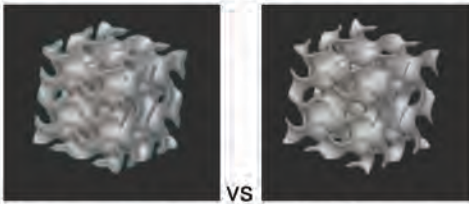
Results:

The TPMS group of lattices received the highest evaluations with the giroyd as first choice.

Additional evaluations were successively made on the proportions of the wall thickness respect the module and the proportions between the module and the volume to be filled.



Unit Cell Size 50x50x50 mm with thickness 10 mm vs thickness 5 mm.



Same unit cells 50x50x50 mm with thickness 10 mm vs thickness 5 mm to fill a cubical volume of 100x100 mm.

The pool of people evaluated more positively the gyroid with thinner walls.

Conclusions:

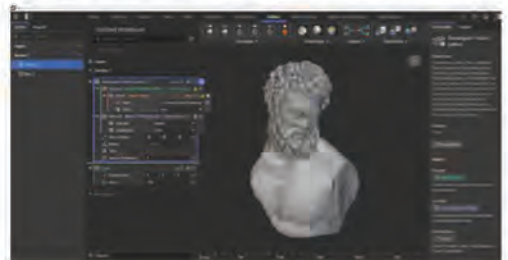
Sculptures that use the gyroid as a lattice structure to fill part or entirely the volume of the form received a higher aesthetic evaluation, especially with thinner walls. To create a modeling process for the modeling with lattice structures, we need first to establish the fabrication technology that will be used. A 3D Printed sculpture in SLA can probably be printed with thinner walls than one printed with binding jetting or FDM. A minimum thickness between 2 and 3 mm is necessary for good strength. The minimum thickness of a CNC carved sculpture (wood or stone) must be much higher. The size of the lattice structure cells must be established by considering the manufacturing technology. This limitation will also impact the main proportions of the lattice structure that fills the space.

"Noble Woman", one of the first sculptures I modeled with lattice structures as the fill of the internal volume, had a minimum thickness of around 3 mm. The internal lattice structure worked well with the external volume, creating an interesting dialogue between the parts.



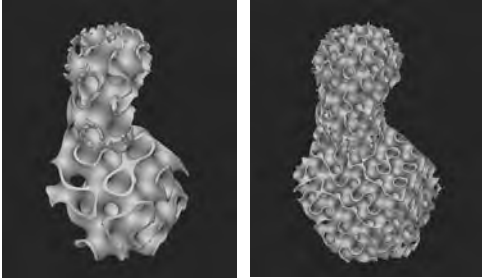
Model Examples:

By exploring a series of sculptures made with the use of gyroid as aesthetical component I can provide some initial considerations:



Dimensions need to be established already at the beginning of the modeling.

Key words: Generative design, additive manufacturing, 3D Printing, computational design.



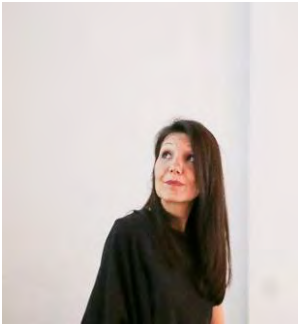
Proportions of the unit cell size and thickness need to be carefully evaluated based on the details of the model and its elements. In my research, it is important to find correlations between the external volume and the lattice structure by opening the volume in the "right" areas. I can carefully balance the relationship between "internal" and "external" shapes with cuts and by removing entire parts that become no longer essential. When well positioned, the showing of the lattice structure enhances the missing details of the sculpture.



The science of networks: network graphs in urban navigation design problems – mobility, transportation systems, and movement paths generation

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Abstract

Within the aim of testing generative computational design methods for design problems at the wider spatial, regional, and urban scale, a specific generative design task has been defined. It has been placed within the interdisciplinary field of urban planning, analytics, and design, computational and data sciences, as well as gaming and spatial experience and scenario construction, targeting particularly one of the territorial systems – mobility and transportation. Due to the fact that such infrastructure represents one of the most developed networks with constant internal and external growth, network science came as a supportive framework for bridging the gap between certain areas of spatial disciplines and data and

artificial intelligence disciplines.

Generative design problem definition branched along the two tracks. The first one addressed the question of the design of the spatial system of urban and regional mobility, with special regard to its dynamics (growth and restructuring); the Grand Paris Express has been taken as a field of operation. The second addressed the subject of movement path generation within such system, according to the defined criteria, movement scenarios and objectives, and navigation and mobility parameters. The network and the moves within, could have been considered as both abstract and real-world environments and operations, susceptible to the research of both – gaming strategies (academic, operational, and heuristic gaming) and real-world problem-solving strategies.

In that respect, the study seeks the best set of computational design methods for solving defined generative problems, including graph methods, along with inquiries into modes of data representation and possible interoperability between various software frameworks. It discusses some of the steps taken in this direction, particularly their viability regarding the posed objectives.

Keywords: computational design methods, generative design problem, urban systems, urban computing, urban movement, network science, network graphs, movement path generation, smart and intelligent mobility, programmable city

1. Disciplinary, territorial, and programmatic scope

1.1. Inter- and cross-disciplinary alliances

Several disciplines had to be called to attention considering a) the aim to test computational design methods for generative design problems at the wider spatial, regional, and urban scale, b) the chosen spatial subsystem (urban and regional mobility), and c) the complexity of the defined problem starting from this end of the spatial magnitude. Due to the fact that the main research subject is operated in space and includes issues at various scales, the overarching function belongs to the architectural and urban sciences. They are taken for those responsible for comprehension and articulation of all the urban/regional subsystems, their concerted work, and built environment, as well as coordination of all the interested parties and powers that operate in space. The topic of infrastructures and urban and regional mobility implied the involvement of traffic, civil, and mechanical engineering and sciences, with a specific impact of contribution provided by operational and organisational sciences, focused on command-and-control systems design considering traffic operation. Finally, a special place providing entrance to advanced modes of operation and

automation, data acquisition, processing, and representation belongs to applied mathematics, or more precisely data and artificial intelligence sciences with special insights in visual programming as a response to the visual representation request. In a convergent interpretation, the project has been placed within the field of urban computational planning, analytics, and design, targeting special contribution of data and artificial intelligence sciences to their new modes [1, 2, 3]. One branch of research placed specific interest in spatial decision-making and spatial experience/scenario construction, too, as well as gaming as either a possible direction of the defined problem development or the medium and environment of its investigation [4,5].

1.2. Territorial-programmatic congruence: spatial scope and boundaries of defined mobility problem

Designing a generative problem required a precise contextualisation regarding the major research subject and its scope and scale in both spatial and programmatic terms.

As regards spatial scale, the problem has been defined by attributes of *regional* and *urban*, implying *city-region* as an operative concept and territory. In this particular case, these have referred to the city of Paris - its metropolitan (greater) area and administrative domain. On the other side, the main computational subject, or a programme, targeted one specific urban-regional territorial system. This system referred to communications as the broadest category, within which the focus has been narrowed down to mobility and transportation, more precisely, rail traffic as the subcategory that has been singled

out. Regarding previously decided spatial determinants, the network of such scope could not have been one-sided (of one particular transportation type), but multimodal.

Based on the territorial congruence between the boundaries of the Île-de-France region, its historical and more contemporary metropolitan counterpoints, and the idea behind the *Grand Paris* (or Greater Paris) concept and strategy [6], along with both territorial and social aims that planned communication infrastructure pursues, the chosen network-as-simulation-environment and its spatial scope, or range of influence, accorded with all of them (Fig. 1). This has also implied the network's magnitude, number of nodes, transportation types, and all lines of connection (edges). It has been decided not to parse its lines and increments, or stay within the smaller city area. Rather, the whole region has been considered, within which even provisional new nodes whose liability yet had to be evaluated, comprised the network's integral part. These new nodes have been of specific importance regarding their role in optimisation tests and investigation of the network's dynamics.

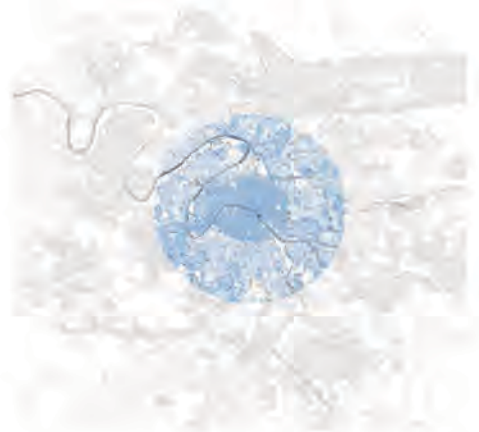




Figure 1. Correspondence between various aspects of the *Grand Paris* (Greater Paris) concept and designation (a, b, c) as references for deciding upon the range of the network to be designed (d, e).

- a. Greater Paris rail line network
- b. New metro network topological map
- c. Grand Paris 2008 competition - MVRDV winning proposal
- d. Grand Paris network - railway transportation system graph; type: undirected graph, Layout: Circular Source: © Dragana Ciric, unit [d]
- e. Paris railway transportation system graph; type: undirected graph, Geo Layout Source © D. Ciric, unit [d], 2023.

In applied tests and functional systematisation regarding the structure of algorithmic computational problem-solving method, the network represented a system of possible *moves* (regarding gaming terminology), or *movements* (regarding physical mobility) within both abstract and real-world geometry, environment, or system of "legal actions". Legal actions have been bounded by the algorithmic "policy", defined as those that

can be performed, and thus will be evaluated and executed.

2. Science of networks: network graphs for computational design

The network science [7, 8] comes as the next to be commented on. By constructing the main theoretical framework for the investigated generative design problem and broader computational problem-solving set of methods, it sets itself as a precondition for each singular method to be tested and applied. Well-analysed and observed in major didactic volume [8], where represented through structured units of a network science training programme with resources and designed student exercises, the science of networks has been made accessible to a wider range of disciplines. Putting upfront its topological model and scaffold for resolving problems based on dynamic relations and contingency between the investigated elements, it became applied to various situations. The mathematical formalism of network science, as well as the network properties of being driven by empirical data and having quantitative, mathematical, and computational nature [8], makes networks and network graphs suitable for investigating many types of systems. Spatial systems have only been some of them. The network that could have been applied in this particular case directly corresponded to the existing spatial configuration of targeted elements (urban mobility infrastructure and network elements, comprising stations-nodes and lines-edges; Fig.3a), though it could have been represented differently (Fig. 2, 3), having been given the form of a network graph.



Figure 2. The fragment of the Paris railway transportation system graph; type: undirected graph, OpenOrd Layout, Source © D. Ćirić, unit [d], 2023.

Network graphs and graph operations represent the next terms to be described. While networks are related to the science of networks, graph definition comes from graph theory, the branch of mathematics that grew out of Euler's proof [8]. To represent the network as a graph implies its definition in terms of graph theory, or through graph-theoretic formalism and language (graph, vertices, edges, degrees, degree distributions, paths, distances, types (weighted/unweighted, directed/undirected and bipartite networks), etc.). Graphs describe how components (nodes and vertices) interact with each other (links, edges) through a *kind of a map of its wiring diagram* [8, p...]. As common formalisms, networks usually refer to real systems, while graphs are used when referring to the mathematical representation of these networks [8, p. 8 (ch. 2)]. The advantage of graphs for this particular design problem, and in general, lies in their property to make certain problems become simpler and more tractable [8, p. 3 (ch. 2)] and express paths which are rather inherent to graphs than the result of some kind of external finding [8] (they are already inscribed in graph concept, functioning, and formal representation). Stated properties encode graph structure,

and therefore limit and enhance their behaviour.

In the case of the following generative design problem, regarding its first part – network construction – two types of graphs and networks have been tried. The real network is sparse and it has been created according to the real situation (Fig. 3). The complete graph for the noted network has also been tested in Grasshopper (Fig. 6), being considered as a transformed provisional geometry for defining optimum problem-solving methods, applicable to both sparse and complete networks or graphs.

2.1. Generative design problem definition

Generative design problem definition branched along the two tracks. The first one addressed the question of the design of the urban and regional mobility spatial system, with special regard to its dynamics (growth and restructuring). The Grand Paris rail system has been taken as a field of operation (Fig. 3 and 6) including all transportation types – metro, tram, regional express, and speed rail.



Figure 3a. Paris railway transportation system graph; type: undirected graph, Geo Layout, created in Gephi. Each node has been assigned its geographic coordinates – longitude and latitude. Source: © Dragana Ćirić, unit [d], 2023.

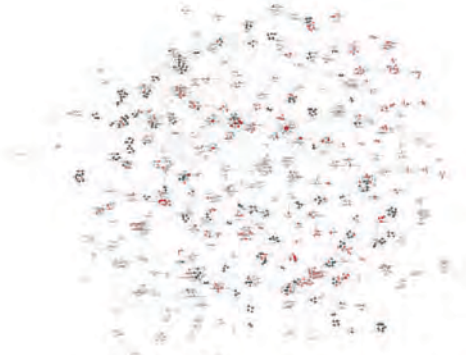
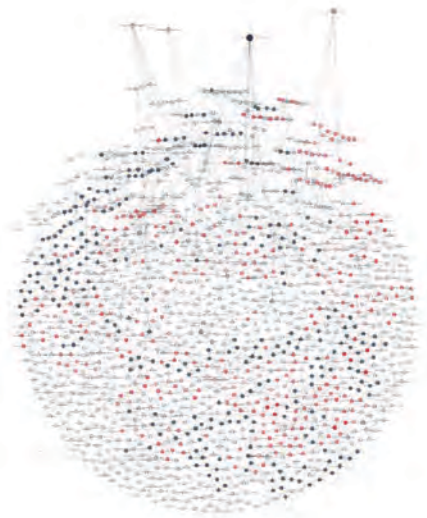


Figure 3b. Paris railway transportation system graph; type: undirected graph, OpenOrd Layout, Source: © Dragana Ćirić, unit [d], 2023.

Figure 3c. Paris railway transportation system graph; type: undirected graph, Fruchterman-Reingold Layout. Source: © Dragana Ćirić, unit [d], 2023.

The second addressed the movement path generation problem within such system, according to the defined criteria, navigation and mobility parameters, and

specified agents with their path preferences, movement scenarios, and objectives. The problem has been defined as follows:

Generate an urban movement path of an agent along the lines of the city rail transportation system while being guided by relations between the states/points within its network (distance, proximity, thematic character, frequency, etc.) and landmark class of destinations (Fig.4). Define parameters for path character, movement objectives, constraints, policies, and movement agendas. Suggest path increment options in each state and continue the process after a decision has been made (a new state has been occupied) with feedback propagation to be included in statistical analysis and to improve new playouts.



Figure 4. Simulation of the dynamic movement along the metro line, while the two closest points on the intersecting or marked metro line and the closest landmark destination are displayed through lines (possible actions) as subsequent points (states) to be occupied. Chosen stills of an animation render simultaneous movement along two lines (two agents) – displaying a variety of presumably the closest landmark and one or two closest transit stations, or only the closest stations along the other rail line of interest. Source © D. Ciric, unit [d], 2023.

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2.2. Computational problem-solving set of methods - sequential tasks

Following a twofold design problem definition, the set of computational methods investigating and offering probable solutions (examining solutions distribution space) has been established [9, 10]. Some of the previous studies

documented their overarching problem-solving methodology in more detail [9] and by constructing it for here analysed case, it provided a framework to be applied in other similar situations. While better explained in stated sources [9, 10], for the purposes of this paper, the methodology has been decomposed and parsed to singular exercises whose computation will eventually become integrated into the final set of methods for network system and movement path generation, as has been indicated by the problem definition.

2.3. Software environment

The question of proper architectural and network design software for required computational problem-solving came next. The software group that has been considered comprised Rhinoceros – Grasshopper, Generative AI Autodesk, and esri ArcGIS or ProGIS software packages. They had to be leveraged in terms of the computational design methods that will be combined and can be supported by their functions.

computational method and software for resolving specific issues within the chosen environment. The algorithm considers 1) real-world geometry and situation along one branch and 2. abstract geometry along the other. The continuing branches/categories contain elements necessary for a modelling process and explain models that are used further in the design process, information systems and data formats used for its modelling, ending with plug-ins and software in which devised operations can be performed and stated data formats made operable. Source: © Dragana Ćirić, unit [d], 2023

A smaller analysis and algorithm of the procedure “how to choose proper software and functions” according to the desired environment and objectives have been made (Fig. 5) Regarding previous analysis of algorithmic, parametric, generative, and AI methods that could have been applied in problem-solving design methods sequences [9], Rhinoceros-Grasshopper visual programming environment has been selected as a starting point, while advanced AI methods have been assigned to experts [11, 12, 13] and to be performed in later phases once first decisions and analyses are finished to prove adequate design problem definition. Architects usually combine a larger number of software products for different design tasks. The most efficient process, however, would be executed by a single software, or by software capable of executing the most number of the required operations, usually those belonging to the same functional cluster (e.g. design conceptualisation, research, drawing and modelling, or visualisation and rendering).

With respect to problem-solving aims and defined methodology, Grasshopper appeared as the most functional, particularly regarding plug-ins specified for some of the urban computing phases



Figure 5. The linear dendrograms with a tree structure/layout represent the way to decide about the environment for the defined design problem’s testing and how to choose the proper

(e.g. Urbano). Prior to its complete use, several software products for network graphs have been tested as well (Gephi, Cytoscape). Even though the process in Grasshopper eventually had to be repeated, the outputs made in Gephi - the urban rail system graph of Grand Paris Express (Fig. 3) – had a significant role in resolving phases of data acquisition (analysis of relevant data and sources), selection (decision on territorial and connectivity scope, including types of transportation), and ordering (creation of lists suitable for targeted graph operations in the available software).

2.4. Parametrisation

Considering the fact that, in order to be represented dynamically and have various values, some of the features needed to be parametrised and considered as variables. They include location (nodes within the designed network, Fig. 3), programme (Fig. 6) transportation type (Fig. 7), specific transportation line with its determinants, including passenger frequency (Fig. 8), and network specificities that will provide distances for proximity operation (Fig. 9)

Figure 6. New topological Paris metro map showing extraction of cultural landmarks as a specific programmatic layer to be used in different movement path scenarios and objectives regarding destinations. Source: © Dragana Ćirić, unit [d], 2023.



Figure 7. The table containing all transportation types (focus on land transportation, while only mentioning air and water transportation kinds), explained by the following: modes of use (public/private), ownership (private/individual, private-company/commercial, public-commercial/company, public-State), financial accessibility coefficient, vehicle type and vehicles details, engine power, energy (production system), energy consumption, zero-carbon agenda evaluation coefficient, area of occupation, safety coefficient. Source: © Dragana Ćirić, unit [d], 2023.

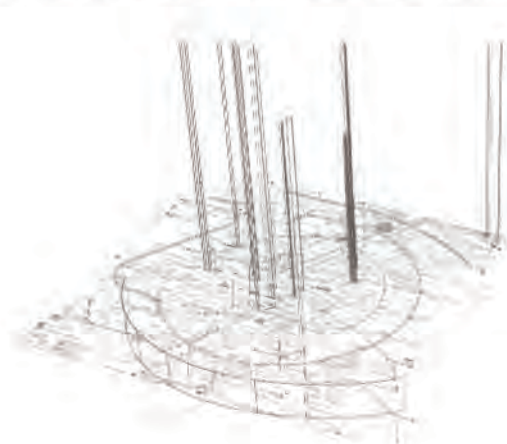




Figure 8. Definition of each transportation line – the examples of metro lines M1, M2, and M3, with the ordering label for each station, station names, daily/yearly number of passengers (frequency) in each, the weight of each node (number of connections, or branching lines), connections labeled by the type (M, RER, Transilien, tram, TGV, etc.), and precise connection label with specific direction. Source: © Dragana Ćirić, unit [d], 2023.



Figure 9. Gephi Geolayout of the Grand Paris network, displaying only connection lines and names of each station to imply correct distances for the proximity search function. Source: © Dragana Ćirić, unit [d], 2023.

3. Problem decomposition, singular problem-solving computational methods and their smaller strings

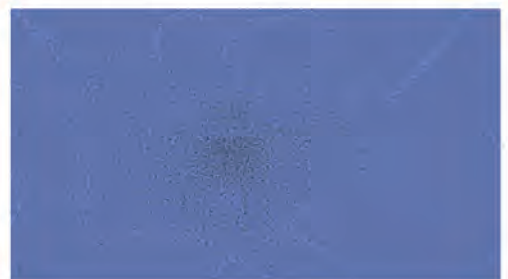
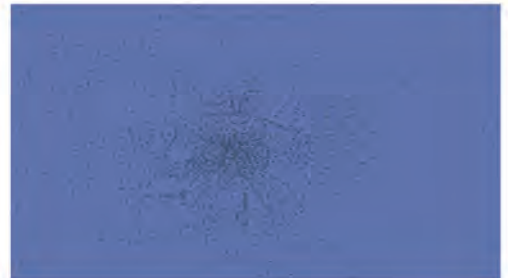
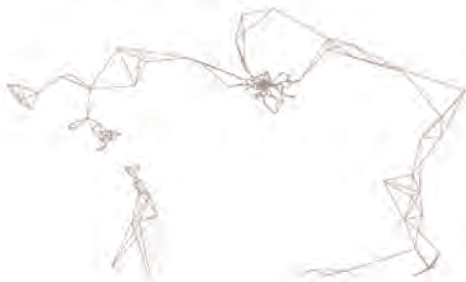
The final section will demonstrate some of the problem-solving methods made in Rhinoceros/Grasshopper. The main design problem has been decomposed according to the sequential design of its elements and functions related to them and the structure of the section will follow problem-solving logic as stated previously and in referent works [8]. The main division follows the bipartite nature of the generative design problem definition, explaining within each part the separate operations that have been performed with respect to problem-solving methodology and final solution. Since not all of the solutions have been finished and refined, the section will focus on elementary ones

whose combinations and concerted configuration lead toward the desired outcome and problem-solving output. The targeted scientific feature is a representation of the advantages of problem decomposition as an inherent property of computational thinking, decision-making, and problem-solving.

3.1. Network

The first part of the design problem is network design or generation. The exercises (subsections) represent the following: 1) network design method (Fig. 10), taking into consideration the possibility of creating a complete network for an abstract gaming environment, too, 2) localisation method (Fig. 11) – construction of the set of function for defining the spatial position, or location within the network, with a possibility of its change (the location is parametrised), 3) location search method (Fig. 12) – the “next movement” search method according to the defined criteria, implying as their concerted result 4) composition of localisation and search methods with respect to the design network (composition of 2) and 3) with respect to 1)).

3.1.1. Network design



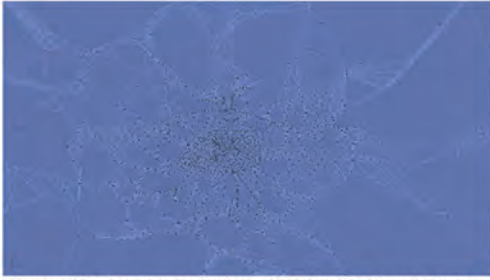


Figure 10. Network design. Software: Grasshopper. Source: © Dragana Ćirić, unit [d], 2023.

3.1.2. Localisation



Figure 11. Localisation within the network, represented only by nodes. Software: Grasshopper. Source: © Dragana Ćirić, unit [d], 2023.

3.1.3 Parametrised location search: suggestions of possible moves, or states to be occupied within the network, calculated according to the defined criteria (e.g. distance/proximity)

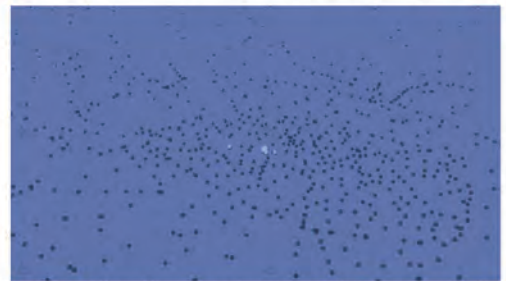
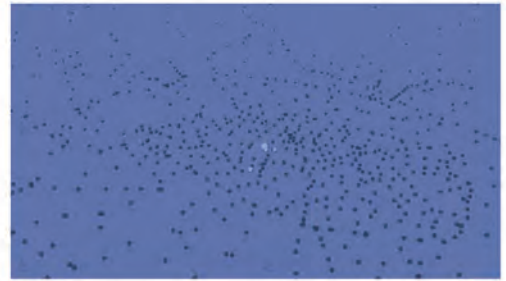
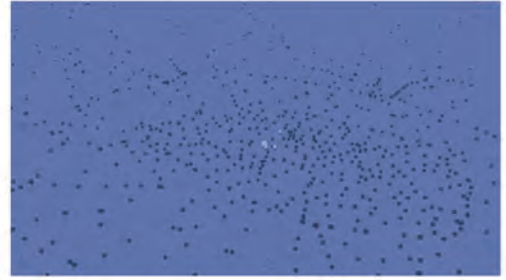
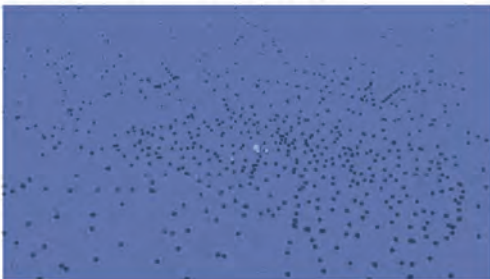


Figure 12a. Search of next states/nodes to be occupied in a movement sequence performed in a single point. Software: Grasshopper. Source: © Dragana Ćirić, unit [d], 2023.

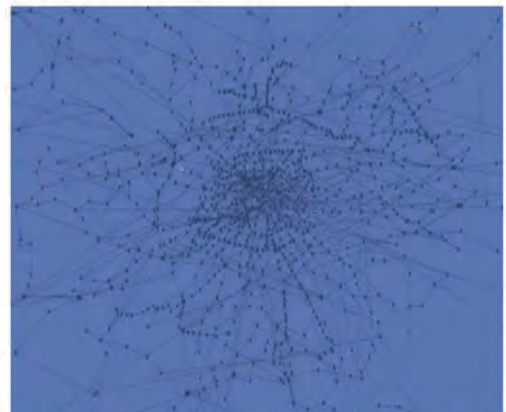


Figure 12b. The search of the states/nodes to be occupied in a corresponding movement sequence,

performed in multiple points (location has been parametrised so as to be applied in a sequence of operations which define movement path). Software: Grasshopper. Source: © Dragana Ćirić, 2023.

3.2. Movement path generation

Movement path generation combines several previously designed computational methods as problem-solutions: a) localisation/positioning function within the network, b) search function, c) parametric control of variable values/entities (type of the destination, number of levels to be searched, and 4) decision-making regarding the next state that will be occupied. Their composition and proper parametric control enabled movement path generation as has been demonstrated in the following subsections and by animation whose stills have been represented to illustrate performed operations (Fig. 13 and 14).

3.2.1. Urban movement path generation with fixed decision-making criteria and its value (same iteration process)



Figure 13. Movement path generation based on proximity search, analysis, and decision-making in each increment point with regard to the defined variable parameter, has been applied.

3.2.2. Urban movement path generation with parametrically controlled and moderated decision-making (variable iteration process)



Figure 14a. Sequential passes from one state to another based on decisions made in each state while being given the range of possible moves within the system from a given point (each point occupied through performed decision-making). The iteration in each state from which the line of movement continues represents the same search-decision order of function, with a difference that the decision on the next state/node to be occupied differs - determined by the chosen criteria, it implies its parametrisation and case in which the agent opts for a different parameter value. The movement path, including the traces of possible movement distribution, is generated and preserved within the given software environment. Software: Grasshopper, Source © D. Ćirić, unit [d], 2023.

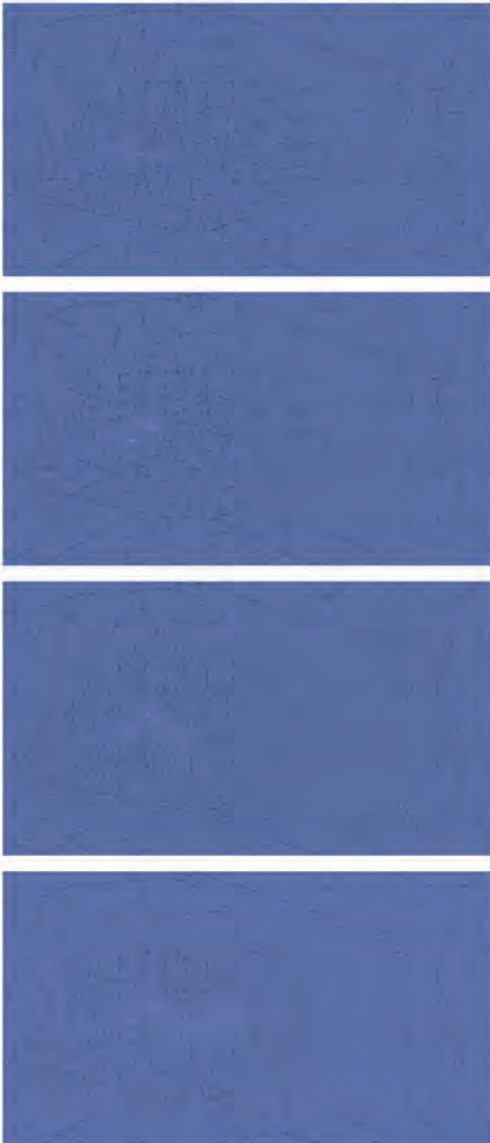


Figure 14b. Rhinoceros interface - Sequential passes from one state to another based on decisions made in each state while being given the range of possible moves within the system from a given point (each point occupied through performed decision-making).

https://va.media.tumblr.com/tumblr_s1fik2ulPa1a96rc8_720.mp4

4. Conclusion

The paper addressed a specific application of networks and network graphs in computational generative design problem-solving at the scale of the urban region. Considering the existing literature in the defined field with regards to both architecture and urbanism [14, 15, 16, 17, etc.], a specific focus has been placed on urban-regional systems planning, analytics, and design and additional sources included [1, 2, 3, 4, 5]. The greater Paris administrative area and rail transportation network have been taken for the exemplary work, the network constructed using several software products, and defined tasks performed within such simulation environment. Exercises for a decomposed problem-solving methodology and set of methods have been provided – designed and tested - and their operation demonstrated to provide the proof and arguments of the successfulness and importance of the explained computational, algorithmic, generative, and AI modes of thinking and their application for both abstract and real-world spatial problem-solving.

5. Supplementary material

Network operations (test).

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Source: Dragana Ćirić, 2023.

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InsightXR: Operative Generative Design in Augmented Reality

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Abstract

This paper introduces InsightXR, an augmented reality application for early-stage massing studies in architecture. InsightXR uses an operative generative design algorithm using Non-Dominated Sorting Genetic Algorithm II (NSGA-II) in the Pymoo framework. To test InsightXR's capabilities, a case study is introduced to generate 3D design alternatives in real-time for a mixed-use project in San Francisco, USA. Design alternatives are generated for 5 generations and visualized in InsightXR.

1. Introduction

InsightXR is an augmented reality (AR) platform that enables user participation in the generative design process. The focus of InsightXR is early-stage massing studies. Integrating immersive technology such as augmented reality in the early-stage generative design process can help with immersion into the design along with

fostering a better understanding of the project's scale and overall geometry. InsightXR uses the Non-Dominated Sorting Genetic Algorithm II (NSGA-II) to generate design alternatives inspired by the volumetric operations discussed by Mari and Yoo [12]. InsightXR uses the operative NSGA-II algorithm introduced by Bailey and Caldas [1]. This paper focuses on the application of Operative Generative NSGA-II in InsightXR [1]. The design operations explored in this paper are expansion and carving [1]. In the proposed workflow, the operative NSGA-II algorithm is accessed using Amazon Web Services (AWS), and the users visualize selected design alternatives from each generation using InsightXR [15]. To reduce user fatigue during this interactive process, InsightXR only shows 3 design alternatives sampled based on the shape similarity of meshes over the five generations [2]. In this paper, the proposed generative design process in augmented reality is introduced using a case study. To assess the capabilities of the proposed algorithm in augmented reality, design alternatives are generated using the following objective functions: Roof and Best Oriented Surfaces (RBOS), Usable Open Space (UOS), and Area Violation (AV). RBOS explores maximizing the total area of the best-oriented facades, which can result in an increase in the potential for renewable energy in addition to an increase in

daylighting [1]. UOS is defined as the total unbuilt area of the site, which is calculated by subtracting the ground floor area from the lot area. The goal of this research is to maximize the UOS value. AV is a constraint violation used as an objective function in this paper [1].

2. Background

2.1 Augmented Reality

Augmented reality (AR) uses computer graphics to overlay virtual content on the physical world [9]. In architectural design, the use of AR has been focused on topics including integration with location-specific information (such as a Building Information Modeling (BIM) model containing different layers of construction details) and portable AR devices in the field [3]. In addition to the use of handheld devices for augmented reality, the use of Head Mounted Display (HMD) AR technology, such as Microsoft HoloLens, enables a hands-free AR experience [6]. Using AR technology can help with providing a realistic representation of the design along with allowing better engagement of stakeholders with the design [4]. In computational design, immersive design research has been focused on topics including exploring real-time object manipulations and visualizations, remote collaborations, and participatory design [10]. The interaction of users and designers during the design and review process can be mediated using AR technologies. Due to a desire to maintain wide accessibility, using AR in handheld devices (iPad Pro) is explored in this paper.

2.2 NSGA-II Algorithms

Evolutionary algorithms are metaheuristic algorithms that apply the concept of Darwin's survival of the fittest [7]. These algorithms apply operators, including mutation and cross-over, to create new individuals for the next generation [7]. Genetic algorithms are a type of evolutionary algorithm that John Holland first introduced in 1975 [11]. In this paper, Non-dominated Sorting Genetic Algorithm II (NSGA-II) is used for generating the design solutions in InsightXR. Non-Dominated Sorting Genetic Algorithms (NSGA) were introduced by Deb and Srinivas [14]. NSGA-II algorithms were proposed later to solve issues such as lack of elitism and the restrictions of sharing parameters in NSGA algorithms [5].

3. Methods

InsightXR uses the Pymoo's framework in Python to run a NSGA-II algorithm inspired by the Operative Generative Design proposed by Bailey and Caldas [1], [16]. The algorithm is run on a local server and generates massing options as OBJ files uploaded to the Cloud using AWS and visualized in InsightXR's AR platform in real-time. In the proposed workflow, the designers will have access to the generated database of different design alternatives produced using InsightXR, and they can decide on the design outcome with full access to that knowledge. InsightXR is created using Unity Game Engine, and the AR capabilities of InsightXR use the AR Foundation framework within Unity.

A case study is introduced to test the capabilities of InsightXR with respect to applying Operative Generative Design in augmented reality. In addition, the proposed case study is used to assess

the proposed clustering methods for visualizing selected design options [1]. This case study explores early-stage massing studies for a mixed-use building on a site located at 74 Mission Rock St, San Francisco, CA 94158 [1]. The site covers an area of 4800 m² and is 80 m by 60 m [1]. The explored objectives, as discussed in the Introduction, include: 1. Roofs and Best Oriented Surfaces (RBOS), 2. Usable Open Space (UOS). Area Violation (AV) is a constraint violation in this case study and is used as an objective. The goal of is to maximize the RBOS and UOS while minimizing the AV. The population size in the NSGA-II algorithm is 30 individuals, with the simulated binary crossover set to 0.9. After 5 generations, the optimization is terminated. Design operations explored in this case study are Carving and Expansion (applied by adjusting the roof mesh points). In each generation, a selection of design alternatives is presented to the users. At the end of the process, the Pareto Front can be visualized for further investigation of the solution space.

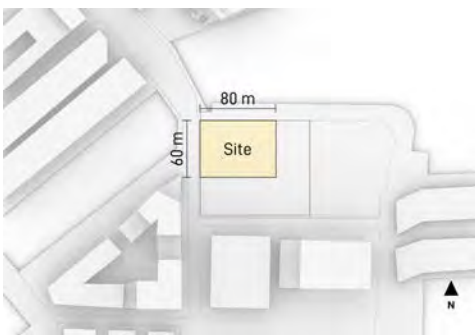


Figure 1. The case study site used in this research [1]

The overall generative design workflow in InsightXR can be described as follows:

- The applied NSGA-II algorithm runs on a local server for the initial generation and creates the first generation of individuals.
- A k-means clustering algorithm based on the Scikit-learn Python module is applied to the initial population to create 3 clusters [13]. Clustering is defined based on fitness values.
- Each cluster's solutions are analyzed using a shape similarity algorithm using the sum of Euclidean distances between each vertex of meshes [2]. The values are then used to rank each cluster's design alternatives from most similar to least. The most representative design alternative from each cluster is selected to be viewed in AR.
- OBJ files representing each selected design alternative are generated and uploaded on AWS.
- In InsightXR, users are provided an interface to visualize the first generation's design alternatives.
- These steps are repeated for each generation until the termination criterion is satisfied (defined as 5th generation).
- In the end, a Pareto-front is generated.

During the experience, the 3D site model is first visualized by finding a predefined QR code in the physical world using the AR camera. Each design alternative's 3D model is created by generating an OBJ file format from the NSGA-II algorithm and uploading the design alternative on an S3 bucket, a dedicated storage space for the algorithm on AWS. Selected design options using the clustering method described earlier are downloaded

from AWS throughout the experience and are visualized in InsightXR.

4. Case Study Results

To discuss the characteristics of the non-dominated solutions, 4 design options are visualized in Figure 2. As the AV increases, UOS increases due to the smaller gross floor area.

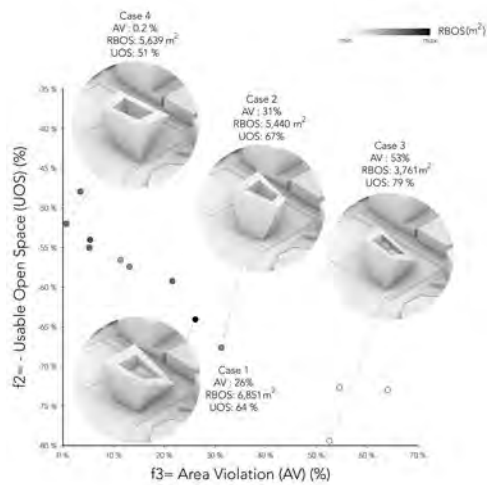


Figure 2. Non-dominated solutions. RBOS is represented using color. Darker color represents higher values.

Case 1 is a hybrid design option (carving and expansion), with the roof facing south and maximizing the roof area. Case 1 provides the maximum RBOS value. Case 2 has an increased height with a reduced value for RBOS compared to Cases 4 and 1 while increasing the UOS value. Case 3 is a hybrid option (carving and expansion) with the highest UOS value while increasing the AV by reducing the gross floor area of the building. Case 4 is a courtyard solution, with carving as the applied operation. Case 4 reaches the maximum height allowed on the site (61 m) while creating a deep courtyard.

This case aims to reach the maximum areas for the southern and northern facades while reducing the first-floor area. Figure 3 shows non-dominated solutions with RBOS and UOS on the horizontal and vertical axes and AV as the third objective using color.

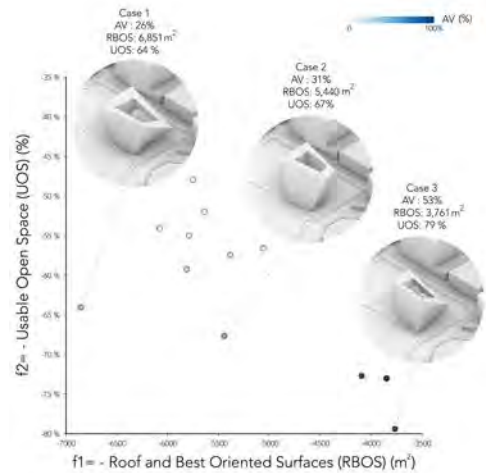


Figure 3. Non-dominated solutions. AV is represented using color. Darker color represents higher values.

4.1 Generation 1

At this step, the initial population of solutions is generated using the applied NSGA-II algorithm. The solutions are then divided into three clusters using the k-means clustering algorithm discussed in section 3. Figure 4 shows the three design options visualized in InsightXR. Case 1 is a result of expansion operation, with a low AV value and a high RBOS value (Figure 5). Case 2 is a hybrid, resulting from expansion and carving. This case maximizes the southern facade and roof area while increasing the UOS. Case 3 is an expansion design option with a low RBOS and UOS value.

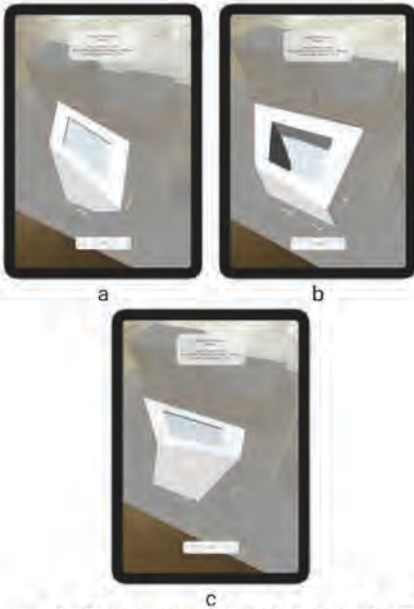


Figure 4. Generation 1 solutions. A. Case 1, b. Case 2, c. Case 3.

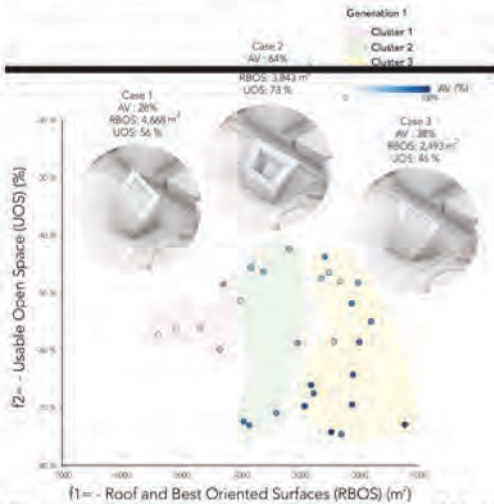


Figure 5. Generation 1 solutions. AV is represented using color. Darker color represents higher values.

Overall, cluster 1 includes options with higher RBOS values and lower AV values, cluster 2 is a trade-off between

cluster 1 and 3 in terms of AV and RBOS values, and cluster 3 includes options with higher AV and lower RBOS values. Cases 1 and 3 have shallow skylights, and in this research, shallow skylights (under one story height) are not considered a courtyard.

4.2 Generation 2

Generation two's clusters are defined similarly to generation one, where cluster 1 includes options with higher RBOS values and lower AV values, which is desired in this case study (Figure 7). Cluster 2 is a trade-off between RBOS and UOS values, and cluster 3 options have the lowest RBOS values and highest UOS values.

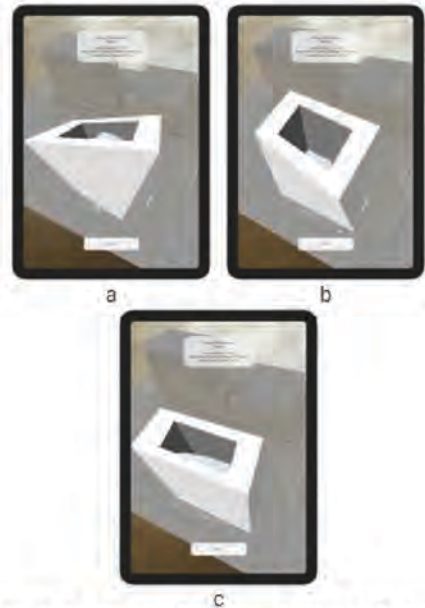


Figure 6. Generation 2 solutions. A. Case 1, b. Case 2, c. Case 3.

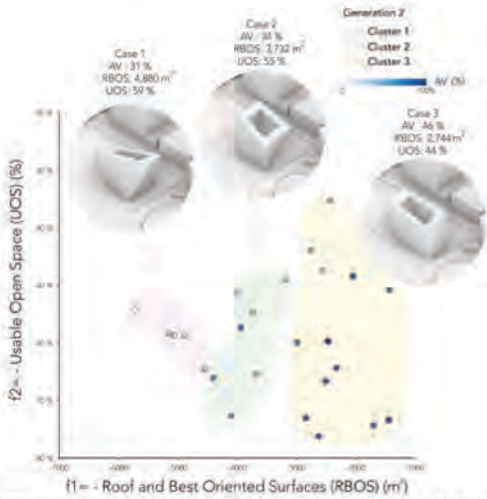


Figure 7. Generation 2 solutions. AV is represented using color. Darker color represents higher values.

Cluster 3 design options have the highest AV values among all options, which is due to their deep courtyards (carving) resulting in smaller floor plates. Similar to generation one, three design options are selected using the algorithm and visualized in InsightXR (Figure 6). Case 1 is a hybrid design option (expansion and carving) with a high RBOS value. Case 2 is a trade-off between Case 1 and 3 in RBOS and AV values. Cluster 3 has the widest variety of UOS values. Case 3 has a lower UOS value and RBOS value, and high AV values.

4.3 Generation 3

Cluster one includes options with the highest RBOS and lowest AV values among all solutions while having UOS values between 50 and 60 percent (Figure 9). On the other hand, cluster two includes solutions with tradeoffs between RBOS, UOS, and AV values compared to the other two clusters.

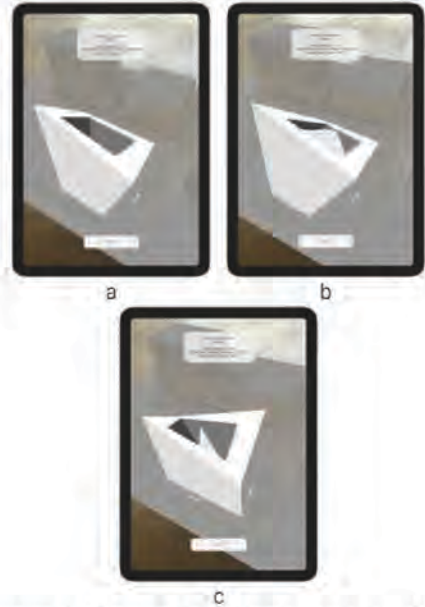


Figure 8. Generation 3 solutions. A. Case 1, b. Case 2, c. Case 3.

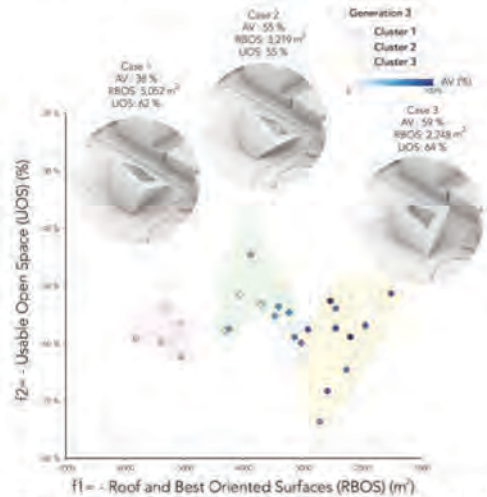


Figure 9. Generation 3 solutions. AV is represented using color. Darker color represents higher values.

Cluster 3 includes solutions with lower RBOS values and higher AV values,

which are not desired, while providing higher values of UOS, which can result in smaller floor plates or larger courtyards. Case 3 provides the highest UOS among the three selected cases while providing the lowest RBOS. Case 3 is a hybrid design option (carving and expansion) with a high AV value that doesn't provide the desired gross floor area. Figure 8 shows the visualized Cases 1, 2 and 3 in InsightXR.

4.4 Generation 4

Generation four's design options are more diversified compared to the previous generations (Figure 11). Cluster 1 includes solutions with the highest RBOS values and the lowest AV values, and as can be seen in Case 1, this option uses carving that includes large floor plates with a shallow courtyard.

Cluster 2, on the other hand, provides a compromise between clusters 1 and 3, where its solutions provide lower RBOS values compared to cluster 1 but higher RBOS values compared to cluster 3. Cluster 3 includes design options with lower RBOS values and higher AV values, and as can be seen in Case 3, smaller facade and roof areas result in a lower RBOS value compared to Case 1 and Case 2. Case 3 is a hybrid solution with a high AV value, which is due to its small floor plates. Case 2 provides a trade-off between Case 1 and 3 in terms of RBOS and AV values and is a hybrid design solution. Figure 10 shows the visualized Cases 1, 2 and 3 in InsightXR.

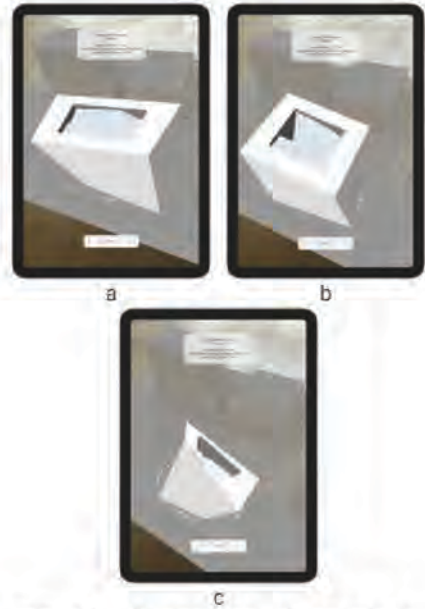


Figure 10. Generation 4 solutions. A. Case 1, b. Case 2, c. Case 3.

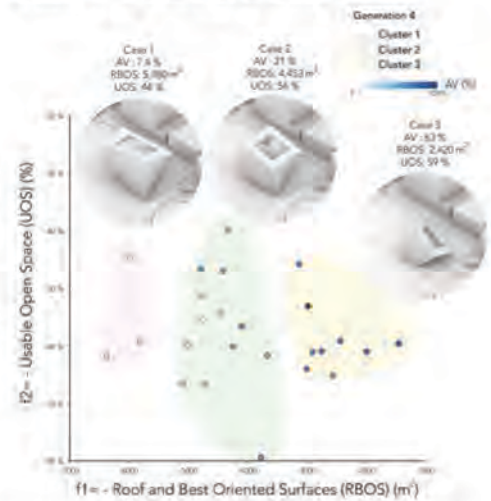


Figure 11. Generation 4 solutions. AV is represented using color. Darker color represents higher values.

4.5 Generation 5

Generation five's clusters are similar to previous generations, where cluster 1 includes design options with higher RBOS and lower AV values (Figure 13). Case 1 is the result of a carving operation with a deep courtyard while providing the lowest AV value among solutions. Cluster 2 includes solutions with a trade-off between RBOS and AV values compared to the other two clusters. Cluster 3 includes design options with lower RBOS and higher AV values. Case 2 is a hybrid solution (carving and expansion) with a tilted roof orientated West. Case 2 has the lowest UOS value. Case 3 provides a higher UOS value with a lower RBOS value compared to the two other cases. Figure 12 shows the visualized Cases 1, 2 and 3 in InsightXR.

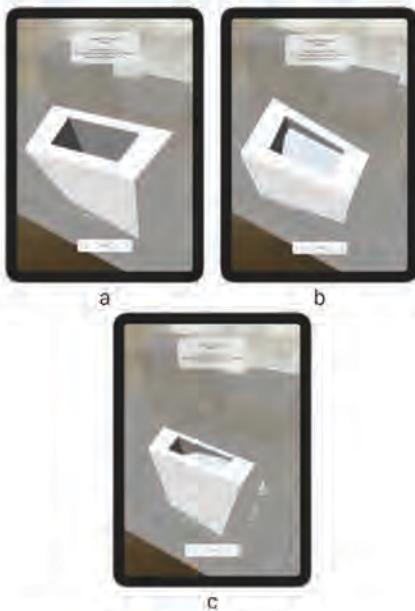


Figure 12. Generation 5 solutions. A. Case 1, b. Case 2, c. Case 3.

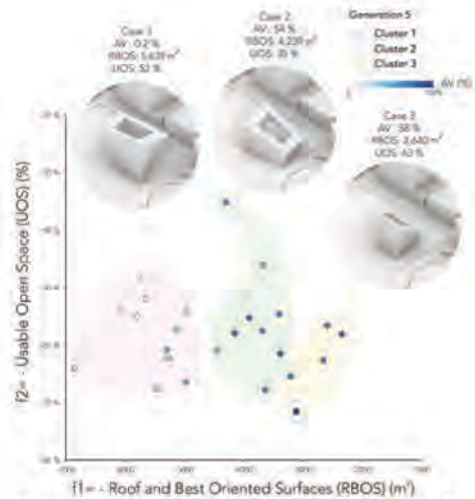


Figure 13. Generation 5 solutions. AV is represented using color. Darker color represents higher values.

5. Discussion

Design solutions in each generation were successfully clustered into three groups, where each cluster had distinct behaviors in terms of all three objective functions of RBOS, UOS, and AV. In all 5 generations, cluster 1 included design solutions with lower AV values and higher RBOS values, which is due to design options that provide larger floor plates. As the generations progressed, design options in cluster 1 provided an improved RBOS value compared to previous generations. Cluster 1 in generations 4 and 5 had selected cases with only carving as the design operation. Cluster 3 in all generations included solutions with the lowest RBOS and highest AV values. Case 3 in most generations was a hybrid solution (except for generation 1, where Case 3 is an expansion operation result). Cluster 2 in all generations provides a compromise between RBOS and AV values, where the selected Case 2

solution from each generation was a hybrid option. The algorithm was able to successfully cluster each generation's solutions and select a representative case among the solutions to be viewed by the users in InsightXR. In addition, InsightXR's application was able to view each generation's selected design solutions in real-time successfully. The proposed generative design process can also be asynchronous to allow users to visualize design alternatives. In the case study, even though the goal is to maximize RBOS and minimize AV, it is essential to note that creating design options with smaller courtyards while having a deep floor plate (e.g., case 1 in generation 4) can reduce the access to daylighting and natural ventilation, which is not desirable. It is ultimately the designer's role to evaluate the proposed non-dominated solutions provided by InsightXR to choose the most applicable design for the design at hand.

Future research can investigate the inclusion of user feedback in the optimization process using an interactive NSGA-II algorithm in InsightXR. In addition, research needs to be conducted to understand the perception of users regarding InsightXR and understand the opportunities and pain points of using InsightXR. In addition, this paper selected five generations as the termination criterion for the algorithm, which can also be tuned or defined with respect to other criteria in future research.

6. Conclusion

InsightXR enables designers and non-designers to participate in an Operative Generative design process using NSGA-II algorithm in real-time or asynchronously [1]. This paper introduced a clustering method based on

k-means clustering using the Scikit-learn Python module. This was combined with a shape similarity algorithm that allowed for selecting representative design solutions to be presented to the users for further investigation, reducing user fatigue caused by the presentation of all solutions per generation [13]. A case study experiment was conducted using three objective functions, RBOS, UOS, and AV, to generate early-stage massing design options on a site in San Francisco, USA. Each cluster per generation successfully created a set of unique options with respect to the objective functions. At each generation, the three presented options spanned the spectrum of the different objectives, presenting one at each extreme as well as a trade-off option.

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Interaction With a Memory Landscape

Tatsuo Unemi

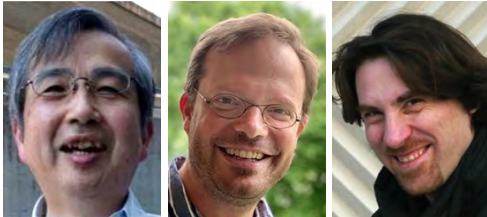
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the learning process but also actively disturb it by placing obstacles in the environment or directly modifying the agent's memory. In addition, whenever the user touches the screen, a sonification of the simulation's state can be heard through headphones.

Abstract

The touchscreen-based application *Greedy Agents and Interfering Humans* addresses the coexistence of humans and an AI system by providing an interactive environment where users can interact with a learning agent. The application is based on the well-known paradigm of reinforcement learning, a framework to model learning mechanisms based on the modification of behaviour through experience.

Instead of being a black box, the learning process is rendered perceivable for the user. The learning agent's memory is interpreted as a vector field, which is visualised by a particle flow. And the learning process is exposed to interaction to make it even more palpable. The user can not only observe the advancement of

1. Introduction

This paper describes a touchscreen-based application entitled *Greedy Agents and Interfering Humans* in which a user can interact with an agent that learns to navigate through an environment. By means of visualisation and sonification, the agent's learning process is made perceivable. This application is the down-scaled version of a tabletop installation that the authors developed earlier, in which up to three visitors, whose hands were tracked by a distance camera, could interact at the same time [1].

Our application employs reinforcement learning, a well-known paradigm with a long-standing history. Reinforcement learning provides a framework to explain how an agent's behaviour is changed through experience.

It is essentially based on a trial-and-error approach in which behaviour that leads to a successful outcome is rewarded and thus reinforced. Our application makes an attempt to render this underlying algorithm perceptible and interpretable through interaction and thus tries to open the black box.

Furthermore, as it turns the algorithm into an aesthetic expression by means of visualisation and sonification, our application also offers the opportunity to engage with contemporary computational art. And finally, it exemplifies the creative coexistence between humans and an AI system. In this sense, it aligns with the authors' earlier works dealing with the coexistence of human and non-human actors [2–5].

2. Reinforcement Learning

The process on which the application *Greedy Agents and Interfering Humans* is based is reinforcement learning. This learning paradigm models how an agent learns to make decisions by interacting with an environment. It is inspired by behavioural psychology and focuses on training intelligent agents to take action in a way that maximises a cumulative reward. Reinforcement Learning is widely used in applications like robotics, game playing, autonomous vehicles, recommendation systems, and more.

This learning paradigm has been researched for more than a hundred years in the fields of psychology and ethology. In the late 19th century, Thorndike [6] initiated scientific research into these phenomena in the context of social psychology. Several decades later, Skinner [7] conducted systematic experiments on pigeons and rats following a

Behaviorism approach. In these experiments, the animals changed their behaviour to increase positive experiences (being fed) and avoid negative experiences (electric shocks). In the 1980s, with the advent of powerful computational resources, it became feasible to adopt principles of reinforcement learning in the context of machine learning. Since the early 1990s, substantial research on computational forms of reinforcement learning has been conducted by Sutton and Barto [8].

The key components of reinforcement learning are an agent, an environment with which the agent interacts, a set of possible actions and a reward in the form of a numerical value that indicates how good or bad each chosen action was. It is the agent's goal to maximise the cumulative reward over time. In order to learn effectively, the agent must be able to build up a kind of memory. It must be able to associate past actions with the rewards it has received to select future actions accordingly.

The memory keeps track of the experience made at every point in the environment. It is thus closely related to the environment's topology and can consequently be described as a memory landscape.

3. Implementation

3.1 Simulation

The simulation on which the application *Greedy Agents and Interfering Humans* is based is an implementation of a Q-learning algorithm [9]. The environment in which the agent moves about consists of a small two-dimensional grid world of 6 x 11 cells (fig. 1). Each cell represents either an empty space or an obstacle. On

each cell, the agent can choose among four discrete actions (up, down, left, right) to move to an adjacent cell, provided it is not an obstacle. The agent has a simple navigation task: find the shortest path from a start to a goal location, i.e., reach the goal location with a minimum number of actions. In the beginning, the agent does not know anything about the environment and moves randomly from cell to cell. As the learning progresses, the probability that the agent chooses a random action (exploration) instead of an optimal action (exploitation) gradually decreases [10].

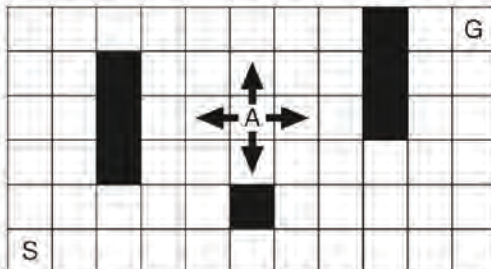


Fig. 1. The 6 x 11 simulation grid.

S: start, G: goal, A: agent, black squares: obstacles.

When the learning simulation starts, two cells at opposite sides of the grid world are defined as start and goal positions. There are no obstacles at this stage, as these are only defined later by the user's interaction. Each learning episode starts by placing the agent on the start position and ends when the agent has either managed to reach the goal position or exceeded a maximum number of actions. Upon reaching the goal location, the agent receives a reward depending on the efficiency of its search. Then it is put back to the start position, and the search begins again. The learning process

steps or the number of times the goal was reached exceeds a predefined value. In that case, the memory is reset and a new simulation cycle is started.

During a learning simulation, the agent memorises the value of an action at each cell, i.e., how fruitful it is to continue in a specific direction to obtain the highest possible reward. The higher the value of an action, the more likely the agent will take this action. When the agent eventually reaches the goal, the value of the last action taken is propagated backwards from the goal to previous positions along the agent's path. In order to accelerate this propagation, a replay mechanism is employed that causes the agent to randomly recall previous navigation steps from a memory pool. This mechanism is similar to the Dyna architecture proposed by Sutton [11].

3.2 Visualisation

The simulation's state is visualised on the screen. The agent's position is shown as a white circle. The user can observe how the agent searches for the goal position and how this endeavour becomes increasingly effective. However, to make this learning progress perceivable in real-time, the learning episodes have to be executed and iterated at a much faster rate in the background. The agent's movements displayed on screen represent one single learning episode taken at a certain point in time and slowed down.

The agent's memory is interpreted as a vector field in which each vector represents the preferred direction of movement for the corresponding cell. The direction and length of each vector are calculated as the sum of the four orthogonal directions of the discrete

their respective value. A particle flow animation consisting of some hundred thousand short line segments moving across the screen visualises this vector field. The movements of these line segments result from the forces exerted on them by the vector field. Each line segment is drawn in a colour that changes according to its moving speed. The agent's learning process and build-up of memory become perceivable as the visualisation changes its appearance during a simulation cycle. While the particle flow is not yet pronounced at an early stage of learning (fig. 2), it becomes more clearly directed towards the goal as the simulation advances (fig. 3).

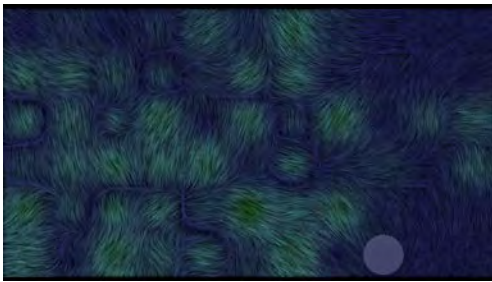


Fig. 2. *The visualisation of the simulation at an early stage of learning.*

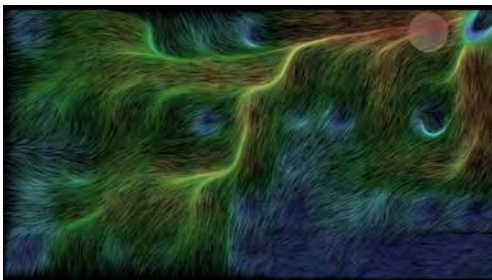


Fig. 3. *The visualisation of the simulation at a later stage of learning.*

3.3 Sonification

The sound played back via headphones also reflects the state of the agent's memory and the dynamics of the simulation. Unlike the visualisation, the sound is only activated when the user touches the screen. The user's finger becomes a stethoscope, as it were, with which the memory landscape can be acoustically examined. Since every touch simultaneously leads to an interaction with the simulation, it is impossible to listen to the sonification without altering it.

Each time the agent moves to a different cell, a short, high-pitched sound is audible. The regular repetition of this sound reflects the rendering steps and, thus, the discretisation of time, which is constitutive for the simulation. It also indicates whether the agent is moving at all and not currently stuck in a dead end of obstacles erected by the user.

The agent's memory is turned into sound by using the values of the actions for each cell as sound synthesis parameters: the higher the values, the brighter and denser the sound. The sound design uses a granular synthesis approach, thus creating a strong link to the particle-based aesthetics of the visualisation. Above all, the notion of the movement of particles is doubled in the sound. In respect to the user's viewpoint, a flow of particles in a horizontal direction is matched by a movement of the sound in the stereo field; a flow in a vertical direction by a continuous movement in pitch.

The position of the touch determines the cells whose values are made audible. To enable the perception of a continuous sound, the values of the cells next to the touch position are interpolated. The

strongly attenuated and superimposed by a low-frequency sound.

3.4 Interaction

The interaction is based on detecting a visitor's touch on the screen. Up to two touch events can be detected simultaneously. The positions of the touch events are mapped into the grid world of the simulation.

Two mutually exclusive forms of interaction exist. The first form of interaction becomes active when the touch remains stationary. If the touch persists for longer than a predefined amount of time, an obstacle is added to the simulation at the location of the touch. If the touch is subsequently removed, the obstacle continues to exist for the same amount of time as the touch has previously been applied. Since the agent cannot traverse this obstacle, it has to learn how to navigate around the obstacle to reach the goal position. As a result, the agent's memory is indirectly modified through interaction.

The second form of interaction becomes active if the touch changes position. As a result of this interaction, the agent will increase its preference for those movement directions aligned with the touch's travel direction and decrease its preference for the other movement directions. Accordingly, the agent's memory landscape is directly modified through interaction.

4. Conclusion

The application *Greedy Agents and Interfering Humans* is an attempt to make a machine-learning algorithm accessible to the user not only by rendering its principles visible and audible but also by

opening them up for human interaction. In a time in which technology, notably AI, enters people's daily lives more and more, it becomes increasingly necessary to find ways to make its principles explainable and thus open up the black boxes. It is our conviction that computational art can be a valuable way to provide this kind of understanding.

Our objective was to create an artistic realisation of reinforcement learning rather than further develop it in an engineering context. From an artistic viewpoint, we believe that creativity is always a joint effort of human and non-human actors connected in a network. Our application deals explicitly with this concept of collaboration, albeit not in the only conceivable way. A wide and promising field for future work still remains open.

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Generative Systems for Art and Design

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Artist Sol LeWitt says of the functions of conception versus perception that “If the artist wishes to explore his idea thoroughly, then arbitrary or chance decisions would be kept to a minimum, while caprice, taste, and other whimsies would be eliminated from the making of the art.”ⁱ This statement about the nature of artistic authorship argues that the degree of pleasantness or awkwardness in a work of art matters less than its process of creation. LeWitt’s conceptual art would today be considered under the title of generative art, which is a creative process more than a genre unto itself. The debate regarding generative art — that which is generated by a computer — has its roots in the second half of the 20th century when the rise of artificial intelligence (AI) caused an uproar in the art world. The corporate and industrious social atmosphere of the 1960s caused some artists to embrace technology and explicitly emulate factory-like production. This is something that can clearly and consistently be seen in the work of Celestino Soddu, whose projects and

general philosophy will warrant further discussion after more context has been established. LeWitt’s words about this era reflect that generative art may come from a programmable formula, yet it still blends processes that are under varying degrees of control by the artist, similar to an artist placing sticks in the water and observing their oscillations.ⁱⁱ While a machine can produce art, the intentional planning of the piece initiates from the artist’s idea. Thinking that the artist’s will is what completes the artwork reflects ego, not creativity.

Ideas fuel art, and a computer is a machine that helps undertake the process. When viewed from this perspective, generative art assumes a long history of tool and machine use that could be said to date back thousands of years. While this thesis does not ask whether there is a direct link, the research on generative artwork will focus on how art is made rather than what art is made, and the degree of autonomy exercised by the artist who expresses it. While AI-created art is different in its process from traditional art, it is also no different than other kinds of generative art. There is still a spectrum of “strong” and “weak” artwork that represents the amount of work done by the human artist who designed the system.ⁱⁱⁱ

The definition of art has changed over the centuries. Fine arts were not included under the heading until the 17th century,

and it took another century or so to include painters as artists instead of referring to them as craftsmen or workers. Today, the tendency is to view and reinterpret older works of art through the lens of contemporary contexts and modern aesthetic standards.^{iv} The terminology has evolved in parallel with the changing dominant styles, bringing us from romanticism and classicism to today's yet collectively unnamed inclusion of computer, generative, algorithmic, and evolutionary art. LeWitt's pioneering work in the 1960s featured collaborative wall drawings made by others who followed the artist's instructions.^v This valued the creative process over the solitary effort to make something unique, and this process is what will be referred to as generative art, including AI-created artwork.

In distinguishing between these newer art forms and carving out a meaningful space for generative art, some emphasize clarity of language and proper framing of generative art's history. They include generative music and architectural design in their discussion of systems that create complex artworks using simpler components and allow for the discovery of new creative methods, stressing the how over the why.^{vi} The controversy comes from asking whether and to what extent to program or procedure can be ascribed some creative autonomy. If the machine alone can create the artwork and make the necessary decisions as to what pieces to include and leave on the studio floor, then the artist/programmer has no autonomy and, therefore, no place in the creative economy. If, however, generative art includes a distributed process that cuts across the

artist/programmer and their tool/computer, then the generative system itself contains the creative autonomy that values both contributors.

An understanding of embodiment is also necessary to address this question and distinguish between the artist's decision and intent to create and the process that ensues. Embodiment is the act of making an idea visible, bringing it to life through tangible expression. When an artist distributes authorship across their skillset and tools, it allows for a deeper introspection into the meaning of agency and creativity.^{vii} A generative artist whose process includes machines outside of their body that help manifest an idea into physical presentation aligns with the interdisciplinary notion from cognitive science of extended cognition. In this field, theorists use the metaphor of a ship to illustrate distributed agency. A ship is not solely steered by the captain but rather accomplished all the way down the chain of command.^{viii} Whoever creates the first command can claim agency just as the AI algorithm that works within the set parameters to create unimaginable outcomes can also claim agency in the process. Both agents can embody the artist's intent, which is what the audience resonates with and values.

Randomness, Computer Imagery, and a Philosophy of Realness

The literature on generative art points to the once-novel idea of electronically created art as cyberspace and technology came into the discussion and began to frame the present norm of the day. Taking inspiration from cognitive science and theories of emergence, evolution, embodiment, and the self-

organization of actual and artificial life, the 1960s saw the beginning of taxonomically classifying the yet unlabeled practice of what was synonymously referred to as generative, electronic, computer, process-based, digital, and AI art. A sufficient list of the important aspects of artwork is needed to categorize and evaluate artwork. Philosophers and AI experts Boden and Edmonds believe that a work of art involves appreciating it in terms of accepted conventions, for no object is inherently excluded from candidacy.^{ix} The art world is also available to anyone who attempts to confer the status of “work of art” upon an object. As such, the art world is a social entity; an institution that serves as an extended tool for cognition and thinking about a work of art.^x Cognitive scientists Gallagher and Crisafi see cognition as a distributed set of processes that loop in and out of brains and social institutions that are designed with cognition in mind.^{xi} This applies to the art world.

Museum goers and art critics alike enact a work of art’s candidacy along socially delineated aesthetical values. Critics compare contemporary works to past masterpieces to discern similar qualities or critique lacking components. Audiences resonate with an artwork’s aesthetic value or not, positioning the work in question along their existing spectrum of experiences with other works of art. In both cases, whoever designates a work of art as such is acting on behalf of the art world as a social institution, and agreeing upon its bestowed status is a social act.^{xii} Bachrach philosophizes that the artworld, as an institution, is open to anyone, and anyone who engages in deliberating its

status is acting on behalf of that social institution. Since no object is excluded from candidacy, anything can be disputed as a work of art. The act of disputing takes place in a social context that builds naturally upon prior beliefs and definitions.

In other words, a “work of art” is not created in a vacuum or produced automatically by either an established artist or a machine. An artwork that is called “art” is the result of a distributive social practice involving the artist, the art world, and the audience. Generative art pushes the boundary a bit further to include AI algorithms and the computers that program them, but this too is a technological evolution of artistic tools and not a whole new concept. Generative art is “art” in that it is socially debated and defined, even though the randomness and chaos that accompany AI can cause critics to question its place in the art world. In response, art theorists reframed seemingly chaotic complex systems as unpredictable rather than random.^{xiii} AI allows for algorithms to potentially produce all possible states of a programmed function, which introduces uncertainty as the artist does not know the specific outcome. AI systems mimic real life in their chaos and sense of cause and effect, so much so that they can feel more lifelike than reality. The outcomes are vast, but they are not random. The role of randomness in generative art is not new. Improv artist Paul Bley is a good example of a creator who has gathered inspiration from the random outcome of coin tosses or rolling dice, but such pure randomness is not the case with computers and programmed deterministic functions.^{xiv} From this perspective, randomness

serves only to humanize the imperfections of a process by intentionally allowing space for incompleteness when creating a work of art.

Early digital art was generative in its process and instruction-based approach. Just as LeWitt's conceptual art was generative in its execution in the 1960s when his hallmark wall drawing installation was completed by telling assistants what to do, pioneer digital artists in the same decade introduced computer-made artwork that was created from a machine-like process that happened inside of the computer rather than physically constructed outside by an artist.^{xv} In simple terms, computers do what artists do, but they do it faster and with better precision, allowing many iterations in minutes that would take a human artist years to complete. Digital art used other objects than the artist to create the work of art, but it accomplished the same result as the artwork that came before it in the ongoing spiral of art and life in imitation of one another. Critics still pressed the issue of whether this kind of art was real even though real, biological life was also produced in the operational process of evolution. This step-by-step process responded to fitness, selection, and survival. The bothersome aspect, then, had to do with what philosopher Jean Baudrillard refers to as hyperreal works -- those that are made in hyperspace. These confound the idea of imitation and simulation, operationally substituting what was real with a digitized rendering of what was real.^{xvi} Instead of real still-life art made up of tangible objects set upon a physical tabletop, there was digitized imagery of real-world objects cut and pasted into a hyperreal space. This

format is imitation in the sense that the digital version is based on the actual version, but it is also simulation in the sense that Baudrillard meant where reality is usurped by a model.

To define generative art as real, there is an important distinction to make between what is simulated and what is not real or false. For the purpose of this thesis, "false" means that the artwork does not produce any kind of emotional resonance in the viewer, yet simulated artwork does in fact produce this effect.^{xvii} Simulation-based artistic processes seem acceptable to the art world if they create the same set of responses in the audience as "real" artwork since "real" is a feature of artwork that emerges in the interaction between the viewer and the art. Interactivity becomes a possible source of criteria to judge the aesthetic value of a work of art, and rather than the typical separation of a work of art as either computer-generated and technological or aesthetically appealing, generative art becomes embedded in the same cultural and historic conventions of both art and science.^{xviii} Artists who represent their experience of the world using advanced technology and computer modeling can create an imagined reality that may or may not unfold for viewers, just as human-made artworks can be relatable or not with a viewer.

Using the fable of a map of an empire that was so detailed it covered the land exactly to explain simulation, Baudrillard philosophizes that the hyperreal territory of today's digital focus does not require a real object to model, which illustrates their idea of simulacra.^{xix} Critics question whether generative art is a

representation of real art or a mere simulation of the creative process. In defense of its artistic status, Baudrillard points to the utopian ideal of equivalence in the symbol and the true object that would accuse a simulation of being false. He claims that it is no longer a question of the work's ideology, as the more traditional ethic will "obscure the real process of work and the objective process of exploitation," but the question should be about the scenario of the work.^{xx} Simulation in the generative sense of process encases the concept of representation as a simulacrum that lacks an original object to simulate. Consider the ancient drawings on the caves in Lascaux. Visitors are allowed to peek at the original but can only physically visit the replica site not far from the caves to preserve the art. In the socially extended and accepted mingling of real and replica, there is no difference regarding the act of experiencing this work of art. In the same way that no one would argue that the ancient artwork qualifies as such, the subjective experience of generative artwork is similar to that of a work of art created under a different process.

When generative art is taken as a process, a picture of reality emerges that captures the artist's intended imagery and emotional effect created in less time and with more accuracy than the artist's hand could accomplish alone and unaided by technology. The question of technology's place in the art world becomes a broader critique of capitalism and the embedded social demand to mass-produce things where it seems unfair to be able to produce a generative artwork so quickly, threatening to destabilize the art world. Such is not the

aim of generative art, though, which offers the masses a transparent method of creativity that is powered by AI and programmed algorithms. From this viewpoint, the idea that the medium is the message implies for generative art not only "the end of the message but also the end of the medium" since there is no physical medium and no universal intended message.^{xxi}

Authorship and Authenticity in Complex Systems and Algorithms

Having established generative art more definitively as a process that spans the artist, tool, and the social context that the work of art enters, the words of LeWitt ring true, "The idea becomes a machine that makes the art," and "the idea itself, even if not made visual, is as much a work of art as any finished product."^{xxii} Critics bothered by the inclusion of this art form under the umbrella term of art and hesitant to confer such a status are perhaps concerned with the complexity of the algorithmic systems and computer programming that underly generative art.

Any complex system is made up of many smaller parts that integrate locally and self-organize without the need for a human agent to continuously control its unfolding.^{xxiii} In this sense, complex does not mean confusing, and these systems have existed in art since primitive times. Consider the geometric patterns of Islamic textiles or repeating border designs in ancient art.^{xxiv} The concept of generative art is old. The controversy comes from the seeming esoteric knowledge required to understand and properly utilize complex systems in computer programming. Here, too, an ancient idea is found where people use

graphics to understand complicated systems. Computer-assisted imagery happens quickly and with little input, and art enthusiasts have tended to stray from high-tech images constructed this way. Using this past trend to keep looking away from computer imagery, though, risks missing the development of new meaning in advanced technology.^{xxv} It is no longer safe to assume that the efficiency of new technology makes art superficial.

The complexity of this art form is one of its most important characteristics in the eyes of the field's artists. Generative art, as embraced by the acclaimed architect, Celestino Soddu, represents a combination of the unpredictably creative with the rigorously structured. A key element of Soddu's art philosophy is the amplification of randomness within the design process. This randomness, rather than being an arbitrary occurrence, serves as a crucial foundation, laying the groundwork for conceptual requirements, personal expressions, and cultural references. In this context, randomness is not an accident but a deliberate act of introducing unpredictability to stimulate creativity.^{xxvi}

The observed chaos, randomness, and algorithmic complexity can be understood as part of a new system that produces a new set of rules for artists to use. In the same way that algorithms swiftly compute a function one step at a time, the process of making art is also iterative.^{xxvii} An artist begins, observes, corrects, and continues to work, mark by mark, in a stepwise process. The rules programmed into the algorithm act as constraints, much like an artist working at the moment would employ decision-

making at each new mark. Critics argue that humans are more attuned to the complexity of form than a computer, which implies a machine could not match the creative process. Often, computer algorithms are trained on input images of existing artwork that inform its progression moving forward with its computations.^{xxviii} Similar to an artist's sense of control with each mark that feels intentional, the computational network can learn to tend toward certain preferred solutions with each iteration.

From a philosophical standpoint, as highlighted by Soddu and Colabella, generative art's allure is deeply rooted in its capability to shift the creative paradigm from static occurrences to fluid transformations. This dynamic approach allows artists to engage in an iterative creation process, wherein they can recycle and refine previously established transformation rules to consistently produce high-quality artworks. The potential for creating an array of variations, each demonstrating different facets of an idea, underscores the essence of generative art. Such an approach, where the artists depict not just a singular perspective, but a spectrum of interpretations highlights the relationship between man and the cosmos.^{xxix} This relationship is ultimately the product of algorithms.

An algorithm is a process. It is a procedure programmed by a human, trained on vast datasets, and left to compute within its constraints. The bulk of the work done by the computer is where questions of authorship and authenticity enter the critique of generative art. Because it is invisible to the outsider, internally manipulated, and

unapparent in the final work of art, critics question where the art comes from – the artist or the machine.^{xxx} If it indeed comes from the human agent who initiates the procedure, then the question is whether technology can exist outside of the programmer's biases and prejudice. Not only can any novice with basic programming knowledge now sculpt generative art, but AI-powered art can perpetuate harmful internalized stereotypes that people possess.^{xxxi} Careful analysis is needed here as the products of generative art can shape how people see the world. Even once authorship and authenticity are properly sorted by the art world, they will still be subject to human bias that could create an unequal experience among audiences and require monitoring to avoid propagating the damage of Western preconceptions.^{xxxii}

An examination of autonomy in generative art begins with a suitable definition and understanding of different types of autonomy in the world. Technologically, there is physical autonomy, as observed in biological systems, and then there is mental autonomy which is characterized by free will. When discussing agency in generative systems, self-organization is the underlying aspect that critics point to. They ask if the system can operate independently and if a computer constitutes a "self" to self-generate results.^{xxxiii} If a computer could learn beyond its programming and adapt and produce in ways that the programmer did not foresee or design, then the artist could concede authorship to the machine. This phenomenon is emergence, and if unattended to the discussion may cycle into further

questioning about the authorship since it is the artist who creates a self-organizing process.

Artists like Jon McCormack argue that the existing language does not accurately capture the behavior of what some call generative art emergence.^{xxxiv}

The concept is appealing and requires further categorization that considers the complex artist-machine system on various levels. Gordon Monro, another generative artist, outlines simple-to-complex emergence, many-agent emergence, difficulty-of-prediction emergence, surprising emergence, and "Frankensteinean" emergence.^{xxxv} In one sense, simple rules lead to complex actions such as in the game of chess. In another sense, the system can produce unanticipated results even though the creator has full knowledge of its work. Still, another perspective to consider is when a system outdoes the human creator and takes on human attributes and emotions. Consider an algorithmically programmed musical composition that has learned to trend toward the emotive properties it trained on. Generative art emergence would have to go beyond the system's rules and perform "on its own" to be truly autonomous, and this concept requires further research before a conclusion can be drawn.

Until then, critics will continue to survey the boundary that separates the artist from the tool just as they continuously question where to draw the line between an everyday object and a work of art. Recall the metaphor of steering a ship to understand extended cognition where the steering happens down a chain of command. Anyone or anything that contributes to the steering is part of the

process. Cognition is human-centered in that it happens inside the brain, but it extends beyond the internal cognitive core and across brains and bodies out into the environment. Functionally, concerning accomplishing a task, the external processes can do things that the internal ones cannot.^{xxxvi} By letting the environment take care of some of the cognitive tasks, external supports are relied upon. While this assumes a stable external structure, it allows for cognition to extend infinitely. This notion from cognitive science informs the discourse on conferring the status of art to works created by a generative art process. Skin and bones, like hardware and software, become arbitrary boundaries that exist conceptually to maintain coherence between separate systems to understand them separately. However, when it is shown that the natural kind of processes that happen inside of a computer also happen inside of the head, then both kinds of processes hold meaning and value.^{xxxvii} Functioning as an extension of the artist's brain, the computer is a creative assistant to realize the artist's vision.^{xxxviii} Further, the computer expands the artist's reach into their own consciousness for what is possible to create and simulate in virtual worlds and realities.

The discussion of authenticity in generative art is worth distinguishing from that of autonomy and authorship. A study of creative adversarial networks (CAN) attempted to produce art that confused the human audience as to its style label (Renaissance, Baroque, Impressionism, Expressionism, etc.), which the network was trained on to discriminate between.^{xxxix} The purpose was to create a system of generative art

that people confused with modern artworks, and they found that subjects could not easily determine whether the creator was a human or a computer.^{xi} They also often preferred generative art over traditional artworks. Aesthetic preference generally increases with familiarity as more viewings positively relate to strong emotional affect or preference.^{xii} Another feature of fine art appreciation is novelty, which also relates to generative art and helps explain the viewer's preference for this kind of art. Aesthetically, it is both familiar and new. It is authentic. Unlike the average art enthusiast, though, experts might suppress their initial effect to intentionally reflect and evaluate the work of art's authenticity.^{xiii}

The possibly suppressed transmission of feeling through generative art practices creates a new conflict for critics. Part of the struggle here is the general tendency to discredit emotional reasoning when determining an artwork's aesthetic value.^{xiii} It is more acceptable to judge art from within its cultural context. Philosopher Arthur Danto believes that an object is "art" based upon a society's inherited body of knowledge regarding the history of art as discussed in the art world.^{xiv} Computer-generated art seems to defy this perspective since it is both similar to and different from what modern culture has deemed as "art." For art to contain the assumed aesthetic essence, it must be from the social fabric and interpretable by the art world. It must be about things that exist in the physical world as well as the product of an artist's actions.^{xiv} To be contemplatively appealing, though, an artwork only needs to be experienced from the attitude of having an aesthetic interest in its

viewing. The art world can still be said to have produced such creations by being a social institution designed with human cognition in mind, which might include the emotive effects that ensue. The art world itself is embedded in the social self that is influenced by its surroundings.

It is helpful to consider the art form's social nature to highlight its inherently valuable trait of uniqueness. The general fear that AI will replace human artistry is invalidated in light of how algorithms are trained. What makes generative art interesting and aesthetically valuable is that it blends the familiar and the unique, yet it still requires original traditional input to form a comparison. Part of its intrigue comes from experiencing something unexpected. In support of the contemporary social commentary that addresses issues of diversity and inclusion, generative art inspires new avenues of creation that are open to anyone who does not identify as an artist but who perhaps has computer programming skills. There could be a wave of aspiring artists who use computers to create and express, thereby adding to the spectrum of "strong" and "weak" art and forming a new basis for future comparison.

Related to the discussion of the social nature of generative art is that it yields unique problems. Machine learning can also take place across datasets comprised of AI-generated art, which poses a specific and immediate concern to concept artists given the rapid growth of online AI art generators.^{xlvi} Since the technology has evolved faster than the relevant legislation that protects copyright infringement and intellectual property rights, artists face great

unknowns regarding income potential and proper compensation for using AI-generated images that are in their particular style. An AI art-generating application can produce hundreds of thousands of images in the style of an artist that the artist did not actually create, and this is a difficult area for the artist while the courts decide how to proceed with these unprecedented issues. The valuable uniqueness inherent to generative art is easily mass-produced under current unrestricted online media culture practices. Some artists have taken AI to court to fight for the protection of their creative work, but there is presently no final decision.^{xlvii} Regardless, this technological leap is forcing many in the art world to journey outside of the contexts with which they are accustomed.

The art journey undertaken by designers, as Soddu sees it, is layered with choices that set the trajectory of the design. Each choice made in the design process becomes an indelible part of the creation. These choices, while being deeply personal to the original designer, may present differently to each observer, which demonstrates the highly subjective nature of the design journey. Consequently, design decisions often deviate from linear thinking, and the designer might embrace inconsistencies or non-linear pathways to spur innovation.^{xlviii} Furthermore, the design process involves embracing randomness and inconsistencies, where methodical deliberations might not always yield the quickest or most innovative outcomes. As established earlier, this apparent randomness is a major component in this field, and this is something that will seemingly always be present. These

perspectives challenge the traditional deterministic approaches in design, advocating instead for a process littered with unforeseen adjustments that push the boundaries of creativity.^{xlix} These stretched boundaries can be seen in the work of Soddu.

In Soddu's seminal work, "Argenia," he went beyond the conventional approaches of design to focus on crafting artificial species, such as cities, architectures, or industrial objects. Argenia operates on a unique structure that combines transformational codes, reminiscent of the concept of DNA, with an organizational approach tuned to the evolutionary dynamics of a project. These transformational codes are instrumental in achieving a blend of artistic and scientific methods, channeling both beauty and balance.ⁱ Generative art, especially in the form presented by Soddu, is not just about the final piece but the very process that gives rise to it. Leveraging technology and artificial intelligence, Soddu's work, like his "Basilica" tool or "Argenia," is indicative of his vision to reshape the environment by harnessing the power of generative processes. Whether it is reimagining the DNA of a typical Italian town environment or crafting unique factory-made products, Soddu's approach to generative art epitomizes the blend of creativity, technology, and environmental consciousness.ⁱⁱ The crux of Soddu's generative art lies in its capacity to reflect human creativity while simultaneously celebrating the unpredictability and uniqueness of each generated artwork.ⁱⁱⁱ

Ultimately, Celestino Soddu's art philosophy and techniques in generative

art advocate for an embrace of randomness, complexity, and iterative refinement. Rooted in a deep appreciation for the intricacies of design and the potential of artificial intelligence, Soddu's work stands as a testament to the infinite possibilities in the combination of creativity and technology.

Conclusion

Generative art holds great potential during the modern digital era when society is saturated with information from traditional and online media sources that imply a gap between the real world and their externally constructed hyper-reality. If this is a digital revolution, then it would mean all information could be reduced to numeric code that translates the simulated world through the human senses using AI technology.^{liii} As machine learning integrates further into everyday life and continues to collect and categorize information, it also allows generative art to penetrate the arbitrary boundary that separates a person's inner world of thoughts and feelings from their external reality. Media sources and art museums become extensions of humanity, existing because of and in support of cognitive evolution, and the art world becomes a place to explore and expand the understanding of virtual agents and where they contradict and overlap the real world.^{liiv} Audiences can experience works of art that are both detached from and created by an artist who exposes AI and ML as akin to natural processes.

In the broad sense of generative art being an ancient process of creation that includes the artist's tools as part of the artist, generative art is older than AI and

ML. These came into the public realm with the advancement of the computer age in the second half of the 20th century. The various versions of generative art that have branched off from the central idea all offer a unique way to reinterpret current artwork rather than force AI art into a genre of its own.^{lv} When generative art is seen more as a process-based lens than a contending category to traditional artwork, then it can enter the shared space of creativity. AI-assisted art simply organizes and processes information and then reproduces it through virtual media for an interactive audience experience. Computers are dynamically organized, which is also a distinctive trait of humanity, and this is no mere metaphor. Generative art often involves a thorough engagement with certain processes that create coded rules and systematic outcomes where “life emerges from the interactions of formal elements in a medium deliberately abstracted from nature.”^{lvi}

While true to their nature as abstractions of the physical world, generative art also extends its reach into the more spiritual aspects of humanity. Through art, humans have always tried to “raise something immortal and transcendent.”^{lvii} When all things can be reduced to simple numerical code, people can exist virtually anywhere given access to sufficient technology. In effect, generative artists such as McCormack and Ian Cheng create a computational “being” that generates creative output. This sort of artistic imitation is not an imitation of life, as ancient philosophers proposed. Instead, AI art imitates art. As creators, McCormack and Cheng infuse their creativity into the AI processes they use,

and the art form surpasses its own medium.^{lviii} This trend has been in motion and is expected to continue in various forms of interactive installations and networks that integrate real and virtual worlds. This is an evolution from machine learning to machine intelligence where the AI system assumes some of the work that human agents usually do by not only modifying its process but also self-reflecting as it grows.^{lix}

The issue of granting creative power to generative systems is relatively new to the art world and a good reason to further explore how AI systems operate. This is especially true considering the innovative output and high “arousal potential” of some generative artwork.^{lx} This term refers to the various patterns of stimuli that can be programmed for and tend to pique the interest of human viewers. For example, consider a generative system that is trained on a vast data bank of art images from the last several hundred years and coded to force the AI system to seek out an outcome that is similar enough in style to count as art yet unique enough to count as original. Researchers studied what happened when this kind of system was evaluated by people in an experiment to determine whether or not they could distinguish between the generated art and the human art. Results showed that people often confused the two and sometimes gave the generated art a higher rating on its novelty, complexity, unexpectedness, astonishment, and ambiguity – collective variables that constitute aesthetic value.

AI systems can learn to adapt their output continuously along these lines, which seems to imply that the system

would require a steady flow of new art to learn from. Abstract paintings, especially, are used to train AI and experiment with simplified duplication studies between real and generated images. A painting by Piet Mondrian from 1917, which is considered the artist's most accomplished work due to its thematic and specific use of vertical and horizontal space (abstracted into ideas of masculinity and femininity) was digitally rendered by computer software and used in a comparison study.^{lxi} When translated to code, this picture becomes a series of attached and detached lines as the program calculates data points according to its instructions. In essence, every picture can be broken down and reverse-engineered in this way whether it is human- or machine-made. In the study, participants were shown both images and then asked which one they preferred and which was produced by which method. The computer-generated image was preferred, and the majority of participants could not correctly categorize which image was produced by which method.^{lxii} The judgment was made solely based on different visual patterns, though, and no weight was given to any emotive effect. The computer acted as an extended medium for the programmer to use in completing the image, yet both images were conceived by a human agent, and no merit is detracted from Mondrian's work.

The full impact of AI and ML on the creation and perception of art where a digital copy can transport the human artist's emotional intention is still underway. As the field continues to clarify terms and refine developments in communication tools and technology, generative art systems move further

away from facsimile-like copy art that was initially created in response to consumer demands and for the simple reason that some machines were invented to make copies.^{lxiii} The term "generative" was meant to distance the field from these aspects of technological capability. Yes, a novice artist can produce a copy of their favorite image that looks sufficiently professional, and there may continue to be a wave of amateurs who lack the full understanding of the nature of their tools and creation. This, plus the previous discussion of misused AI art generators, is not a call to align with anti-machine efforts that work against creative impulses but rather an observable phase of what happens when new technology is adopted by society.^{lxiv}

In light of the case studies herein that illuminate the complexity of the dynamic system that cuts across the artist, their tools, and the interaction with an audience, Baudrillard's notion of the hyperreal and simulacra can be revisited. The generative works of McCormack and Cheng do not represent any sort of external truth but rather a "symbolic exchange of signifiers" that refers back to coded input in the absence of an original model to simulate.^{lxv} The issue is not about modern society and its artistic processes becoming artificial, but that people need to recover their ability to make a distinction between real and artificial. Generative art occurs on screens, which have infiltrated all layers of modern society. For some theorists, the output is both a simulation of reality – evolutionary processes, for example – and a simulation of the creative process, making both the content and the medium artificial.^{lxvi} It has been argued, also, that even though generative artists make their

artifice explicit, the work has not sufficiently supported people's ability to distinguish between generative art and human art, and it has instead confounded the audience. People need to be told that an image is AI-generated to know that it is so. This marks the onset of transaesthetics where the value of generative artwork like McCormack's and Cheng's surpasses the usual categorizations and challenges the way people think about art and perhaps themselves.

In this hyperreal era where the algorithm has superseded the artist, concepts of real and artificial may matter less than issues of process and intent. In 2018, an AI-generated artwork, *Portrait of Edmond Belamy*, sold for \$432,500 at auction, which was about 40 times greater than its estimated worth.^{lxvii} Trained on 15,000 portraits from over seven centuries of artwork, a new image was created that had been cultivated according to programmed discriminatory rules. Machine art can be just as inspiring and thought-provoking as human art. In the past, the artwork was defined primarily by the aesthetic intent of the artist. To say something about the world and express emotions, there had to be a human agent steering the ship. Today, the artist is whoever has the idea to set in motion using generative techniques, and the machine is an extension of their creative process. When the whole chain of command is considered, the artist may be at the wheel, but it is the wheel and its connection to the vessel that gets the work done. The whole system is art, not just the image produced.

The sublimation of art to symbolic code brings new and greater value to the

system. Technological advances in computers have solidified them as extensions of human cognitive processes with new potentials to explore. Among these, certain aspects of interpersonal communication and relationship dynamics are being emulated by interactive installations as computer scientists and artists work toward the dream of computers with human-like agency and reasoning enough to emote and engage with viewers.^{lxviii} The transparency is refreshing and allows for models that demonstrate the opposite expectation as well. Some systems are designed to show how people fail to communicate by evading questions, stalling, or giving trivial responses.^{lxix} In almost any case, creators work toward repositioning art's place in the broader social context where the final product is complete when the audience interacts with it, softening the divide between the artist, the machine, and the viewer in unprecedented ways.

Generative artists are like every artist who has gathered inspiration from past styles, physical sciences, and universal creative energy to understand the form and function of parts as they relate to the whole. They combine abstract symbols from artificial worlds into concrete images that embody natural and formal structures into artwork that evolves in its own direction.^{lxx} AI's role in the process is as an extended tool for artistic abstraction onto a virtual medium that is capable of creating ever newer forms brought to life by the artist wielding the tool. AI art has a prehistory that is valuable in itself for destabilizing traditional notions about contemporary approaches to art. Generative art borrows from and applies computational

methods that center on natural physical processes and progress toward sometimes metaphysical expression that transforms the real world into an endless space for further innovation.^{lxxi} From this perspective, generative art is like all art that is primarily concerned with creativity.

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ⁱⁱ Margaret A. Boden and Ernest A. Edmonds, "What is Generative Art?," *Digital Creativity* 20, no. 1-2 (2009): 30, <https://doi.org/10.1080/14626260902867915>.

ⁱⁱⁱⁱⁱⁱ Jon McCormack, Oliver Brown, Alan Dorin, Jonathan McCabe, Gordon Monro, and Mitchell Whitelaw, "Ten Questions Concerning Generative Computer Art," *Leonardo* 47, 2 (2014): 2.

^{iv} J. P. Hodin, "Contemporary Art: Its Definition and Classification," *College Art Journal* 10, no. 4 (1951): 342.

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^{xi} Shaun Gallagher and Anthony Crisafi, "Mental Institutions," *Topoi* 28, no. 1, 2009: 47.

^{xii} Bachrach, "Dickie's Institutional Definition of Art," 29-32.

^{xiii} Galanter, "What is Generative Art?," 6.

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^{xvi} Jean Baudrillard, *The Body in Theory: Histories of Cultural Materialism*, trans. Sheila Glaser (Ann Arbor, MI, 1994), 2.

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^{xx} Baudrillard, *The Body in Theory*,

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^{xxi} Jean Baudrillard, "Simulacra and Simulation," *Wordpress*, December 2014, <https://0ducks.files.wordpress.com/2014/12/simulacra-and-simulation-by-jean-baudrillard.pdf>

^{xxii} LeWitt, "Paragraphs on Conceptual Art," 82.

^{xxiii} Galanter, "What is Generative Art?," 5.

^{xxiv} Galanter, "What is Generative Art?," 12.

^{xxv} James Elkins. "Art History and the Criticism of Computer-Generated Images," *Leonardo* 27, no. 4 (1994): 336.

^{xxvi} Celestino Soddu, "Generative City Design, Aleatority and Urban Species, Unique, Unrepeatable and Recognizable Identity, like in Nature." *Domus Argenia Pub* (2020), 21.

^{xxvii} Boden and Edmonds, "What is Generative Art?," 26.

^{xxviii} "Is Artificial Intelligence Set to Become Art's Next Medium?," *Christie's*, December 11, 2018, <https://www.christies.com/features/A-collaboration-between-two-artists-one-human-one-a-machine-9332-1.aspx>.

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Au gré de l'onde: Ukiyo-e as a metaphor for generative art (Abstract)

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In Japan, the Edo period [1] was marked by the pictorial style of *ukiyo-e*, which mainly refers to woodblock prints, at first monochrome, then soon in color [2]. This talk will highlight the convergences between a personal work entitled “Au gré de l'onde” and *ukiyo-e*, particularly as practiced in the early 19th century.

We will present a series of still images [3] generated by a program written in *Processing* and driven by hydrological data from a river—level, flow, temperature. These images are based on recorded data from the Rhine near Basel. The project will eventually take the form of an animated installation *in situ* and in real time, requiring the installation of a hydrological sensor in the river involved.

Literally meaning “images of the floating world” [4], *ukiyo-e* emphasizes the ephemeral nature of terrestrial life and promotes a light, hedonistic attitude, a definition of which is given by Asai Ryōi in the preface to his *Tales of the Floating World*:

“Living only for the moment, turning our full attention to the pleasures of the moon, the snow, the cherry blossoms and the maple leaves, singing songs, drinking wine, and diverting ourselves just in floating, floating, caring not a whit for the pauperism staring us in the face, refusing to be disheartened, like a gourd floating along with the river current: this is what we call *ukiyo*.”[5]

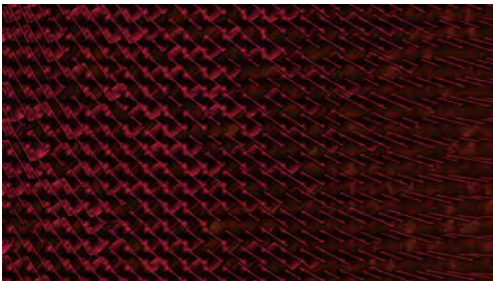
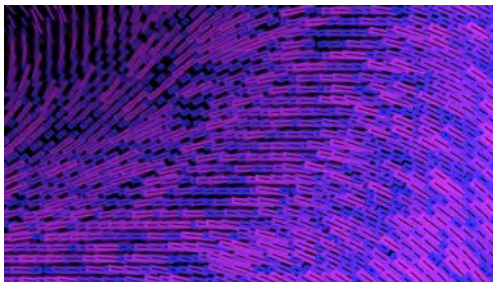
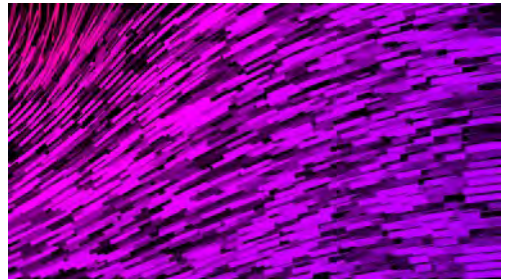
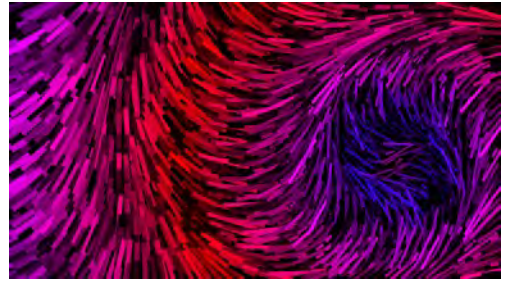
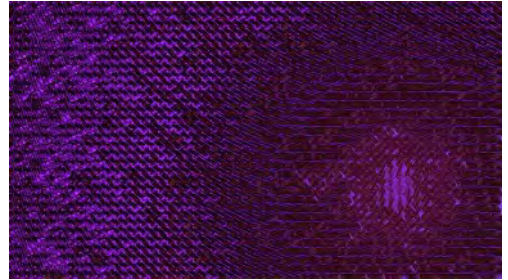
This floating world is envisaged here as a metaphor for the generative program, a process in perpetual evolution, a succession of ephemeral, unseizable moments, which material embodiment eternalizes in the manner of the snapshot constituted by *ukiyo-e*. [6]

Although *ukiyo-e* prints are best known for their representations of everyday life, depicting the pleasures of the city, the genre underwent a revival in the 19th century with the return to favor of landscape painting, of which Hokusai and Hiroshige were two of the leading figures.

The hedonism associated with kabuki and red-light districts was replaced by contemplative pleasure tinged with spirituality: the observation of nature and its eternal recombinations, but also of its destructive power.

This relationship with nature is at the heart of “Au gré de l’onde”, which seeks to extend the river beyond its banks. While the real-time installation delivers a rendering of the forces that animate it, such as the Kami that inhabit it in the Shinto tradition, the extracted still images underline its multiple faces, like Hokusai’s *Thirty-six views of Mount Fuji*.

The images presented here will give rise to high-quality digital color prints, echoing the artistic status acquired by *ukiyo-e* in the late 19th century. To recapture the popular and ephemeral dimension of the original *ukiyo-e*, more numerous prints in postcard format are envisaged. In both cases, each copy will be unique to highlight the continually changing character of the generative artwork.



Notes

[1] This period stretches from 1603 to 1868, i.e. from the beginning of the Tokugawa Iyasu shogunate to the Meiji Restoration. It takes its name from the city of Edo, now Tokyo, which became the capital of the shogunate.

[2] IWAO, Seiichi and al., 1995. *Ukiyo-e. Historical dictionary of Japan* [online]. Tôkyô: Maison franco-japonaise. [Accessed July 28, 2023]. Available from: https://www.persee.fr/doc/dhjap_0000-0000_1995_dic_20_1_951_t1_0018_000_0_6

[3] The images attached to this abstract illustrate the various visual avenues explored, and this work is still under construction. It will be finalized for the final paper..

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https://www.persee.fr/doc/ephe_0000-0001_1966_num_1_1_5073

[5] Quoted by Richard Lane:
LANE, Richard, 1957. The Beginnings of The Modern Japanese Novel: Kana-zōshi, 1600–1682. *Harvard Journal of Asiatic Studies* [online]. 1957. Vol. 20, no. 3/4, pp. 644–701. [Accessed September 14, 2023]. Available at:
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[https://www.clio.fr/bibliotheque/bibliothequeenligne/le monde flottant de lukiyo e la perennite de lephemere.php?letter=A](https://www.clio.fr/bibliotheque/bibliothequeenligne/le_monde_flottant_de_lukiyo_e_la_perennite_de_lephemere.php?letter=A)

Quantum Genetic Algorithms for Generative 3D Creations

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Abstract

This article presents an experimental generative artistic work based on bio-inspired algorithms, more specifically quantum genetic algorithms.

(Wolfram, 1984), John Conway (Conway, s. d.), Christopher Langton (Langton, 1984) in particular).

1. Introduction

Since the discovery of fractal geometry by Benoît Mandelbrot (Mandelbrot & Mandelbrot, 1982), it has become clear that much of the world around us is better described by fractal geometry than by Euclidean geometry. This is true of trees, plants, mountains, rivers, clouds, the distribution of planets in the universe, human lungs, and so many other things that make up the world we live in. Other very interesting algorithms are used to better model the world, notably cellular automata, developed by a number of major researchers (Stephen Wolfram



Figure 1 : Quantum Cellular Automata (Lioret, 2021)

The other great discovery that interests us here is that of quantum mechanics, which also gave us a new vision of the world at the beginning of the 20th century. Without going into too much detail, this new physics, which perfectly describes the microscopic world, is based on principles that are very confusing for humans: superposition of

states (elementary particles can be in several places at once), entanglement (particles can be linked by instantaneous information systems, breaking the barrier of the speed of light), teleportation (information from one particle can be teleported to another particle). We will use these hypotheses to explore new avenues of computational creativity. Because with the advent of quantum computing, users and artists are now able to play with theories in very practical ways.

Here, we'll be experimenting with fractal art, quantum art, cellular automata art and some of the major scientific concepts that link these three worlds. And this will lead us on to some experiments in quantum fractal art and quantum cellular automata, which we find interesting from both a conceptual and aesthetic point of view. This article shows some generative experiments using Genetic Algorithms based on Quantum Cellular Automata (Arrighi, 2019), Quantum Fractals (Nottale, 1989), Cellular Fractal Automata (Willson, 1984) and Quantum Cellular Automata with Fractal Structures (Farrelly, 2020).

2. Quantum Genetic Algorithm

Genetic algorithms (GAs) are evolutionary algorithms inspired by Darwinian natural selection. They are heuristic optimization methods that use simulated genetic mechanisms like mutation and crossover, as well as population dynamics such as reproduction and selection. In the last decade, the concept of emulating quantum computers has led to a new

class of GAs known as Quantum Genetic Algorithms (QGAs).

In the late 1980s, genetic algorithms gained popularity for optimization and machine learning. The Nobel Prize-winning physicist Richard Feynman proposed the concept of a quantum computer, which operates on the principles of quantum mechanics. The intriguing idea of designing a genetic algorithm to run on a quantum computer emerged but posed the question of its feasibility.

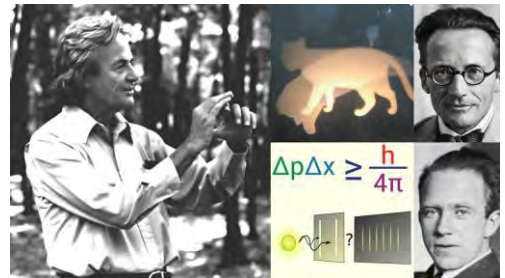


Figure 2 : Richard Feynman, father of quantum computing

Genetic Algorithms are search algorithms grounded in Darwinian natural selection and genetic mechanisms found in organisms. In a Simple Genetic Algorithm (SGA), solutions are encoded as chromosomes, which are arrays of information. Typically, the process starts with a randomly generated initial population of chromosomes. The algorithm then iteratively evolves this population to find an optimal solution.

Each generation of chromosomes is evaluated to determine their fitness, reflecting the quality of the solution they encode. The fittest chromosomes are selected as the "parents" for the next

generation, simulating natural selection. The new generation is then produced through genetic mechanisms like crossover and mutation. (Lahoz-Beltra, 2016)

3. Comparison of Genetic Algorithm and Quantum Genetic Algorithm

It's interesting to compare a classical genetic algorithm with a quantum genetic algorithm. Zakaria Laboudi and Salim Chikhi, compares Conventional Genetic Algorithms (CGA) with Quantum Genetic Algorithms (QGA). Evolutionary computation, the basis for genetic algorithms, has been a part of computer science for over four decades, originating in the 1970s with John Holland. Quantum computation, combining information science and quantum physics, gained prominence with algorithms from Shor and Grover for factorization and database search, respectively. QGA represents a fusion of GA principles with quantum computing, aiming to enhance the exploration of search spaces.

Laboudi focuses on comparing the computational capabilities of GA and QGA, particularly using the classic 0/1 knapsack problem as a test case. (Laboudi & Chikhi, 2012)

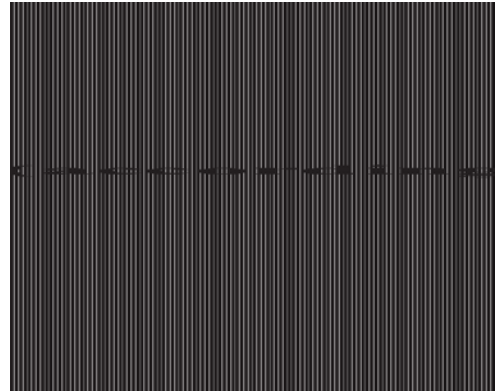


Figure 3 : Comparison of Classical Genetic Algorithm and Quantum Genetic Algorithm

4. RQGA : Reduced Quantum Genetic Algorithms

The Reduced Quantum Genetic Algorithm (RQGA) is a Python program demonstrating how to implement a 'true' quantum genetic algorithm, based on a fitness quantum gate and Grover's search algorithm. It is used for educational and research purposes. The RQGA was introduced as a fully quantum method to run genetic algorithms on a quantum computer, presenting a new methodology for this type of algorithms. As its name suggests, the RQGA aims to be a quantum version of the classical evolutionary process in a simplified setup. There has also been a proposal for a circuit level implementation of the RQGA using Python and Qiskit, with the main goal of analyzing the circuit complexity from various perspectives.

The Reduced Quantum Genetic Algorithm (RQGA) was proposed by Udrescu, Prodan & Vlăduțiu in 2006. Mihai Udrescu explores the application of genetic algorithms (GAs) within the quantum computing framework to solve the NP-hard graph coloring problem. Genetic algorithms, which are inspired by natural selection, have been adapted in the form of a Reduced Quantum Genetic Algorithm (RQGA). This adaptation leverages quantum computing's capabilities to potentially solve problems more efficiently than classical algorithms.

The RQGA specifically addresses both vertex and edge coloring of graphs and is also capable of determining the chromatic number, which is the minimum number of colors needed to color a graph without any two adjacent vertices sharing the same color. The authors propose a method that can solve the graph coloring problem in $O(N^{1/2})O(N^{1/2})$ time, which is significant given that graph coloring is known to be a computationally intensive task.

Ardelean and Udrescu's implementation is tested in a quantum simulation environment. Their work details the algorithm's convergence and performance metrics, suggesting that the RQGA is a robust tool for tackling this class of problems. The research presents a compelling case for the application of quantum principles to evolutionary algorithms, potentially opening new

avenues for solving other complex computational problems.

This work demonstrates the ongoing integration of quantum computing principles into broader computer science applications, highlighting the quantum genetic algorithm's potential to outperform its classical counterparts in specific instances. The study's findings contribute to the growing body of knowledge supporting quantum computing's role in addressing and solving NP-hard problems. (Ardelean & Udrescu, 2022)

5. Quantum Art

A number of artists have seized on quantum theories to experiment with their art. These include the work of Julian Voss-Andreae, Libby Heaney, Alain Lioret and Omar Costa Hamido (Hamido, 2021).

Some of these artists only used analogies with the principles of quantum mechanics, whereas more recently, the emergence of quantum computing has made it possible to work directly and practically with its concepts. This is how artist-researchers such as James Wootton (Wootton, 2020), Russell Huffman and Alain Lioret (Lioret, 2016) laid the foundations for the first true quantum artworks.



Figure 4: Quantum Sculptures by Julian Voss Andreae

6. Towards new experiments in computational creativity

We have embarked on a journey of artistic experimentation utilizing a quantum genetic algorithm. This advanced algorithm has been applied to the deformation of mesh structures, infusing them with new, unexpected forms. Moreover, we extended its application to fractal objects and shapes generated by cellular automata, exploring the boundary between algorithmic precision and creative expression. Below is the algorithm that we employed in our quest to meld science and art:

QGA Algorithm :

- Create a population of randomly initialized qubits by applying a Hadamard gate.
- Measure and evaluate its correspondence with the desired result
- Retrieve the N best elements according to their correspondence with the desired result
- Mutation of previously selected elements using a flip on the X-gate and the application of a Hadamard gate

- Repeat for the defined number of generations
- Recovery of the best elements

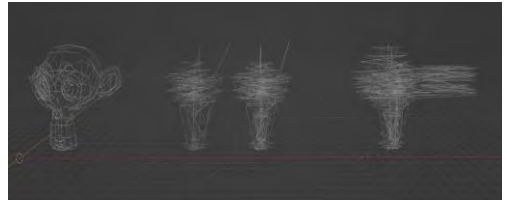


Figure 5: Genetic quantum deformation of a mesh made with QGA

In our continuous exploration of the intersection between technology and art, we have implemented a variant using the Reduced Quantum Genetic Algorithm (RQGA). This cutting-edge algorithm has been adeptly adapted to manipulate mesh deformations, introducing a novel dimension to our digital sculptures. Furthermore, we have employed this variant to shape fractals and patterns emerging from cellular automata, pushing the envelope of generative art. This initiative harnesses the RQGA, integrating its sophisticated mechanisms into our creative toolkit:

RQGA Algorithm

- Initialize a circuit containing n qubits
- We set each qubit in superposition state with a Hadamard gate
- We modify the state of each qubit starting from a random angle between 0 and π / n , (π / n can be increased if we wish a slower evolution between each

generation), modifying the state of our qubits in a random way allows us to observe the evolution of other genes than the one we wish and thus observe a more natural evolution.

- We apply Grover's algorithm to select the gene we want our population to evolve towards

- We observe the result after 1 generation; if required, we can apply Grover's algorithm several times to simulate evolution over several generations.

We present here a collection of creations crafted with both the quantum genetic algorithm and its variant, the RQGA. These pieces represent a fusion of algorithmic complexity and artistic vision, showcasing the transformative power of mesh deformation and the intricate beauty of fractal and cellular automata-generated objects. Each creation is a testament to the seamless synergy between advanced computation and the boundless realm of art, illustrating the rich possibilities that emerge when these two worlds collide.

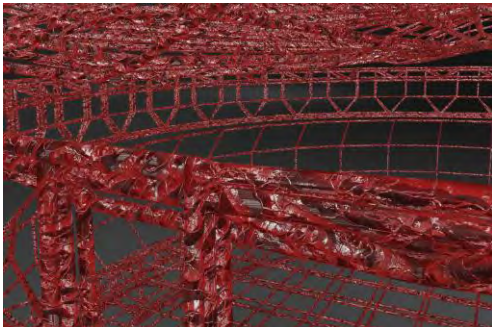


Figure 6 : quantum structure of a Burger

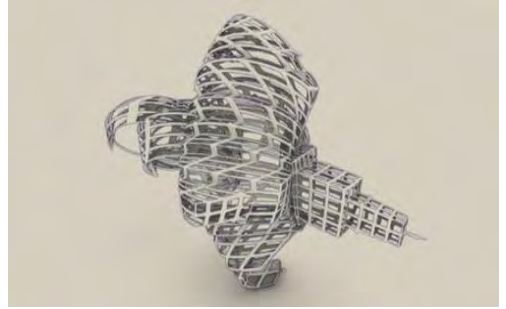


Figure 7: Quantum Fractal Creation made with QCA Algorithm (2023)

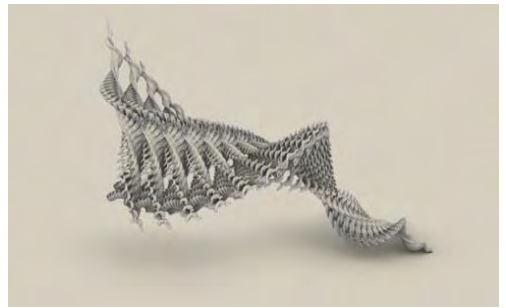


Figure 8: Quantum Fractal Creation made with RQCA Algorithm (2023)



Figure 9: Quantum Mesh Creation made with RQCA Algorithm (2023)



Figure 10: Quantum Mesh Creation made with QCA Algorithm (2023)

7. Future Works

These first quantum genetic algorithm experiments are very interesting and enable us to create 3D generative forms with innovative creation processes. The method used here remains fairly simple, and it would be very interesting to introduce Machine Learning concepts to further explore the possibilities offered by complex space computations where bio-inspired algorithms and quantum computation meet.

Looking ahead, we envision future works where animation becomes a central element, bringing our algorithmic creations to life. By incorporating motion, we aim to explore the temporal evolution of forms, where meshes unfold and fractals breathe, all orchestrated by the RQGA. This dynamic layer will add a new dimension of interactivity and realism, inviting viewers to witness the dance of pixels and vertices, a choreography guided by the sophisticated rules of quantum genetics. These animated artworks will not only captivate the eye but will also stir contemplation on the fluid nature of digital artistry.

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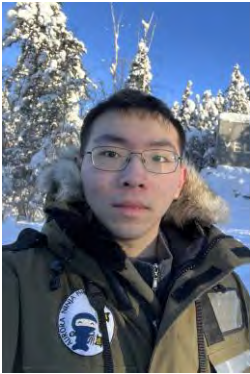
Exploring The Generative Art Of Integrating Natural Elements Into Geometric Architecture

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Abstract

My work is titled 'Flowering.' It is a tower building generated using Rhino/Grasshopper. The entire structure is composed of tubular elements and hollow surfaces, drawing inspiration from the natural structure of a flower. Inside the hollow interior, a flower-like structure is concealed, faintly visible from the outside. The building features a double-roof structure, with two symmetrical hollow roofs connected by a tubular framework. Surrounding the sides of the building are sheet-like structures that resemble both flower petals and wings.

In this project, I explore the transformation of natural elements into geometric structures and their integration into our built environment. Geometric architecture is renowned for its modern

visual appeal. I believe that incorporating floral forms into geometric architecture preserves its visual impact while also enhancing its human connection.



Figure 1. "Flowering", model image.

Keyword : *Generative Art , Geometric Architecture , Rhino/Grasshopper*

1, Introduction

Since ancient Rome, geometric elements have been widely used in the field of architecture, and the Roman Colosseum is the most famous case, which contains a large number of geometric designs. In modern times, with the development of science and technology, digital media

technology has been more and more used in architectural design. In the last two decades, the CD techniques applied in architectural design surpassed the automation of drafting tasks. [2]

This makes the design of geometric architecture more and more convenient, and brings us a large number of geometric architecture works. Modern geometric architecture often have a simple, regular, contemporary appearance, that makes the modern geometric architectures are usually aesthetically attractive. However, excessive geometry will also make the building appear monotonous and lack of intimacy with people. Therefore, I aim to integrate natural elements into geometric buildings, believing that this can enhance the connection with people while preserving the visual appeal of geometric architecture.

2, Project Structure

The whole project was generated by Rhino/grasshopper, and it has three different structure.

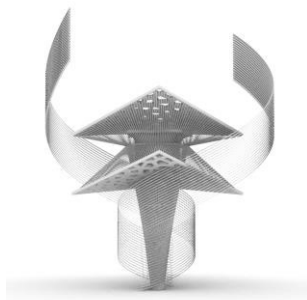


Figure 2. Model Image.

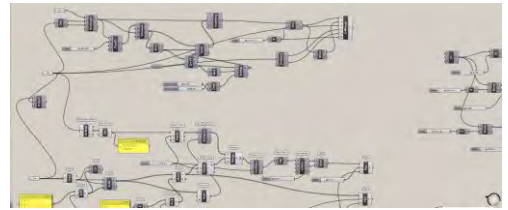


Figure 3. Grasshopper code screenshot.

2.1, Outer Structure

The outer layer consists of a pair of flaky multi-storey structures that surround the subject building, it simulating the leaves of a flower in its shape, also it like a pair of wings that surround the main building.

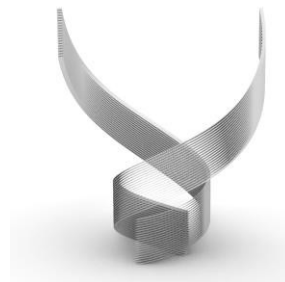


Figure 4. Outer structure model image.

2.2, Main Building Structure

The main building is a tower with double roof structure, the whole tower is composed by tubular structure, with two hollowed roofs that are symmetrical up and down. Each roof is connected to the tower by tubular structure.

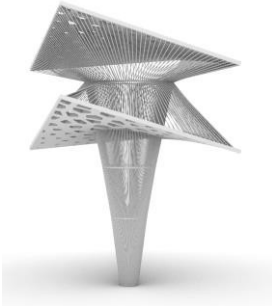


Figure 5. Main building image

2.2, Inner Structure

Inner structure is a flower-shaped hollow column structure, from the outside through the tubular structure, you can see the shape of the tower flowers.

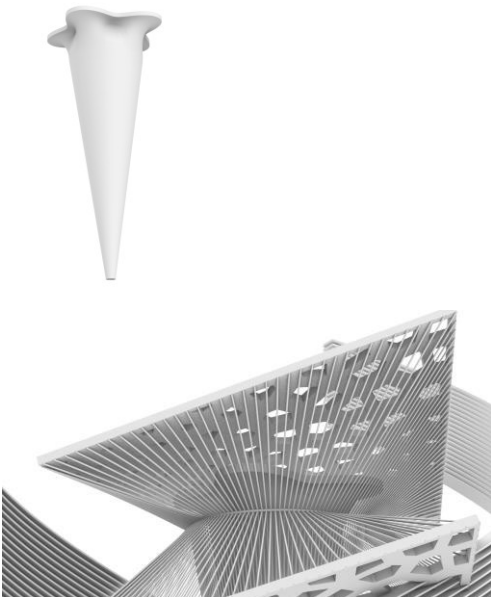


Figure 6&7. Inner structure image.

3, Architectural Generation

With the development of technology, the application of digital technology has been involved in all walks of life, and the architecture field is no exception. New digital architectures are emerging from the digital revolution, architectures that have found their expression in highly complex, curvilinear forms that will gradually enter the mainstream of architectural practice in the coming years. [4]

Digitally generated buildings are known for their complex structures and stunning geometry, and designers can use digital technology to realize many ideas that were impossible or difficult to achieve in the past. Also, there is a lot of differences in the design process. Instead of modeling an external form, designers articulate an internal generative logic, which then produces, in an automatic fashion, a range of possibilities from which the designer could choose an appropriate formal proposition for further development.[4]

This process also happened when I developed this project. I first thought about the general structure of the model and then generated the code for the model using Grasshopper. I designed multiple versions of the Grasshopper-generate code and adjusted the parameters to choose the best version. This design process is very different from traditional design methods and, in a way, I think it's more akin to software development steps.

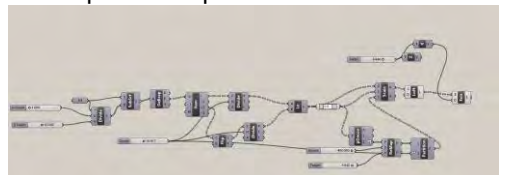


Figure 8. Grasshopper generate code (Outer Structure)

As digital methods, tools and techniques have become central to the design process itself, we are witnessing the emergence of novel processes of mediated design which challenge certain of the cherished assumptions of traditional design theory.[5] I think the digital generation is not just a technique, it is more like a new set of styles and trends. The digital generation techniques through the parametric modelling and scripting – have inspired a new collective movement with radically new ambitions and values. [6]

4, Incorporating Natural Elements Into Geometric Architecture

Geometric architecture, especially modern architecture generated by digital media technology, possesses a very strong visual appeal, which is its most prominent advantage. However, an excessive use of geometric effects can create a sense of distance and stress between people. Therefore, my goal is to integrate natural elements into geometric designs, preserving their visual impact while also reducing the sense of distance among people.

“Life creates conditions conducive to life,” writes Beynus, “and life, if we invite it into our buildings, can also create conditions conducive to our life.”[1] I agree with that. I think that inviting nature into our architecture is not just about incorporating nature into our buildings, but also about creating visually friendly modern architecture by imitating elements from nature.

I made this project with reference to the concept of “biophilic” design, use of shapes and forms in buildings and landscapes that directly, indirectly, or symbolically elicit people’s inherent affinity for the natural environment. [3] I attempted to structure the shapes of flowers and abstract them into various sizes of geometric shapes. I then combined these geometries with the tower’s structure that I aim to design.

I think the combination of plant form and geometric structure can reduce the pressure brought by geometric buildings. At the same time, the use of existing geometric shapes in nature as prototypes can also increase the viewer’s sense of closeness to the building.

5, Conclusion

I believe that digital generation technology will see wider applications in various fields in the future, and understanding how to utilize this technology to explore the boundary between technology and design will become increasingly important. Designers should not be constrained by technical limitations and should continually experiment with new possibilities.

Computational formal explorations do not intend to eradicate human imagination but rather extend its potential limitations. Computation is not a substitute for human creativity and therefore cannot be antagonistic.[7] Thinking about how to integrate technical means with their own design to create captivating works may be an important topic for future designers to consider.

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A Visual Music Exquisite Corpse

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restrictions related to the pandemic focus has been on the translation of the project from a purely online performance modality, to one that is hybrid encompassing both physical and virtual participation in order to celebrate the liveness in our work. The hybrid format provides the opportunity to create community and to expand our connection with the audience and each other.

Abstract

A Visual Music Exquisite Corpse is an audiovisual performance that started as an online experiment during the pandemic as a way to build community within the *nd::StudioLab*¹ at York University, Toronto, Canada. In the project, lab members live code and share audio-visual signals with each other using tools such as Zoom, Shifter, Twitch, and Discord. Unusual network topologies were created using these tools providing a foundation for exploration of live coded audio-visual media and real-time interactions. Since the relaxing of

The motivation for the continued development of this work stems from a desire to create art collaboratively with the environment and the conjoined histories of living beings and places. In this collaboration we wish to explore the unexpected through indeterminate processes in order to nurture the boundless creativity of generative art.

In this project, we collaborate creativity through an audiovisual performance that is constructed of a chain of live audio-visual feeds, each of which influences the other, and loops in on itself. The concept draws inspiration from Alvin Lucier's artwork/performance *Quasimodo the*

¹ <http://www.mdhosale.com>

Great Lover (1970)², which featured a chain of audio systems across a large performance space and conceptually followed the example of how certain marine mammals communicate spatial information through echolocating songs over long distances.

In *A Visual Music Exquisite Corpse*, the real-time manipulation of audio-visual content will be processed using live coding and focuses on the creation of experimental computationally authored improvisational tools and content. By using audio cables and video cables we will create networks of signals whereby one performer can pass their outputs to another performer that uses the incoming signal as a source for their own content. By arranging the ensemble so that the signals are passed in a loop we can create a multi-node feedback system that has no beginning or end.

Content of the performance is derived from performers, the audience, and the environment. During the performance we will inject signals from the human body (e.g. heart (ECG) and brain signals (EEG)), climate and environmental data (e.g. weather, pollution), and non-human

(e.g. biosignals from plants, bacteria, and other lifeforms). Audience members will be invited to move around, lay down, sit, and congregate freely. Through the introduction of interactive devices and sensing systems, audience members will also be invited to participate in the work and have greater agency in the activity that is unfolding.

This project is a collaboration of the following artists:

Kwame Kyei-Boateng, Jacob Cram, Kimberly Davis, Filiz Eryilmaz, Grace Grothaus, Marcus Gordon, Mark-David Hosale, Hrysovalanti Maheras, Fransesc Morales, Nava Waxman.

² "Quasimodo the Great Lover (1970)- for any person who wishes to send sounds over long distances through air, water, ice, metal, stone, or any other sound carrying medium, using the sounds to capture and carry to listeners far away the acoustic characteristics of the environments through which they travel." *Also see:* Marshall, Stuart. "Alvin Lucier's music of signs in space." *Studio International* 192, no. 984 (1976): 284-290.

Netnature: a bio-inspired speculative installation exploring novel forms of human-robot behaviors.

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human perception, relying on nonverbal communication cues such as facial expressions and body movements. Similar to plants in nature, these flowers possess an artificial intellect that improves through interaction with people; the more visitors interact with the flowers, the more perceptible and recognizable their stem and bulb movements become. To generate this artificial empathic behavior, the six robot flowers employ internal cameras and pre-trained machine learning models in the fields of pose estimation and facial detection.

Abstract

In recent years, scientific studies have increasingly focused on exploring the cognitive, relational, and interactive abilities of plants. Neurobiological research has revealed that plants are capable of engaging in interspecies communication and forming relationships with other organisms [1]. Additionally, they exhibit strategies influenced by swarm intelligence [2] and can establish nonverbal communication channels with humans [3]. This article introduces the speculative artwork called "netnature," a physical installation comprising six robotic flowers designed to respond to the physical and emotional resonance of the audience. The aim of netnature is to explore new forms of human-robot interaction inspired by the intelligence of plants, which often goes unnoticed by

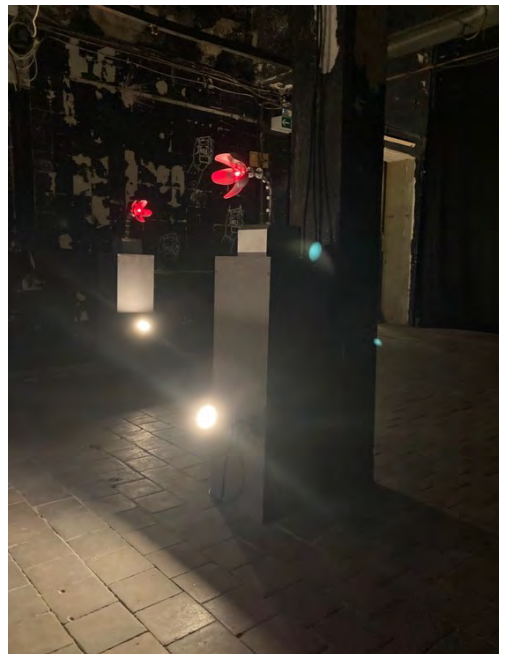


Fig. 1. The robotic flower are scattered randomly throughout the exhibition space. ©Ivan Iovine

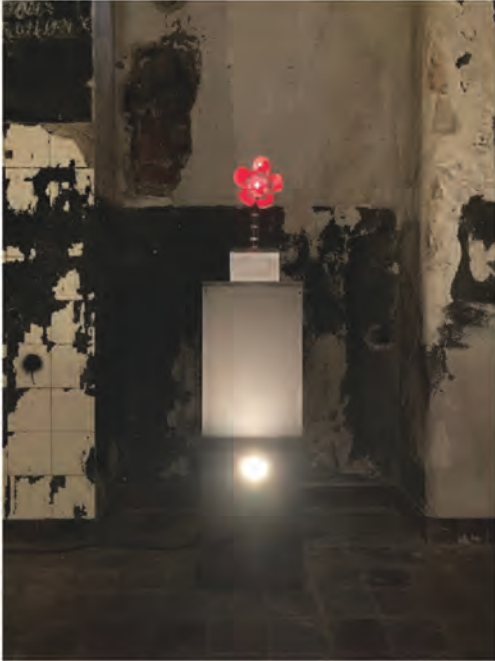


Fig. 2. A robotic flower placed on the pedestal. ©Ivan Iovine



Fig. 3. Audience interacts with a robotic flower. ©Ivan Iovine

Notes

<https://vimeo.com/543262974>

https://www.dropbox.com/s/gm1esai8zp1n7sc/netnature_prototype.mp4?dl=0

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Instantaneous Deformations of Camera and Video Images.

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Abstract

We show an app, called CaViDe, written in Processing [1,4], that enables the user to deform instantaneously the images of a camera or a video. Images of cameras or videos are normally enclosed in rectangles. CaViDe enables the user to deform this rectangle by adding a corner, deleting a corner or moving a corner. In this way we obtain a polygon. The content of the rectangle, hence the image itself, is also deformed such that it fits into

the obtained polygon. Remark that, when the image in the rectangle is changing during playing the video, the deformed image is also changing without any delay.

In <https://player.vimeo.com/video/845059906?h=415e7001c2> one can see an application of CaViDe.

1. Introduction

Software for deformation of images of photos is well known. However the deformation of images of cameras and videos is more complex, especially when this deformation is realised without any delay. Images of cameras or videos are normally enclosed in a rectangle. CaViDe, the app that we discuss, enables the user to deform this rectangle. In this way we obtain a polygon. The content of the rectangle, hence the image itself, is also deformed such that it fits into the obtained polygon. Remark that, when the image in the rectangle is changing during playing the video, the deformed image is also changing without any delay.

In Section 2 we describe how the rectangle that contains the image can be deformed into a polygon. In Section 3 we give necessary

conditions for the deformation of the image contained in the polygon. In Sections 4 - 6 we handle CaViDe. We describe the deformation of a polygon, the deformation of the content of a convex polygon and the deformation of the content of a non-convex polygon [2,3].

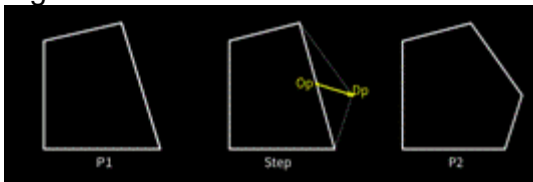
In <https://player.vimeo.com/video/845059906?h=415e7001c2> one can see an application of CaViDe.

2. The Deformation of a Polygon

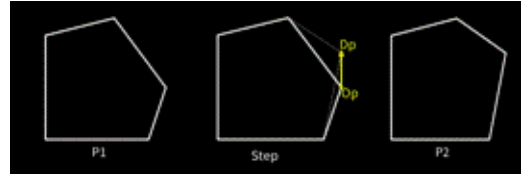
First we define a position (i,j) as a point on the screen whose horizontal coordinate is i and whose vertical coordinate is j [2,3]

We start the deformation with a rectangle. This rectangle is deformed by a series of steps, each deforms the polygon P1 into a new polygon P2. We also suppose that the number of corners of a polygon is bigger than three. There are three kinds of steps, S1, S2 and S3, each characterized by two positions on the screen: the original position O_p and the destination position D_p . The vector $\langle O_p, D_p \rangle$ defines the deformation direction :

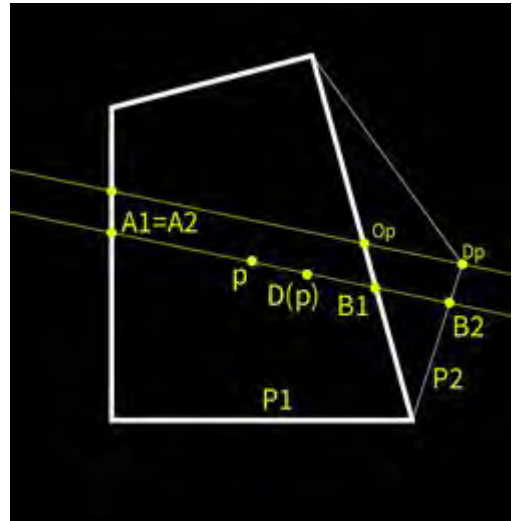
S1. Adding a new corner between two consecutive corners of P1, obtaining P2, Cfr. Figure 1 ; Figure 1



S2. Changing the position of a corner of P1, obtaining P2, Cfr. Figure 2. Figure 2



S3. Deleting a corner of P1, obtaining P2. Here the destination position D_p is defined by $|O_p, A| / |O_p, B| = |D_p, A| / |D_p, B|$, where $|p, q|$ denotes the distance between position p and position q, Cfr. Figure 3. Figure 3



3. Conditions for the Deformation of the Content of a Polygon

The set of positions contained in P1 (resp. P2) is called C1 (resp. C2). C1

has to be deformed into C_2 . This deformation is called D . So D is a function from C_1 to C_2 . D must be such that the deformation of the image in P_1 into the image in P_2 is elegant and natural. Clearly, D also has to satisfy a number of obvious and natural conditions.

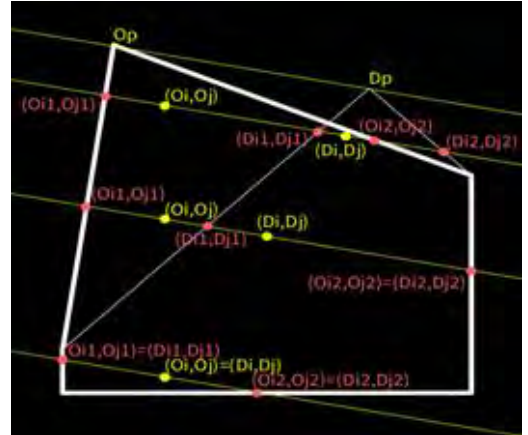
- Condition 1 : If $P_1 = P_2$ then D has to be the identity;
- Condition 2 : $D(O_p) = D_p$;
- Condition 3 : No information can be lost, ie. for every position p of C_1 $D(p)$ has to be a position of C_2 ;
- Condition 4 : For every position p_2 of C_2 there is a position p_1 of C_1 with $D(p_1) = p_2$;
- Condition 5 : All the positions of C_1 have to be deformed in the same direction, ie. the vectors $\langle p, D(p) \rangle$ must be in the same direction for every position p of C_1 ;
- Condition 6 : If position p is on a side of P_1 then $D(p)$ has to be on a corresponding side of P_2 ;
- Condition 7 : If p_1 and p_2 are close to each other then $D(p_1)$ and $D(p_2)$ have to be close too;
- Condition 8 : (Cfr. Figure 4) Consider a line that is parallel to the deformation direction and cuts P_1 in positions A_1 and B_1 and P_2 in positions A_2 and B_2 . If position p belongs to the line segment (A_1, B_1) then $D(p)$ belongs to the line segment (A_2, B_2) and $|A_1, p|/|A_1, B_1| = |A_2, D(p)|/|A_2, B_2|$.

For convex polygons conditions 1 - 8 can be satisfied as will be proved by CaViDe in Section 5.

For non-convex polygons all the

conditions cannot be satisfied together. It will be discussed in Section

Figure 4



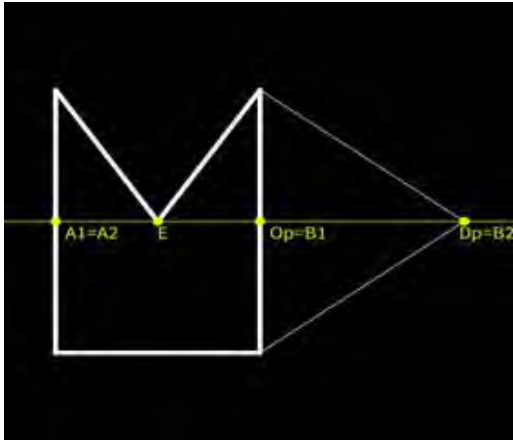
4. CaViDe: The Deformation of a Polygon
Recall Figures 1-3. We now show how the steps S1, S2 and S3 are implemented in CaViDe.

S1. The mouse is set of a side of P_1 , position O_p , resulting in a red dot, the mouse is left pushed and is moved to a new position, position D_p . When the mouse is released, D_p is the position of the new corner obtaining P_2 .

S2. The mouse is set to a corner of P_1 , position O_p , resulting in a green dot, the mouse is left pushed and it is moved to a new position D_p . When the mouse is released, D_p is the new position of the corner obtaining P_2 ;

S3. The mouse is set to a corner of P_1 , position O_p , resulting in a green dot, the mouse is right pushed. When to mouse is released the corner vanishes, obtaining P_2 .

5. CaViDe: The Deformation of the Content of a Convex Polygon
Figure 5



In this section we discuss how a deformation step for the content of a convex polygon is implemented in CaViDe. This implementation is mainly based on Condition

8. It is independent of the kind of the step (S1, S2 or S3) but only depends on the polygon P1, the polygon P2 and the deformation direction.

We illustrate this implementation in Figure 5 for step S2. Steps S1 and S3 are analogous, mutatis mutandis

We show 3 different pixel positions (O_i, O_j) of C1. For each of them we have a line parallel to the deformation direction. This line cuts the polygon P1 at position (O_{i1}, O_{j1}) and (O_{i2}, O_{j2}) and the polygon P2 in (D_{i1}, D_{j1}) and (D_{i2}, D_{j2}) .

By condition 8 we have

$$\frac{|(O_{i1}, O_{j1}), (O_i, O_j)| \cdot |(O_{i1}, O_{j1}), (O_{i2}, O_{j2})|}{|(D_{i1}, D_{j1}), (D_i, D_j)| \cdot |(D_{i1}, D_{j1}), (D_{i2}, D_{j2})|}$$

where $|(O_{i1}, O_{j1}), (O_i, O_j)|$ denotes the distance between (O_{i1}, O_{j1}) and (O_i, O_j) .

so

$$O_i = O_{i1} + (O_{i2} - O_{i1}) \cdot (D_i - D_{i1}) / (D_{i2} - D_{i1}) \quad (1)$$

$$O_j = O_{j1} + (O_{j2} - O_{j1}) \cdot (D_j - D_{j1}) / (D_{j2} - D_{j1}) \quad (2)$$

Let P be the polygon between two steps.

There is a function that gives for every position of P the corresponding position in the rectangle captured by the camera or video.

In order to represent the function above we use a two dimensional array called 'conversie' of positions. Let (i, j) be a position of P. $conversie[i][j]$ gives the corresponding position in the rectangle captured by the camera or video.

Initially $conversie[i][j] = (i, j)$. During a step $conversie$ is updated as follows:

$$conversie[D_i][D_j] := conversie[O_i][O_j]$$

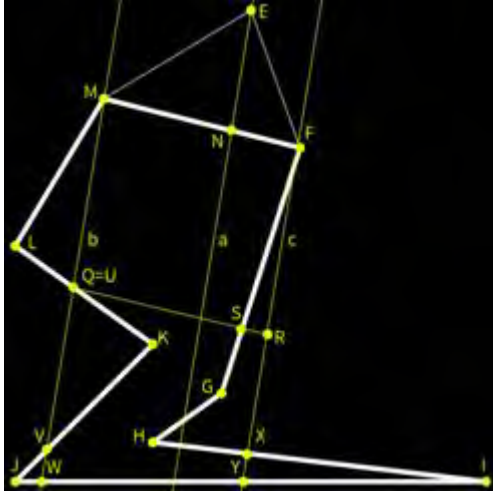
where D_i, D_j, O_i, O_j satisfy (1), (2).

So, between two steps, the picture captured can change and the picture shown also changes, but the array 'conversie' does not change. During the step the value of 'conversie' changes.

In the implementation of CaViDe the actual polygon is brown between two steps and the actual content changes accordingly to the picture captured. During a step the actual content is frozen and the polygon is red.

6. CaViDe : The

Deformation of the Content of a Non-convex Polygon
Figure 6



For non-convex polygons the conditions 1 - 8 cannot in general be satisfied. Indeed in Figure 6 $D(E)=E$, by Condition 6 and $D(E)=B1$ by Condition 8, which is a contradiction.

We propose to weaken Condition 8 in this way:
Condition 8a: There exists two convex polygons $P3$ and $P4$ (with content $C3$ and $C4$ respectively) such that

- $C3$ is a subset of $C1$ and $C4$ is a subset of $C2$;
- $D|C3$ obeys Conditions 1-8;
- $D|(C1-C3)$ is the identity. Clearly the deformation of the content of convex polygons, that we discussed in Section 5, also satisfies Conditions 1-7,8a.

We now give an implementation that satisfies Conditions 1-7,8a for non-convex polygons, Cfr Figure 7. We only

discuss Step S1. Steps S2 and S3 are analogous.

Consider the non-convex Polygon $P1 = (F,G,H,I,J,K,L,M)$ that is deformed to polygon $P2 = (F,G,H,I,J,K,L,M,E)$ by a step of kind S1.

We define consecutively:

- line a that contains Op and Dp (here N and E);
- line b that contains M and is parallel to a ;
- line c that contains F and is parallel to a ;
- T is the set of all corner points of $P1$ and all intersections of $P1$ with b or c , that are between b and c or on b or c .

Here $T = \{G,H,K,X,Y,Q,V,W\}$.

- Q the closest point of T to line segment (M,F) , with the

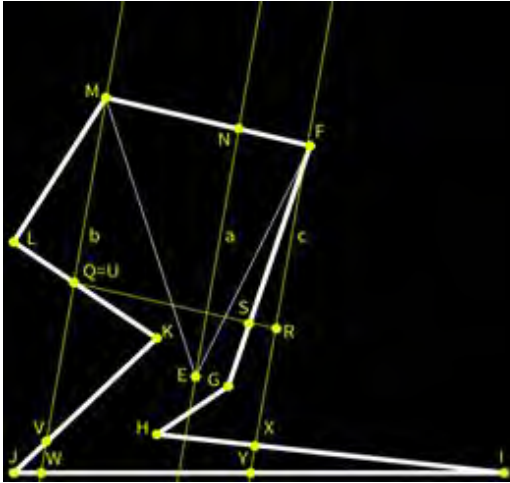
Figure 7 exception of the points of the line segment (M,F) ;

- line segment (Q,R) that is parallel to side (M,F) ;
- if line segments (F,G) and (Q,R) have an intersection then S is that intersection, else $S=R$;
- if line segments (M,L) and (Q,R) have an intersection then U is that intersection, else $U=Q$;
- $P3 = (F,S,U,M)$ and $P4 = (F,S,U,M,E)$;

This construction is almost always possible and satisfies Conditions 1-7,8a.

But, in one case, there is a problem, Cfr. Figure 8.

Figure 8



Here again we consider the non-convex Polygon $P1 = (F, G, H, I, J, K, L, M)$ that is deformed to polygon $P2 = (F, G, H, I, J, K, L, M, E)$ by a step of kind S1. But the result $P4 = (F, S, U, M, E)$ is not a polygon anymore. Such a deformation is excluded.

This problem could be avoided by replacing the line segment (Q,R) by a more complex series of line segments between Q and R.

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Reading Color: Type in and on Color

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Abstract

Historical literary works, from hand-written illuminated manuscripts to illustrated books, to desktop published pages, contain black letters on a white ground. Digital typesetting and printing technologies today offer limitless opportunities for information design with myriad dimensional configurations of letter forms in near infinite spectra of colour.

This fusion is absent in the study of typography and colour theory, where they are currently studied separately.

In typography books, examples show letters in alphabetical order in a variety of sizes, presented as words and paragraphs. Books on colour theory illustrate colour with shapes, colour wheels, and continuous bands. Each fall short of modelling the contemporary media land-

scape where the demands of readability, legibility, and screens meet and where typography and colour are intrinsically bound, inseparable, and synergistic.

My project merges them for a better, more cohesive study. It initiates a synthesized, inductive approach to bring together the scientific and historic disciplines of colour theory and visual perception with the discipline of typographic design.

The exercises developed by Josef Albers on the properties of colours in *Interaction of Color*, along with Johannes Itten's theories of *contrast of extension*, aka *contrast of proportion*, are the basis for understanding how simple and complex letter forms in colour-on-colour visually interact.

My hypothesis asserts that the matrices of letters and colour forms can, in fact, better elucidate both aspects when put into practice. It picks up where Albers and Itten's studies leave off by applying code to typography and imagery that reconfigures the visual information to mathematical proportional and quantitative analysis. Like recipes, each uses a set of rules and ingredients I've developed to create a series of generative designs that are then reassembled into visual works.

Introduction

My project is to research, produce and publish a book that addresses new, intensive possibilities in the relations between typography and colour. This is the next step in a research trajectory that I have worked on for several years, and the resulting text promises a better, more cohesive, and far-ranging approach to this essential topic in design, whether print or digital. The working title is *Reading Color: Type in and on Color*. This approach not only introduces new methodologies in type and colour relations it contributes to the generation of new knowledge formations in design and design-thinking.

The creative and persuasive fusion of typography and colour is almost totally absent in the pedagogical fields of typography design and colour theory, where they are studied and approached separately. Typography books use examples of letter forms in alphabetical order in various sizes, presented as words and paragraphs; in books on colour theory, the properties of colours are illustrated with shapes, diagrams, charts, wheels, and continuous bands. Each of these falls short of modeling the contemporary media landscape where the demands of readability, legibility, and viewing devices meet and where typography and colour are intrinsically bound, inseparable, and synergistic.

In 2008, I outlined an early stage of this project while studying at Transart Institute, Danube University, Krems, Austria for my MFA. In that work I posited a new pedagogy for typography and color theory that built upon the “hands-on”

exercises developed by Josef Albers in his book *Interaction of Color* (1963). Since its first iteration as a two-volume edition of original plates, text, and commentary in a slipcase, to the current paperback version, the *Interaction of Color* is a perennial and highly sought-after teaching aid for studying the properties of color and is used by art and design students around the world. [1] In February 2023 *Yale News* reporter Eric Gershon noted that “Josef Albers’s classic book on color relationships ranks among Yale University Press’ all-time bestsellers.” [2] It has sold millions of copies since its first printing and is now available as an interactive app. [3]

The purpose of my research is to prepare a manuscript that initiates a synthesized, inductive approach, bringing together the scientific and historic disciplines of colour theory and visual perception with the discipline of typographic design. The exercises in color properties that Albers developed in *Interaction of Color* with Johannes Itten’s *contrast of extension* theory, [4,5] also known as *contrast of proportion*, are the foundation for understanding how the simple and complex letter forms in colour-on-colour composition visually and psychologically interact. My hypothesis asserts that the matrices of letters and color forms can, in fact, better elucidate both aspects in practice.

Methodologies that facilitate the study of typography and color *in context* and *in situ* will enhance the practice of design, communications, art, and media, as well as being of inestimable benefit to pro-

professionals in these fields. For educators, infusing color theory into the study of typography has advantages for curricula and course development, addressing today's needs for efficiencies in student degree pathways. For today's graphic and information design student, learning about color with letter forms integrates their exploration and training to develop heightened visual acumen. Drawing on material and examples from design, art, aesthetics, anthropology, psychology, scientific and cultural studies, this project addresses and fulfills an urgent contemporary need.

The handbook's rationale includes the following: What would educators, professionals, and students alike, require to facilitate the study of type and colour together? The application of Albers's experimental colour studies and those of his Bauhaus mentor, Johannes Itten—whose *contrast of extension theory* employs area, size, and proportion to colour considerations—offer a starting point to the study of the visual gestalt of typography. [6] Both Josef Albers and Johannes Itten approached colour theory through colour perception with positive and negative forms, shapes, and pattern.

The handbook will be accessible, written for students of graphic design, artists, and educators, and will focus on colour as applied to message construction by mixing practical know-how and theory with digital and photographic examples in print, screen, and dimensional forms. Every example will be examined for its typeface, style, orientation, and alignment in and on colour. The handbook will be composed of examples of alphanumeric characters in many languages for a more holistic approach to a world-

wide audience. [7] This component is an homage to my students, especially those whose first language is not English. They are my inspiration, and they are now actively participating in the development of the handbook through their assignment submissions in my classes.

My research will take place at the Getty Research Institute in Los Angeles, CA and the Johannes Itten Foundation in Bern, Switzerland, where Itten's studies, art, and student work are held, to further develop my manuscript about theoretical and practical assignments.

Currently, I am developing exercises for classwork for testing in the coming year.

Impetus

My research topic is a hybrid in both content and context—part scientific, part design research, and part inspiration—where type and colour are bridged and evidenced in all media. It reflects my experiences as a Design Director with a global clientele in the areas of human rights, social justice, and arts and culture since 1986. The messaging and reporting of these agencies range from dense, in-depth coverage of human suffering, injustice, and other global and local social issues, such as migration, resource exploitation, economic injustice, disparities in health and wealth, sustainability, and more. [8] All this messaging requires an understanding of what colour means on a global level. The ever-expanding global platform which designers work in requires educators to train students beyond the properties of colour and appropriate font choices and increase awareness of the sensitivities of communicating through colour and text with the juxtaposition of images.

As a student, I took a course in which colour was explored using a box of colour-aid paper, an Exacto knife, white card stock, glue, and Josef Albers' book, *Interaction of Color*. The experience taught me how colour operates through positive and negative forms, shapes, and pattern. I have been a practitioner of design and an academic since the mid-1980s when graphic design became popular with students, elevated from its subclass status to the field of fine art. During this time, digital tools radically changed graphic and information design. Print became more complex, screen design emerged, and academia started cutting costs and combining majors. Colour theory, a fundamental and critical skill in art, was dropped from graphic design curricula. Graphic design majors then took 2-D courses whose exercises explored the basics of design — line, shape, pattern, and texture. Typography was another course.

In 2004, I set out to find a basic but comprehensive textbook for a class I was preparing in Media Design for communication majors. I considered the type books in my library by Robert Bringhurst, Walter Tracy, James Craig, Ellen Lupton, Rob Carter, and others. I searched through design books for chapters on colour and typography. An internet search for typography with “look inside” features revealed many new books on the subject — I could even find older editions of books as PDFs. But none were quite what would meet my or my students' needs.

In 2008, I outlined my hypothesis and wrote an outline for a handbook that explored typography and colour theory, which I then put aside. In my studio and in my teaching, I continued to see a need

for such a book in a global environment that was rapidly changing due to technological changes and innovations and the emerging varied and profuse media. In 2018, I revised the proposal, expanded it, and started submitting it to peer-reviewed conferences.

The outline for my handbook is based on my observations and experience working with and teaching typography and its history. Through that historical lens, my premise to integrate the study of type and colour is both obvious and logical. I believe there is the potential for this new field of inquiry to set a new standard in design education.

The study of graphic and information design is underpinned by the theories associated with the development of communication and language. Beginning with cave drawings, the through-line evidence shows how humans have employed the materials and technologies of their time to impact the design and evolution of written language. In 1455, Johannes Gutenberg's invention marked a milestone for written communication and its distribution with the mechanization of movable type and printing. Metal type was then upended by photo-graphic typesetting techniques around 1950. And a short time later, in 1985, desktop publishing with a personal computer enabled the placement of black type and simple textures to combine on screen and on paper. Many incremental changes to technologies in printers, computers, monitors, etc. gave way to today's digital typesetting technologies allowing for the application of colour to letters, words, layers, and backgrounds.

Of course, type in colour is not without historic precedent. Gutenberg's invention of letterpress printing with a movable-type

press produced Bibles with black and red inked letter forms. Other colours were hand-painted into the text (Fig. 1). Almost every print- and screen-based graphic found today can be composed in a similar manner. But today's digital technologies do, in fact, present challenges for the fields of typography and colour because each discipline falls short of modelling today's digital communication technologies. For instance, the examples in coursework and in books about typography typically use letter forms in varying degrees of sizes and contrast to demonstrate colours' influence on legibility (Fig. 2). In books on colour theory, the properties of colour are often demonstrated with pie-shaped diagrams, colour wheels, grids, and rainbow bands (Fig. 3). [9]

Digital technologies have fused together typography and colour to present myriad possibilities of type design, fonts, size, and layouts suspended in infinite colourways. There is even a scalable vector font



Fig. 1 (left): Gutenberg's Bible.

Fig. 2 (center): James Craig's book on *Designing with Type*; Cover of *Interaction of Color* by Josef Albers.

Fig. 3 (right): Johannes Itten's contrast of extension examples.

format called *Chromatic Type* that now embeds colour in typeface design. [10]

Appropriating Albers's book title, *Search versus Re-search*, [11] my current search and "research" sets out to find ways to

study type and colour together and create new knowledge that combines them. Testing this approach can best be measured within programs where type in and on colour are practiced.

When I ask students if they have taken a class in colour theory, very few raise their hands. Since 2021, I have introduced a section on colour theory in my classes using my original research, which I have taught each semester. The presentations I've given about my research launched my special topics syllabi development. Their clear interest and understanding of the thesis encouraged me to develop a seminar taught annually with 3 sections. The class is structured as follows:

- 5 weeks applying hands-on colour properties with *Interaction of Color* among other books;
- 5 weeks applying digital methods to colour to type experiments; and
- 5 weeks applying Processing [12], an algorithmic software app designed to employ code to create visualizations with colour and type.

I am continually tweaking my typography assignments to encourage a students' design thinking, analytical skills, and creativity — to make the indescribable describable.

In 2016, I presented "Cook the Recipe" at the 19th Generative Art Conference in Milan, Italy, where I presented my thesis and process for projects using algorithms when I introduce iterative and generative design principles and processes. [13]

These studies (Figs. 4–8) were produced since 2014 incorporating Itten's contrast of proportion theory and applying code to typography and imagery that reconfigures the visual information to mathematical proportional and quantitative

analysis. Like recipes, each uses ingredients along with a set of rules I have developed to create a series of generative designs that are then re-assembled into visual works.



Fig. 4: *how I spent my summer vacation*, 2023, giclée triptych of covers. *After Eden*, © Suzanne Anker (photo, A. Oppenheim); *Peace & Health*, © Community Health Center; *Thinking Twice* © Phyllis Crowley.

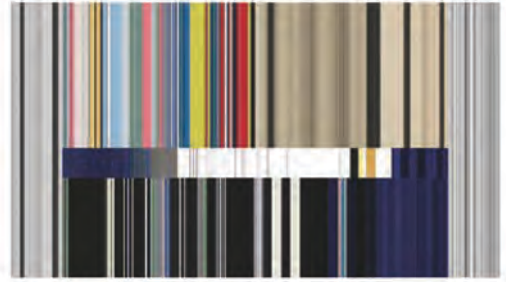


Fig. 5: *Nests*, 2020, giclée print of generative assemblage.

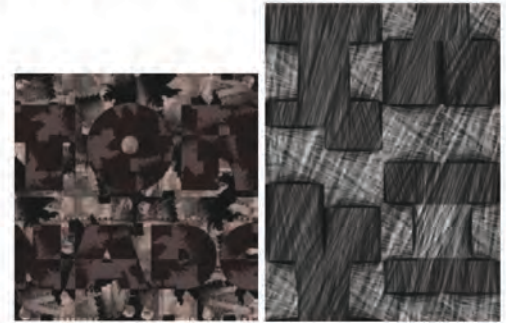


Fig. 6: *Tornado*, 2018, giclée print of generative assemblage.

Fig. 7: *Storm*, 2017, giclée print of generative assemblage.

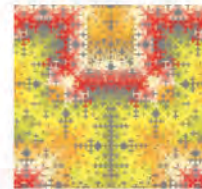


Fig. 8: *Fractor*, 2015, giclée print of generative assemblage. Detail.

Next Steps

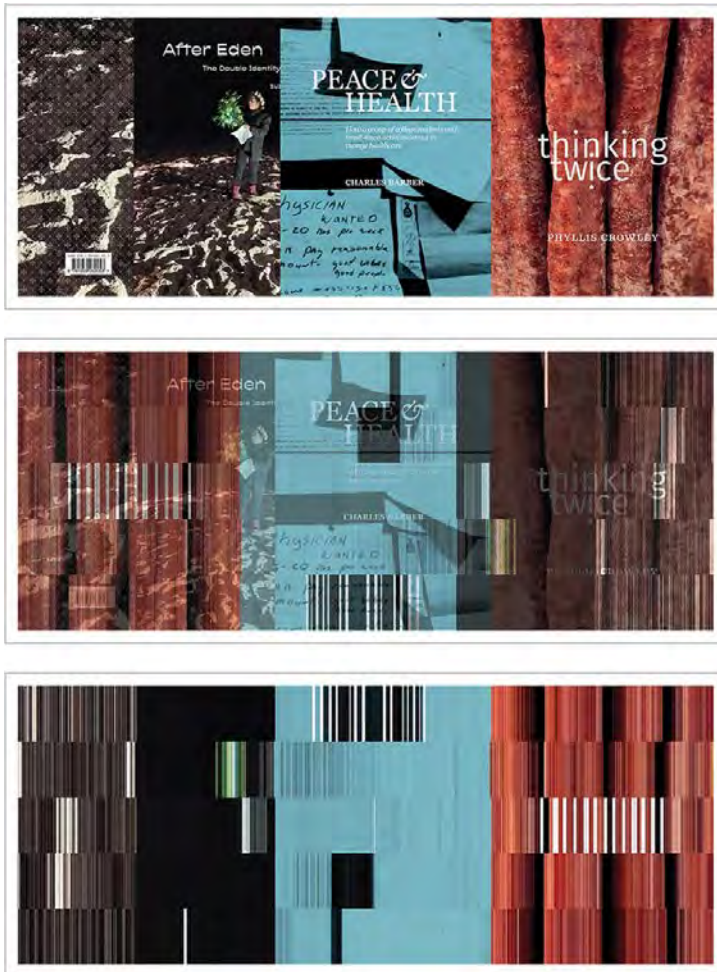
My project not only has a local pedagogical benefit, substantially informing my own students and courses, but is of benefit to the study of information design in general, as it informs a wide number of topics and approaches that are offered at in university curricula. In addition, there are implications for the broader field, in disciplines as varied as digital studies, art, art theory and criticism, design, and technical and historical cultural studies.

I would like the handbook to illuminate something that I find somewhat daunting to describe — the relational intricacies of type on the properties of colour. It will prepare users to visualize ways to place type and colour together, arming them with a critical competency necessary for today's design careers, in a field that increasingly demands it. The handbook will present a new way to learn visual perception with the study of colour and letter, bringing together the typically separate disciplines of colour theory and typography.

Design today shows strong evidence that technological advances are crucially impacting and evolving communication modes and norms again. The future is very colourful as well as being highly participatory. The ways in which we study graphic and information design must adapt to this paradigm shift.

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From left to right: *After Eden: The Double Identity of Carbon* Book Cover, © Suzanne Anker (photograph, Amy Oppenheim); *Peace & Health: How a group of college students and small-town activists set out to change healthcare* Book Cover, © Community Health Center (photograph, CHC Archives); *Thinking Twice* Book Cover, © Phyllis Crowley (photograph, Phyllis Crowley)

Keywords

Typography, Colour, Colour Theory, Code

Ghostdance: Evolving soundscapes in an Immersive Virtual Reality Experience

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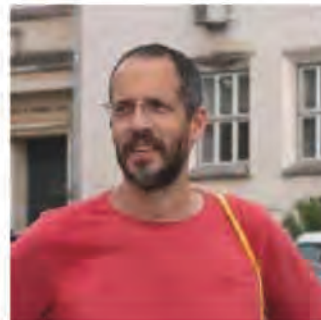
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Abstract

"Ghostdance" is an innovative ongoing work in progress of generative art that explores the captivating blend of visual, auditory and immersive experiences in the realm of virtual reality (VR). This project harnesses the potential of generative algorithms to create a dynamic soundscape that continually transforms, inviting participants on a journey through ever-changing abstract and visual soundscapes. In the immersive VR experience, participants are transported to an environment where

the auditory field evolves in real time, thanks to central generative algorithms that continually adapt and reshape the experience. Ghostdance's generative algorithms respond to the user's presence and action, detecting the properties of their movement, as defined in Laban terms. Each user embarks on a unique and unpredictable visual and auditory adventure, actively influencing the evolution of the environment through their movements and interactions in the virtual space.

Ghostdance takes its name from a research project on dance in virtual reality [9]. It challenges the traditional boundaries between art forms, blurring the line between composition and improvisation. As performers move through the VR environment, they not only witness the harmonious fusion of sound and images, but also actively co-create the evolving composition.

1. Introduction

Since its arrival in the 1980s, Virtual Reality (VR) technology has captured the imaginations of experimental artists who were keen to explore its potential to reshape perceptions of the human body, space and time. The nineties saw a surge of experimental use of VR in the field of performance art, exemplified by artists such as Eduardo Kac and the Blast Theory collective.

When performance incorporates virtual reality (VR) and dance, several questions arise. Aesthetics, the creative processes behind the performance, the physicality of the performances, the relation between the VR environment and the physical movements of the dancers, are only a few of the aspects the new technology calls into question.

Surprisingly, the world of dance has largely remained an uncharted area in the context of VR.

Although one can ponder the reasons behind this relative absence, traditional dance performances, known for their profound physical dialogues between performers, possess a unique depth and richness. VR headsets, often seen as a perceptual barrier, impose limits on the performer's sensory connection to their immediate environment. However, VR challenges us to see dance through a different lens, encouraging us to break free from convention and explore new frontiers.

Recent advances in VR technology have brought it into mainstream use, with such products as the Meta Quest, HoloLens and HTC Vive offering high-definition headsets and powerful VR-ready computers that deliver high-quality, immersive, real-time graphics. In addition, fast network technology now allows several users sharing the same virtual space, and cell phones have become platforms for VR experiences, thanks to 360-degree viewing techniques. Such developments have sparked renewed interest among artists and content creators, raising the question of whether VR has the potential to bring something truly new to dance itself.

With "Ghostdance", our aim is to delve into the fundamental nature of physical movement. What happens when one of the performing bodies in a duet is not physically present? As part of this project, we have conceived a multimedia performance in which a human dancer interacts with "ghostly" entities, and this article focuses on this effort. The public performance consists of three intertwined

components: a) a duet featuring a human dancer and an avatar that mimics the movements of an absent person; b) the transformation of the human dancer's body movement into the visualization of a hybrid body, continually being redefined as a swarm of virtual entities; and c) the sonification of the dancer's movements, adding an auditory dimension to the exploration of movement.

2. State of the art

Virtual Reality (VR) technology was initially designed to create artificial environments so convincing that human cognition interprets them as real. By VR we mean a computer-generated three-dimensional environment that a person can explore and interact with in a real or physical way, using special electronic devices such as a headset with internal screens or gloves equipped with sensors. This person enters this virtual space or lands in this environment and, while there, is able to manage objects or perform a series of actions. VR artificially creates sensory experiences that can include sight, hearing, touch and vision. Despite this filtering of the human essence to generate perceptual and emotional responses, it manages to immerse users in a simulated world relatively successfully. How does this perceptual trick affect performance?

Since its inception in 1980, VR has been a playground for innovative artists, each of whom has explored its creative potential in a variety of ways and with a variety of approaches (360° footage/computer-generated environments, many/one solo artists, different approaches to the role of the audience, etc.). For example, Brenda Laurel's film "Placeholder" uses VR to

manipulate the audience's perception, allowing viewers to feel the world through the eyes of various animals and birds, offering a very unique sensory encounter [16]. VR has also been used for socio-political commentary, such as "Desert Rain" by the British collective Blast Theory, which looks at the virtualization of reality, particularly in the context of the disinterested and "playful" nature of modern warfare [13].

In recent years, VR technology has become more accessible to a wider consumer base, giving rise to numerous creative initiatives, including in the field of dance. One example is the Dutch Opera's VR ballet "Nightfall", a 360-degree experience using stereoscopic cameras and quadraphonic audio [7]. EU-funded research projects such as WhoLoDancE [22], Moving Digits [18] and BlackBox [3] have also contributed to this growing visibility and interest. Pieces such as "Giselle VR" [20], "Stuck in the Middle" and "Man A" [8] blur the boundaries between spectators and performers, actively involving the audience in the show. Google Labs teamed up with the Martha Graham dance company to explore motion capture and environments created with TiltBrush (which allows volumetric drawings to be edited) [24]. One of the captivating aspects of VR is the way it defies the constraints of the traditional space-time of the stage. In "VR_I", Gilles Jobin challenges the conventional scenography by transforming the virtual actors into giants or tiny elements on the virtual stage, reformulating the traditional concept of spatiality [12]. "Dust", a collaboration between Andrej Boleslavský, Mária Júdová and choreographer Patricia Okenwa,

immerses the audience in the presence of dancers, allowing them to transform into floating dust particles that interact with the performers [2].

The combination of VR, 3D and artificial intelligence makes it possible to transform the perception of space and objects in the virtual world, providing them with dynamism and some level of intelligence. Works such as "Virtual Reality on 5 Dollars a Day" [15] and "Barcode Hotel" display dynamic interactions between objects, the audience and the performers [11]. In "Boidance", Caporal et al. allowed the dancer to dive into a dynamic landscape and interact with a swarm of graphical elements [4].

Although there have been numerous experiments in the field of VR and dance, there is still a relative scarcity of development in the field of VR and sound in the context of VR dance performances (as illustrated in the overviews of the field, for example in Sophie Smith [21]).

3. Description

Three duets were choreographed by Cecília de Lima, with the participation of dancers Miguel Santos, Ester Gonçalves and Daniel Marchão. These duets were the subject of exhaustive rehearsals, with countless repetitions to perfect their execution. After these rehearsals, we used motion capture techniques to record the precise movements of each dancer.

Using a wearable motion capture device, specifically a suit equipped with inertial sensors from XSens Awinda [23], we obtained a digitized representation of a dancer, capturing their movements with detailed information about positions and

orientations at each moment or frame. The movements were converted into a comprehensive set of 17 reference points, discerning the exact positions and orientations of various body parts, including the head, spine, limbs, arms and legs, within 3D space in time. This data is structured hierarchically, mimicking the kinematics of the body within a skeletal structure. This information was then associated with a visual representation, which was eventually mapped onto 3D avatars (Fig.1).

These dancing avatars were then used to create six different 3D scenes, each with a single digitized dancer to perform the choreographed dances.

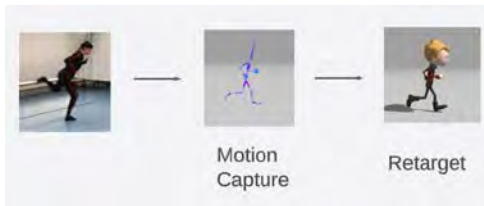


Fig. 1. Motion capture allows us to retarget the movement from a human to a virtual character.

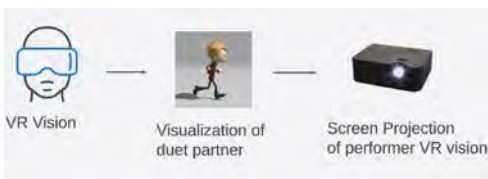


Fig. 2. The audience witnesses the performer's point of view.

For the live performance, we invite the dancers to put on VR headsets and perform the choreographed dance. Through the VR headsets, they can see

the duet pair as a 3D representation, replicating the movements of the missing duet partner.

In the immersive VR environment, the human dancer is presented with the other half of the duet, visually present but tactilely absent. This unique perspective allows them to interact with a virtual representation of their partner.

This visual experience of the performer is then shared with the audience via a projection screen, ensuring that the audience can also witness this fusion of technology and dance in action (Fig. 2).

3.1 The body swarm

In Ghostdance we investigate the ghostly nature of the virtual representation of the dancers, but some authors such as Steve Dixon dispute this idea of the immaterial body in the virtual environment. "When the body is transformed... in digital environments, it is not an actual transformation of the body, but the pixelated composition of its recorded or computer-generated image" [6, p.212]. In this work, we aim precisely at the ontological potential offered by this "pixelated composition", or as Cisneros puts it: "Avatars offer the user a variety of choices that do not exist with the living body ... expanding the conventional ways of doing dance." [5, p.17]

This fact is highlighted in the second part of the work. The second element of the show revolves around the visual representation on a second screen, capturing and transforming the movements of the human dancer physically on the stage. To bring this visual element to life, we used a swarm of geometric figures to represent the dancer.

Swarm Behavior is an algorithmic technique that allows us to emulate the behaviors observed in nature, such as the grouping patterns of fish, insects, and birds. In this virtual space, a swarm made up of graphic elements reacts to the artist's movements and gestures throughout his performance.

The swarm's behavior emerges from the interactions of the individual elements that make it up. In 1987, Reynolds introduced "Boids", an algorithm designed to simulate biological swarms [19]. This concept is based on three fundamental rules:

1. Separation rule: Avoid clustering and collisions with the closest members.
2. Alignment rule: Move in the direction of the group's average heading.
3. Cohesion: Converge towards the center of mass (average position of the group).

The movements of the dancer's body directly influence the behavior of the swarm. Each of the 17 points obtained from the motion capture process, which defines the dancer's body, corresponds to an element of the swarm. Consequently, the postures, rotations, accelerations and gestures of the performer on stage have a continuous impact on the actions of the swarm, which strives to maintain balance.

In the absence of external influences, the swarms tend to reach a state of near equilibrium, producing repetitive but subtly varied patterns. However, when the performer enters this virtual environment, her actions disturb this

balance, inciting dynamic responses from the swarm's elements.

As a result, the visual landscape is dynamically transformed, guided by the self-organized behaviour of the swarm elements, which synchronize their movements with those of the performer. This symbiotic interaction results in a distinct and constantly evolving dance collaboration between the human dancer and the virtual swarm (Fig. 3).

3.2 Movement analysis

In addition, we use machine learning techniques to decode the dancer's movements using Laban Movement Analysis (LMA).

Contemporary dance encompasses a wide range of movements, covering not only traditional dance steps, but also gestures from everyday life, sport and even animal behavior. Analyzing such diverse movement possibilities is a formidable challenge, a field initiated by Rudolf Laban and perfected by Irmgard Bartenieff [1][10].

The structure of Laban's Movement Analysis consists of four key components: Body, Space, Effort and Form, which intertwine to create phrases and relationships. The Effort component, in particular, comprises four critical factors: Weight (light or heavy), Spatial relationship (direct or indirect movement), Time (sustained or sudden), and Flow (free or bound) [17].

The combination of these factors in space, time and weight leads to what Laban calls the "action impulse", which encompasses eight fundamental actions: Punch, Cut, Dab, Flick, Press, Twist, Slide and Float. These eight basic actions serve as the basis for our

Artificial Intelligence training through Machine Learning.

This interpretation of movement according to Laban influences the variable weights of the parameters that govern the rules that define the swarm's behaviour. As the algorithm translates the movement into LMA, this interpretation adjusts the parameter weights for the attraction, separation and orientation rules that shape the swarm's behaviour. Since the three simultaneous rules of interaction that guide the swarm's behaviour have specific weights, influenced by Laban's characterisation:

Direct to indirect movement affects the Alignment weight. •
Heaviness to lightness influences the Separation weight.

Sudden to sustained movement impacts the Cohesion weight.

Consequently, the swarm is shaped mainly by the dancer's movements, with each point recorded by the motion capture device being considered part of the group of virtual boids. It is also influenced by the Laban interpretation of the movement performed (Fig.3).

The audience experiences this fusion of human and machine performance through two large-screen video projections. In one of them, the dancer's point of view is seen as he immerses himself in the virtual world. In the second projection, the entire scene unfolds, with dynamic camera angles and manipulation of the swarm's parameters, including behaviours, colours, shapes, and sounds. This thought-provoking performance leads viewers to consider whether they are watching a dancer or a live swarm.

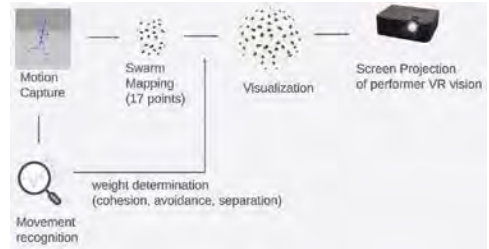


Fig. 3. The body of the performer is visualized as a swarm with 17 reference points of his body mapped as members of a larger group.

3.3 Immersive Audio

The third element that contributes to the audiovisual experience of the show is immersive audio. Unlike conventional sound generated by modulating sine waves in the Fourier tradition, the auditory component of this show is a mass of sound - a sonic cloud, so to speak. It can best be described as a real-time composition in which sound is transformed into a granular texture. This process begins with an existing piece of music (in this case, the 1981 song "Ghosts" by Japan), which is broken down into small fragments, each lasting just a few milliseconds.

Starting with the original sound file of the original song, this is read into a buffer. Next, a random segment of the sound file is chosen for granulation. Once this reference area has been defined, the whole process is confined to its boundaries. These fragments are further divided into 40 small segments, each lasting 10 milliseconds, called "grains", which are then assigned to the dynamic elements of a swarm, allowing each grain to be positioned in the stereo field. This link between the granular sounds and the swarm particles results in a dynamic and constantly evolving audio texture,

moulded by the spatial arrangement of the swarm elements. To manipulate the sound properties of these individual grains, a FAUST plugin integrated into the Unity3D platform is used. FAUST, which stands for Functional Audio Stream, is a versatile programming language designed for sound synthesis and audio processing. It provides a wide range of capabilities in audio and music production, including sound synthesis, audio effects and signal processing. This versatility allows for precise control of every grain.

The interpreter's movements are analysed using Laban's classification module, which provides data on its direction, weight and speed. These factors influence the movement of the grain pointer through the selected region. The weight of the movement determines the transverse speed of the grains. A slower movement leads to a slower movement of the reading pointer and vice versa for a light movement.

During moments of immobility when no movement is detected, the pointer remains fixed at a specific point, causing the sound grain to repeat continuously.

The volumetric shape of the swarm, defined by the area of the bounding box, alters the length and amplitude of the grain envelope. Depending on their position within the swarm, the sound grains can have different audio envelopes. These envelopes can take the form of simple curves, rectangles, or slopes on both sides at an angle of 45 degrees. Closer to the centre of the swarm, the envelope looks rectangular. In a secondary radius area, the sides of the envelope become slanted at an angle

of 45 degrees, and, beyond these two areas, the original curve is maintained.

Sudden movements affect the transversal direction. When the pointer reaches the end of the region selection, it typically jumps back to the opposite end. However, when two sudden movements are detected in sequence, the transversal direction shifts. The pointer may change its direction depending on the current orientation.

The overall directness of movement determines the grain rate, or how quickly grains are produced. If a grain is produced before the previous grain's envelope ends, they overlap and accumulate. The time between the start of one grain and the start of the next is known as the grain onset, measured in grains per second.

This system generates a rich and ever-evolving audio environment, creating a dynamic soundscape that enhances the immersive experience of the performance.

4 Discussion

We are exploring the relationship between dance in simultaneous physical and virtual environments and this work raises questions about the crossroads of technology and art, the nature of sound manipulation, the role of movement in audio composition and the impact of such innovative techniques on the audience's sensory and artistic experience.

Granular synthesis creates a complex and textured soundscape. It introduces numerous tiny grains of sound, each with its own unique characteristics, resulting in a rich and intricate aural environment.

The texture in the Ghostdance performance is dynamic and constantly evolving, changing in real time based on the artist's movements and interactions with the swarm's behaviour. The positioning of the sound grains in the stereo field is influenced by the behaviour of the swarm and the actions of the performer. The position and movement of the swarm elements are closely linked to the spatial positioning of the sound grains. As the swarm elements move in virtual space, they trigger the panning and spatial distribution of the sound grains. This synchronisation creates a spatially immersive audio experience that aligns with the visual elements. This spatial dimension adds depth and dimension to the listening experience, creating a sense of movement and space that complements the visual aspects of the performance.

Using a versatile programming language like FAUST provides a high degree of precision and control over the individual grains of the sound. FAUST's versatility extends to real-time adaptation. The composition adjusts in real time to respond to the performer's movements or the swarm's behaviour. This adaptability ensures that the audio remains strongly integrated into the performance, increasing the overall artistic impact.

The performer's movements, as analysed by the Laban classification module, directly affect the behaviour of the sound grains. The direction, weight and speed of the movements are translated into changes in the transverse rate of the grains, the onset of the grains and the parameters of the grain envelope. This dynamic response creates an interactive, real-time link between the performer's

physical actions and the audio component.

Changes in the audio texture correspond to actions or behaviours of the visual swarm. This synchronisation of the sound environment and the visual representation of the swarm increases the cohesion between the auditory and visual aspects, creating a multi-sensory experience for the audience. For example, when the elements of the swarm change direction or speed, the sound can also adapt in real time. This feedback loop reinforces the visual-auditory connection, making the show seem more integrated and interactive. As the swarm moves, the sound can shift in stereo space, creating a 3D auditory experience that complements the visual depth of the performance. The dynamic and evolving nature creates a sense of unity between the visual, auditory, and kinaesthetic aspects of the show, an interaction that keeps the show fresh and engaging. The audience becomes aware of the connection between the performer's actions and the evolving soundscapes, encouraging audience members to actively observe and interpret this relationship. The unpredictability and constant evolution of the two elements adds a sense of liveliness and surprise.

5 Conclusions

We presented "GhostDance", a work-in-progress immersive performance driven by cutting-edge technology. This is a work in progress that explores new artistic possibilities and raises profound questions relating to the nature of digital art. It does so by delving into the interaction between the physical and digital realms. The dancers perform

physically while simultaneously engaging with virtual avatars of their duet partners in a virtual reality environment.

The audience witnesses the interaction between the physical and digital elements. This immersion is further enriched by the audio environment, which includes sound granulation and real-time manipulation. The audience, in the midst of a constantly evolving auditory landscape, observes the live, flesh-and-blood dancer on stage, clumsily interacting with the void, perceiving through the screens an overlapping of realities that interact with digital entities. This coexistence between the tangible and the virtual, amplified using swarm behaviour and algorithmic elements, introduces an unpredictable and dynamic dimension to the visual performance. This dynamic creates a symbiotic link between the human dancer and the digital swarm, thus prompting reflections on the boundaries between reality and virtuality.

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Sonification as a Composition Technique and Means of Artistic Expression

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Dr. Maria Kallionpää

Abstract

Despite of the ever-expanding variety of technological means accessible to composers, performers, orchestrators, music producers, and music pedagogues of our time, the essence of music composing has mostly remained the same for centuries: the key question is, how to form an artistically innovative core idea of a musical piece and to find the most ideal instruments for it? This paper discusses composers' explorations on establishing

their individual voices, as well as finding and selecting the tools and techniques that would best serve their artistic goals in today's complex and pluralistic network of aesthetics. To facilitate this, various software solutions have surfaced to enable a wider palette of sounds to be used as musical "raw material". Rather than using pre-composed music based on the rhythms and pitches organised by the composer, we will focus on how to translate other kinds of data into "notes", or more largely "sound events", and how to use it in an artistically meaningful manner, resulting into musical compositions in their own right. To do this, we will present compositional case studies based on sonification, realised by various methods and technologies. These include, for example, the application of the software "Orchidea" [9] in artistic practice. We will showcase Maria Kallionpää's environmentally themed work "El Canto del Mar Infinito" (2020) and her composition "The Reef" (2023), which uses sounds recorded from a coral reef. Furthermore, we will discuss how Olga

Neuwirth incorporated seismic data from the Sumatran area into her work "Kloing!" which was influenced by the 2004 tsunami disaster.

Sonification techniques do not produce musically utilisable aesthetics per se. This raises the question for the creative domains in which composers engage when involving sonification techniques in their process. These domains include:

- the choice of the data or subject being sonified,
- the preprocessing of this data (e.g. the quantization of a series of floating-point values to integer pitch values and metronomic timings),
- a specifically musical design of the sonification method, i.e. the transformation or mapping of the data to sound structures, and
- a purposeful work with the parameters of the sonification.

The TouchNoise system (2014-2017), developed by Axel Berndt, Nadia Al-Kassab, and Raimund Dachselt, explored a further approach. It is a sonification of a particle simulation. The compositional domain here is primarily spanned by a palette of interaction techniques with a particles field, including direct manipulations of the particle distribution as well as flow field and flocking algorithms. We will discuss the aesthetics that this approach evokes.

Introduction

Since the beginning of music history, composers have been ambitious in composing music that would bring out the highest abilities of their performers. Simultaneously, instrument developers have been anxious to respond to their call

by designing tools that would enable increasingly technically elaborated musical performances [1]. The evolution of computer-based systems to expand the contemporary composers' technical "toolkit" can be seen as a continuation of the same pursuit. As rigid forms of classical music (such as the sonata form and specific expectations of harmonic progressions in its context) lose on relevance in the creative process, the prospects of experimentation on musical forms seem endless. This paper focuses on the potential outlook of these liberated forms towards new avenues for sonification as a composition tool.

The modern-day pluralistic music aesthetics and technologies allow for a wider scope of consideration on what to regard as musical material. However, the key question remains: how to form an artistically innovative core idea of a musical composition and its instrumentation? The case-studies discussed below utilise computer-generated, non-musical data as a form of "raw material" only. Creating notated or orchestrated materials using computer-based analysis doesn't absolve the composer of artistic responsibility or authorship. Instead, the composer oversees organising their work into an artistically meaningful unity.

Indeed, drawing inspiration from non-musical data material is not a novel approach per se. A plethora of historical composers have attempted to replicate, for example, patterns that are exhibited in nature. Composers during the Romanticism and Impressionism eras often imitated water patterns and movements in their music. For example, Franz Liszt, Maurice Ravel, and Claude Debussy composed many pieces inspired by water, fountains, and the sea. Early modern composers, including Oliver

Messiaen, were similarly inspired by nature, such as birdsong (c.f. "Catalogue d'oiseaux", 1956-1958). The composer was also known for attempting to notate the noises made by birds.

Previously, pen and paper were used for analysis and notation, but modern signal processing methods give rise to much higher data resolution that sometimes remain elusive to the attentional bandwidth of human cognition. With the case studies below, we'd like to demonstrate the complexities of translating overwhelming amounts of information into easily understandable stimuli in artistic contexts.

Sonification as Inspiration: "Kloing" by Olga Neuwirth

Like their predecessors, contemporary composers draw inspiration from nature, too. The rigorous ways of measuring data and the means of translating it into other forms of information provide the artists of today rich possibilities of using aspects of natural phenomena as part of their selection of techniques and expressive vocabulary. For example, the novelty of Olga Neuwirth's work "Kloing!" (2008) for computer controlled piano, live-video, and pianist lies in its original use of sonification as part its compositional structure. The music is partly based on the seismic data collected in the Sumatran area during the tsunami disaster of 2004. Using mathematical modeling, Peter Plessas transformed this data into audible form, including rhythms and pitches. Rather than being a subtle side element of the musical material, the seismic outbursts are present both audibly and visibly when experiencing the work in a concert setting. The rapid computer-generated movements of the piano keys give an impression of natural forces beyond human control. Specifically composed for

a Bösendorfer CEUS grand piano featuring a dynamic resolution of 1000 velocity layers per key, the human pianist plays with and against an overwhelming machine (the musical part of which is based on the sonified data), that slowly takes over the part of the human performer.

Composition Case Studies: The Reef (2023) and El Canto del Mar Infinito (2020) by Maria Kallionpää

Musical creation should prioritize a strong core idea and suitable instruments, rather than any technical means. In this vein, data sonification only partially informed the notated material to "The Reef" and "El Canto del Mar Infinito". Both pieces share a similar theme (protecting the ocean environments), but differ significantly in their approach and instrumentation. While "El Canto del Mar Infinito" is a large-scale chamber music work for seven performers and a conductor, "The Reef" is an interdisciplinary duo for two pianos and a live video artwork created by the visual artist Andre Veloux.

"El Canto del Mar Infinito" was created with the theme of "Nature" in mind for the 2020 Tampere Biennale festival. Kallionpää had previously written sea-themed works, making it a good fit to that years' thematic direction of the commissioning music festival. The question was how to tackle the topic in a fresh way, given that the Impressionist and Romantic era composers have already covered it thoroughly. Sonification of underwater sounds seemed like an organic solution to this problem, as part of the creation of the work would be handed over to the ocean itself.

To start composing, suitable underwater sounds were sought out. An ideal sample

would not have too many overlapping sound signals, as that could make the notated result of the computer-based analysis garbled. Conversely, too limited sound signals would not offer enough characteristic features for the sonic material to be divided between seven performers. To ensure the composer's control over their material (and by this to keep the overall composition texturally and aesthetically coherent), only a selected number of distinctive samples were selected, and then analysed by the computer-assisted orchestration tool Orchidea [9]. The goal of the analysis was to generate notated pitch material that the composer would then interpret into music. The resulting computer-generated notated excerpts were not regarded as music in their own right, nor were the listeners expected to associate them to the concrete sounds originally used. The intention was to put together a musical composition with a dramatic arch and narrative, which called for further compositional work. To ensure continuity, the formulated motifs were elaborated into a complete musical texture, while expanding or tightening the time values of the formed pitch material, and structuring the timing and proportions of the dramatic events.

At the beginning of the composition project "The Reef", a similar challenge was faced to that of "El Canto del Mar Infinito". However, the selection process of the original sounds, and their transformation into rhythms and pitches followed a different rationale. Instead of using multiple short sound clips, "The Reef" only used one big sample from Thailand's Mu Koh Lanta National Marine Park. Being somewhat limited in its spectral composition, this sample consisted of a swimmer proceeding towards a coral reef. Furthermore, the

sample's procedural structure would lend itself as the dramatic arch of the composition. Upon finishing the composition process, a MIDI rendition served as reference for the video artwork created by the visual artist Andre Veloux. Its abstract visual surfaces follow the music in a detailed manner: on top of serving as a structure of the musical composition, the timing of the original sound recording also informed the structure of the live visuals.

Like "El Canto del Mar Infinito", also "The Reef" required a lot of processing of the computer-generated notated material. Although the software helped to translate the natural sounds into a MusicXML file consisting of notated pitches and rhythms, in its original state, the results seemed to unstructured and entropic for meaningful sonic renditions. As with the human mind, a composition necessitates an organic entity with internal rules and organised timing. These musical events and their proportions cannot simply be drawn from the raw recording of a sonic environment consisting of seemingly random signals. It is the task of the human composer to gather and organise the material by empathically communicate to audiences a coherent and meaningful representation of said data points.

Data-driven vs. musically satisfying

As demonstrated by the examples above, deriving musical structures from extra-musical sources is a well-known compositional concept. It can be observed early on, for instance, in program music. These structures, however, are mostly based on the composers' intuition and abilities to rather freely translate an observation into musical aesthetics and gestures. With the primary aim of a musically satisfying result the composers

even to the point where listeners will hardly recognize the link anymore.

Sonification, by contrast, being subject to its purpose of communicating information about the data it is fed, seems all too restricting or “naturalistic” for use in artistic contexts – at first glance. According to Kramer et al. „sonification is the transformation of data relations into perceived relations in an acoustic signal for the purposes of facilitating communication or interpretation. “ [2] Sonification techniques do not necessarily (have to) produce musically utilizable aesthetics.

Nonetheless, composers seem to be attracted by sonification methods and started adopting them in their creative work as soon as the technology became available. In fact, sonification methods offer a range of domains to interact with that are not only compositionally utilizable but open fresh approaches to the creation of musical structures. The following list is intended less as a conclusive inventory and more as creative food for thought. This is contextualized with the question for artistic freedom between the two poles of the data-driven, pragmatic nature of sonifications on one side and the aim for musically satisfactory results on the other.

Probably the most obvious creative domain in which composers engage is the *choice of the data or subject* being sonified. Barrass and Vickers [3] report of several artistic works that involve a deliberate selection process of data that features inherent aesthetic qualities and translates well to musically satisfying results.

While the selection of aesthetically interesting data is already a clear decision against an “uncensored” objectivity of

be of untouched nature. Just as a photographer arranges his/her motif, the input data of a sonification can be deliberately *arranged*. In the case of real-time sonification the composer might even *interact in the input domain*. The input domain effectively becomes a kind of user interface to the sonification, which then serves as a synthesizer. Input domain and sonification combine to create a musical instrument and make the composer a performer at the same time.

An example for this is the TouchNoise system by Berndt et al. [4]. It is a sonification of a particle simulation. Each of up to several hundred particles is sonified by a sine wave. Particles move on a 2d plane with the vertical axis being mapped to the sine wave’s frequency and the horizontal axis being mapped to its position in the stereo panorama. The particles’ default behaviour is Brownian motion. The creative domain of TouchNoise is spanned primarily by a palette of multitouch interaction techniques with the particle field, including direct manipulations of the particle distribution as well as flow field and flocking algorithms that the user applies to the field in order to exert an influence on the particles’ motion characteristics, see figure 1. Consequently, the sound aesthetics of TouchNoise are defined by the particle dynamics, i.e. the distribution of the particles on the 2d (frequency and stereo panning) plane and how it evolves according to the movement speed and influences on the direction.



Figure 1: The TouchNoise system sonifies a particle system. Particle motion is influenced by multitouch interaction.

The input data of a sonification can be further conditioned before it is mapped to sound. Such *preprocessing* can make the data more music compliant, e.g. by quantization of floating point values to integer values, transposition of the values into musical pitch ranges, or sampling of (quasi-)continuous data to metronomic timings. Preprocessing can involve information loss. Thus, it is important to make sure that this loss does not affect the data properties that are meant to form the basis of the musical structure.

If the data does not sufficiently establish a musical structure it may also be defined by the composer. Spondike [5] describes that he first collected sonifications, took away those that were musically unsatisfactory and arranged the remaining ones in a *collage*-like fashion.

A core challenge of sonification is the *mapping*, i.e. to define which data properties are to be sonified by which sound properties. Two major conceptual frameworks to develop such mappings are Parameter Mapping Sonification and Model-Based Sonification. Both allow a specifically musical design. Most software tools for sonification can, thus, be

and mapping strategies, thereby, becoming compositional tools. An example for such a creative tool is SUM [6] which Adhitya and Kuuskankare use to transform images to music. In [7] the authors demonstrate SUM sonifying so-called “visual music” paintings by Kandinsky and Mondrian and further use it to “recompose” music from a graphical score of Ligeti’s *Artikulation* by Rainer Wehinger. Sonification has the mapping problem in common with the development of NIMEs (New Interfaces for Musical Expression) and computer music in general [8]. In fact, input data can also be interpreted as gestural data from a musical performance. Hence, it is worth seeking for inspiration also from mappings found in the NIME field.

Once a mapping is found, the parameters of the sonification are set. But they do not have to remain static. The composer is free to *modulate the parameters* over the course of a musical piece, thus, adding to the expressive gesture of the input data a second expressive layer. This layer might, e.g., represent a personal statement. It might be used to emphasize certain aspects or even act in a contrapuntal fashion. But it should also be clear that this method will obscure the link between input data and sounding result. It will hardly serve an objective information transmission any longer.

To move even further away from a pragmatic concept of sonification, the input data can even act as *seed for more complex generative processes*. These will likely involve substantial transformations of the material. The sound output will carry the data-inherent information in an encrypted fashion. With this approach, the input data are rather to be seen as a first

expanded into an idiosyncratic musical work.

Towards a Psycho-Aesthetic Design Paradigm of Agency in the Arts

This paper has only but touched on the difficulties arising in preparing ‘machine data’ for human perception, that is, aesthetic experience. Indeed, the original meaning of the term *aísthēsis* (ancient greek αἴσθησις) refers to the human condition of perception by intellect and the senses, rather than a particular artistic or romantic idea of experience [10]. It is thus even more remarkable that the original meaning finds its return within its respective academic quarters. The plethora of data, as presented by the ‘machine’ or its recordings, reminds us of Plato’s allegory of the cave, where not only the question of constructivism but also the inconceivability of the sheer number of perceptual stimuli of physical reality is being raised. By nature, humans will remain within the confines of the cave and experience reality as shadows reflected onto its walls. In a similar vein, composers face the challenge of interpreting the ‘recording’ (i.e. *linear* abstractions of reality, such as, but not restricted to, audio or even notation), that is, a comprehensive artifact limited only by its linear depth and frequency of data points, for an audience that utilize processing mechanisms that are all but linear. Thus, while musicians have always been confronted with the daunting task of translating meaning for audiences, it is in this day and age that they find themselves in the role of a cognitive-affective interpreter more than ever before. The composer applies implicit and explicit rules of stimuli organization to match

artifact presents it. This involves the selection, processing, but also the functional integration and representation of the artifact as part of the composition.

Looking at the artifact, as previously exemplified by audio samples, we recognize additional challenges for modern composers. Were composers of romanticism impressionistically inspired by their subjective representations of perceptual memory, so are composers of the present concerned with the detailed presentation of materialistic features of the artifact (i.e. an audio recording). However, rather than relying onto a subjective component of the materialistic percept of the artifact, the discussed case studies showcase techniques to contextualize the raw material within a social *relevance* of external reality (i.e. the subjective world outside of introspection; such as the impact of the environment on *us*).

In contrast, data sonification, while also restricted to external/physical reality, strives for abstraction towards perceptually critical data points that enable its audience to grasp the materialistic properties of the artifact rather than its social/cultural context. In the scientific application of data sonification, there is no relevance given to the artifact outside its underlying inquiry/research question (, which, ironically, remains human-determined in nature). Nevertheless, the act of data sonification aims to interpret materialistic properties and its consequences for the purposes of enabling intentionality of the agent. It is, thus, a goal-oriented, utilitarian process and preconceives and prepares cognitive processing towards a specific action (i.e. decision-making). This element of agency entails its translational

serves as a vehicle of improving our understanding of the external world by perceptually grouping and setting up expectations towards the relationship of its constituent parts for the consequence of our actions. Accordingly, we speak of a level of agency that is introrrelational as it has utilitarian relevance for the actions undertaken by the perceiving subject only. Armed with these expectations, perceptual cognition can foresee and more easily adapt to the challenges of processing complex data streams [11].

It may seem that this poses a challenge as rigid and complex that it may not apply to any kind of indulging, artistic experience. Indeed, our experience of artistic intent is fueled by the same ingredients of agency but rather than focusing onto the immediate actionable affordances of sonification, the main purpose of its artistic interpretation serves the interrelatedness of the addressee. Thus, artistic experience, whether through the eyes or ears of the creator or the audience, will inherently act as a reductionistic, abstract communiqué between humans. Its relevance can be pinned down to the interrelational aspects of agency (i.e. how do we relate to, perceive, and, most importantly, interpret other agents). The artist's task is to treat the material to make it compatible for social discourse. Amongst others, it is a task of translation by selection, empathy by alteration, and reflection by presentation. It is art.

The Bottom Line

Ultimately, the present paper tries to achieve the impossible within the limited space that is allotted to this format. It illuminates the dynamic intersection of technology and music composition, with a focus on sonification as a potent tool for artistic expression. It underscores the

enduring challenge faced by composers: How to forge innovative core ideas and choose optimal instruments amidst a technologically rich yet complex musical landscape.

The discussed case studies, ranging from Olga Neuwirth's seismic data-inspired work to Maria Kallionpää's environmental compositions to Touch Noise's intuitive interface, showcase the diverse ways in which sonification can be integrated into the compositional process. The exploration of creative domains, including data selection, preprocessing, and parameter modulation, highlights the nuanced decisions composers make to transform raw data into cohesive musical pieces. The authors encourage a departure from a rigid dichotomy between data-driven pragmatism and musically satisfying results. Instead, we advocate for a fluid and creative engagement with sonification techniques, allowing composers to navigate a spectrum that spans from objective information transmission to liberal artistic treatment. Ultimately, we argue that, in this era of technological advancements, the composer's artistic responsibility remains paramount in shaping and organizing computer-generated material into meaningful and impactful musical compositions.

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Spiralling around

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ways, and to the consideration that spirals are as much generic to this centred geometry as straight lines are to our more familiar one.

Then, spiralling back to phyllotaxy, we will show the transition between the concentric spiral patterns, and proper phyllotactic patterns. We will wonder what type of genetic spiral may be chosen, and what it changes about the resulting conspicuous spirals.

Abstract

Spirals are everywhere in nature. Phyllotactic spirals have particularly attracted the attention of scientists such as biologists and mathematicians, but also artists, including architects.

Much has been discussed about phyllotactic spirals, in particular the emergence of parastichy pairs of spirals in consecutive Fibonacci numbers. Here, after showing a dynamical model capable of displaying all features of phyllotactic spirals, we will take a step aside, by describing, analysing, and generalising non-phyllotactic spirals appearing in ancient Roman mosaics tessellating disks. This will lead us to a transformation from square to disk, which translates Cartesian coordinates into polar ones, in at least two

1. Phyllotactic spirals: a basic dynamic model

I already tackled the topics of phyllotactic spirals in my paper for GA2018 [1], by digitally simulating the analogue experiment made by Douady and Couder [2]. I used this experiment as an example of some distant force, here magnetic repulsion, creating interesting forms, here phyllotactic spirals. Douady and Couder invented an apparatus consisting in drops of ferrofluid falling at the centre of a dish filled with silicone oil and placed in a vertical magnetic field which repels the drops from the centre. The centre of the dish has a small bump, so that *a priori* the drops fall in a random direction, and continue in that direction until they reach the edge of the dish (where they fall into a ditch). But the drops are repelled from each other as well, so that the direction of each new drop depends on the repelling effect of one or more of the previous ones. A first emergent phenomenon takes place: a steady regime of divergence (the angle between the direction of two successive drops) appears, which leads to the fact that the drops are points of a spiral, the generative or genetic spiral.

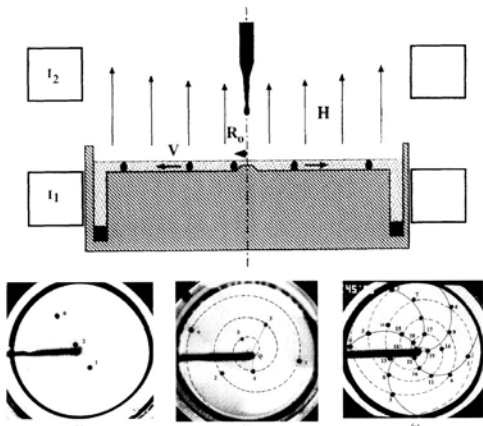


Fig. 1: Douady and Couder experiment

For some divergence angles, a second emergence occurs, which is the one we admire in sunflowers and many other phyllotactic spirals: what we perceive is not the genetic spiral itself, but secondary spirals, which happen to be in consecutive Fibonacci numbers.

Two parameters are involved in this experiment: the periodicity of the falling of drops, and the initial velocity of the drops. The constant divergence angle emerges whatever the choice of parameters, however phyllotactic spirals emerge only for some values of the parameters.

In my algorithmic model, particles are created at the centre at regular times, and travel in a straight line towards the periphery. The direction of the two first particles is random, but after that, the direction of each particle is determined by the position of all the previous particles, according to the law of magnetic repulsion. The absolute value of the speed of each particle is set at a given value, and does not change in time, nor its direction, once it is determined. The particles travel from the centre to the periphery along a radius, with the same constant speed. Douady and Couder acted upon the periodicity of the fall of drops, because it was the easiest to adjust, but I chose to align the creation of particles with the frame rate in processing, so the parameter upon which I act is the absolute value of the speed.

The first few particles act in a chaotic way but, rapidly, a constant divergence angle between consecutive particles emerges, giving way to spirals. For some value of the speed, the famous $360 / \varphi^2 \approx 137.5^\circ$ (where $\varphi = (1+\sqrt{5})/2$ is the golden mean) divergence angle appears, and produces the phyllotactic spirals we are familiar with. A slight change in the given speed

will produce so-called degenerate spirals.

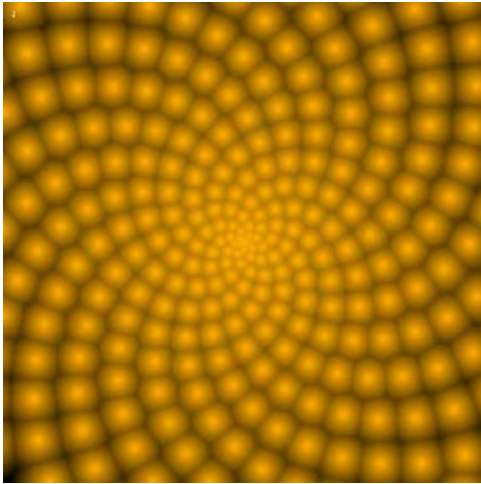


Fig. 2: Overall pattern

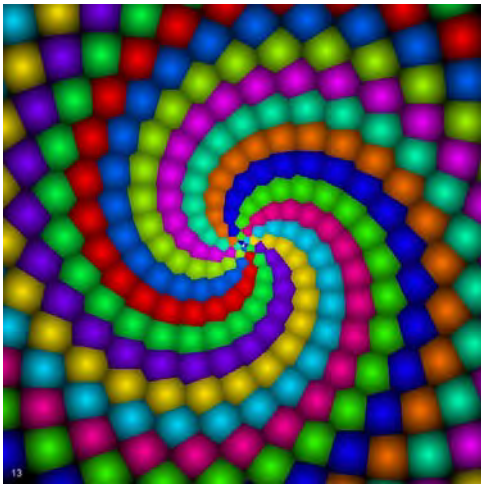


Fig. 3: 13 clockwise spirals

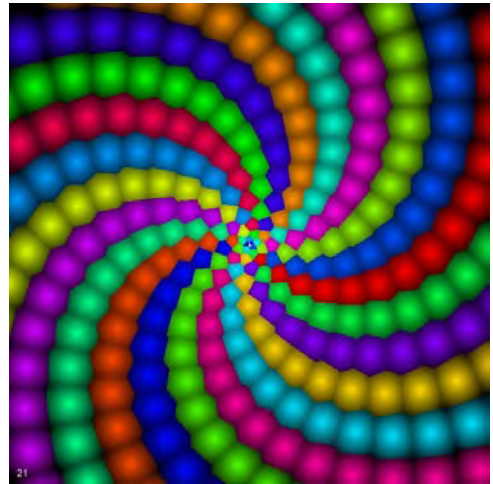


Fig. 4: 21 anti-clockwise spirals

As efficient as this model seems to be – it is dynamic, it provides phyllotactic spirals without explicitly using the “noble” divergence angle, which is what we expect if we do not subscribe to any teleology or intelligent design – it is not without providing some more questions: what would be the equivalent system of repulsion in a botanical organism (as obviously it would not be magnetism), and moreover, does not deciding on a given absolute value of speed instead of the divergence angle simply displace the teleological problem? As not a botanist, I shall not try to answer those questions, which have been amply discussed among more competent scientists.

However, this model has got all the constituents of the phenomenon of emerging phyllotactic spirals observed in botanical nature: there is a **genetic** or **generative spiral** formed by consecutive particles separated by a constant **divergence angle** and, more importantly, with the right speed, this model displays **visible** or **conspicuous parastichy pairs** of spirals in **consecutive Fibonacci numbers**.

2. Non phyllotactic spirals in concentric tessellations

2.1 Ancient Roman mosaics: description and analysis

All spirals are not phyllotactic, which means that spirals may be seen without any genetic spiral. So I was very surprised to find this illustration in the “bible” of phyllotaxis [3]:

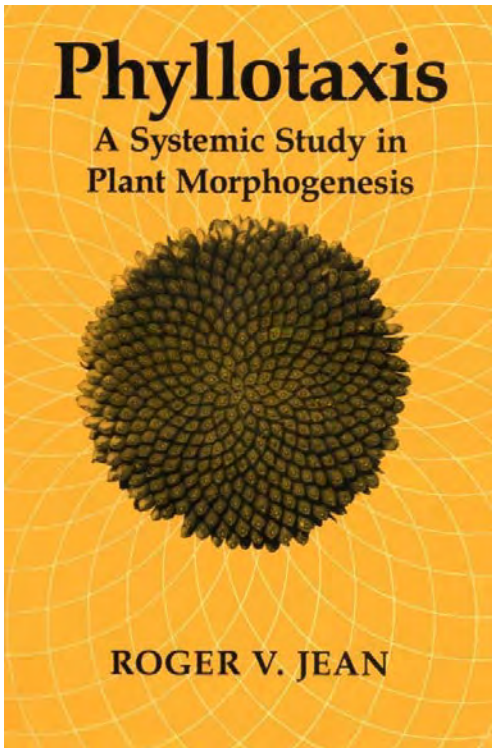


Fig. 4

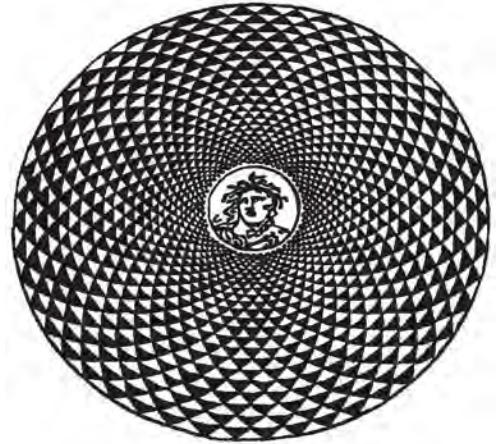


Fig. 5: [3] p. 234

It is actually a bad reproduction of the ancient Roman mosaic shown in Fig. 6:



Fig. 6: Roman mosaic with Head of Medusa, 115–150 AD. Museo Nazionale Romano—Palazzo Massimo alle Terme.

This mosaic looks very much like this other one, but with the head reversed:



Fig. 7: Mosaic Floor with Head of Medusa, 115-150 AD. J. Paul Getty Museum

The principle of this mosaic is simple: triangles are put regularly along concentric circles around a centred ornated disk, and layers are offset from each other, in a quincunx pattern.

Other mosaics obey the same logic, like those:



Fig. 8: Gorgon head in spiral pattern mosaic. Archaeological Museum, Athens.



Fig. 9: Spiral pattern mosaic. Palazzo Massimo Museum, Rome.

where emerging spirals are enhanced, or this one:



Fig. 11: Head of Dionysos in spiral pattern mosaic. Corinth, Greece.

where spirals in both directions are enhanced.

All mosaics above show triangles with size increasing with the radius, which makes them roughly isometric. But there is at least one exception to this rule:



Fig. 12: Roman geometric mosaic roundel, circa 3rd Century AD.

which does not prevent the emergence of spirals...

Other mosaics show spirals emerging from concentric quadrilateral shapes, without the quincunx:



Fig. 13: Roman mosaic, Syria, circa 4th-5th century AD.



Fig. 14: Roman mosaic, Antioch, circa 400 AD.

Those spirals are certainly not “phyllotactic”, and Fibonacci numbers have nothing to do with them. There is no genetic spiral, there are as many spirals as there are shapes around the central disk, all concentric layers have the same number of shapes, and lastly, there are as many spirals in one direction as in the other one.

We can analyse the patterns made of triangles according to the number of triangles in each layer, and to the number of layers (which happens to be the number of triangles in each conspicuous spiral).

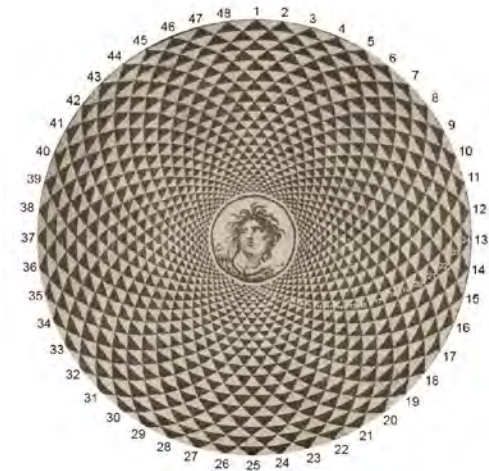


Fig. 15: 48 triangles by layer, 24 layers



Fig. 17: 38 triangles by layer, 10 layers

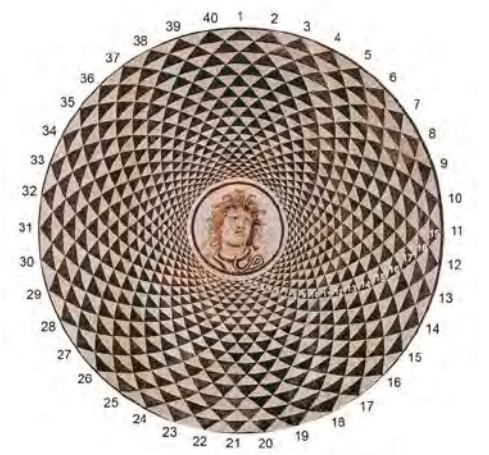


Fig. 16: 40 triangles by layer, 19 layers

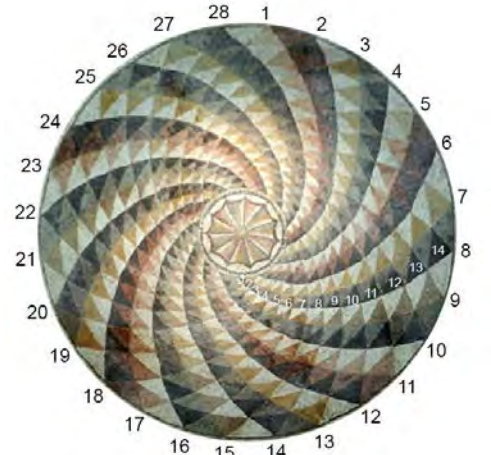


Fig. 18: 28 triangles by layer, 14 layers

This analysis ascertains that those two mosaics are very different, even if they look alike at first glance.

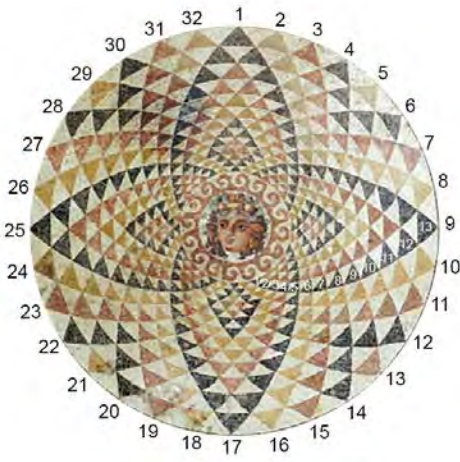


Fig. 19: 32 triangles by layer, 13 layers

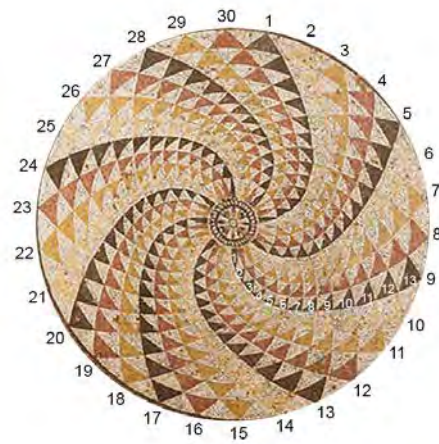


Fig. 20: 30 triangles by layer, 13 layers

The first mosaic with squarish shapes is much less elaborate, the mosaicist has struggled with the pattern in some parts, the difficulty being that one must make roughly squarish shapes of different sizes, each size corresponding to a constant fraction of the changing perimeter, and all that with a very small number of fixed size pieces... It is a relevant example of the conflict between

discrete (the pieces of stone) and continuous (the fraction of the perimeter), or between integer and real numbers...

The pattern starts in a rather straightforward way. The mosaicist has managed to place 63 2-by-2 squares around the inner disk. But things go bad at a certain point and there are only 61 squarish shapes at the boundary...



Fig. 21: 61- 63 squares by layer, 7 layers

Faced with the same problems, the rabbit mosaicist managed rather well...



Fig. 22: 48 squares by layer, 4 layers

Let us now try and make our own idealized version of those patterns. One must take into account the way in which the height of the triangle or quadrilateral shape, i. e. the width of the annular layer, varies from centre to boundary. Without direct access to the original mosaics, it is difficult to exactly measure it. But in most cases, if not the result, at least the intent of the artist seems to be that all triangles are isometric. In one case (Fig. 12, 20), the height is approximately constant. As the base of the triangle is defined by the perimeter of the central disk and the number of triangles, once the initial type of triangle and the number of layers are chosen, the whole pattern is determined.

Applying this method for our two first first mosaics, this is what it provides:

48 24

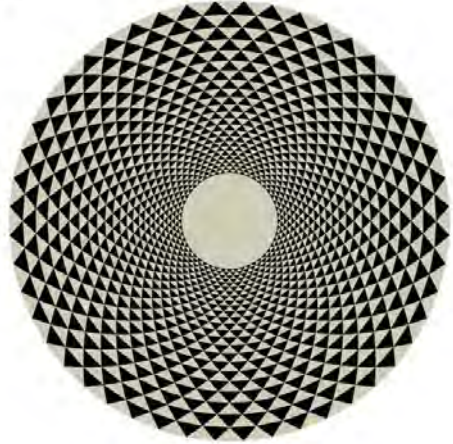


Fig. 23: cf. Fig. 6, 15.

40 19

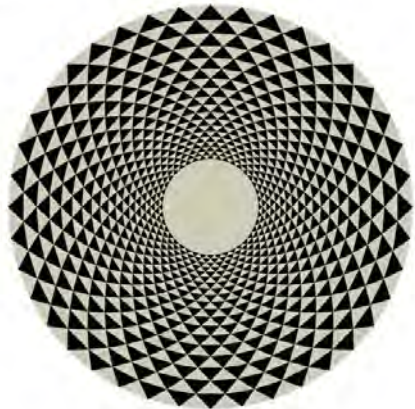


Fig. 24: cf. Fig. 7, 16.

The most compliant to the isometric model is the Gorgon (Fig. 8, 17), and it is also our first example of enhancing the spirals by colour. The mosaicist has encountered a problem with this attempt: by choosing 38 shapes surrounding the disk, he could not properly arrange the colours periodically (as $38 = 2 \times 19$, and 19 is a prime number). Anyway, here is our rendition of this pattern:

38 10



Fig. 25: cf. Fig. 8, 17.

The next mosaic shows spirals whirling in the opposite direction:

28 14



Fig. 26: cf. Fig. 9, 18.

The colouring of the next mosaic is more tricky, but by adjusting the numbering of the triangles, we manage to obtain this:

32 13



Fig. 27: cf. Fig. 11, 19.

Remains the 6th mosaic, where the triangles of the first layer around the central disk are very elongated, while the last ones at the boundary are more squat. It is not clear what the progression actually is based upon, but we shall assume that the intent was that all layers would be of the same width, all the triangles of the same height, regardless of their base.

Once again, the mosaicist has encountered a problem with the colouring of the spirals, or maybe he wanted some irregularity. Having chosen 30 shapes by layer, it would have been logical to make 5 sequences of 6 colours, or 6 sequences of 5 colours, but there are 6 sequences of 4 colours, and 2 of 3 colours. We shall be more rational, and opt for 6 series of 5 colours...

30 13



Fig. 28: cf. Fig. 12, 20.

The mosaics with quadrilaterals do not have the quincunx arrangement. Spirals are not so conspicuous, unless one colours consecutive shapes differently. Here are approximations of the two mosaics:

60 7

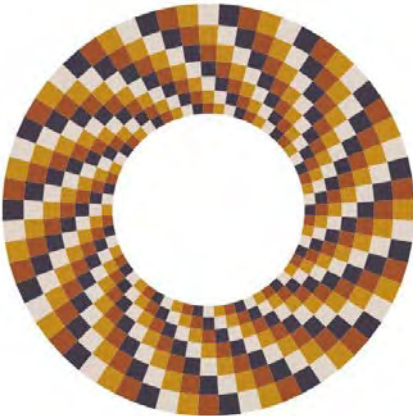


Fig. 29: cf. Fig. 13, 21.

46 4

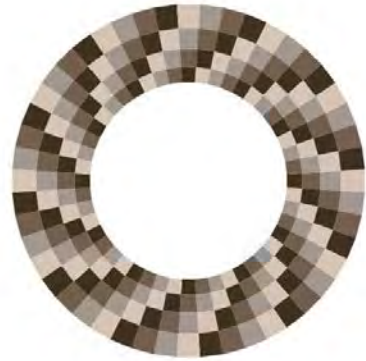


Fig. 30: cf. Fig. 14, 22.

2.2 Generalisation

All those mosaics do not tile an entire disk, but rather a ring, they all have a disk at the centre, decorated with a mythologic figure.

But, ideally, one can tile a disk in a similar way, by packing concentric layers of a given number of regularly distributed shapes. We simply divide the perimeter of any circle by the number of shapes we desire. The width of each layer depends upon the rule we choose to implement, the most natural being that the shapes are isometric. Obviously, there is a problem at the centre, where the perimeter tends to 0, as does the width of each shape... So we cheat a little, by starting with a radius of 1 instead of 0.

For instance, the tiling disk equivalent to the first mosaic we analysed is this:

48 89

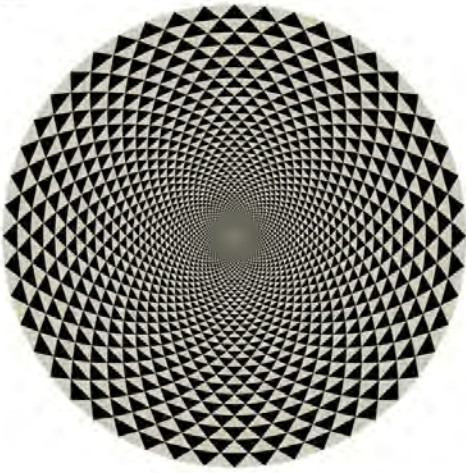


Fig. 31: Generalisation of Fig. 24.

but we note that it needs much more layers: 89, instead of 24.

We can now generalise this construction by choosing any number of shapes we want (for triangles we consider only the black ones), and letting the layers go as far as we want, and enhancing one of the generated spirals. The depth of each layer may be such that shapes are isometric, or it can be constant:

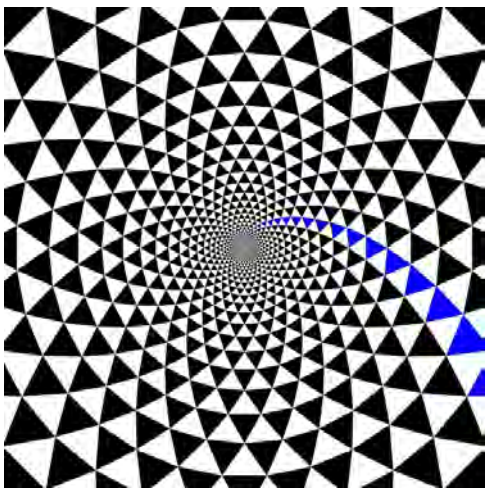


Fig. 32: 32 shapes, varying depth.

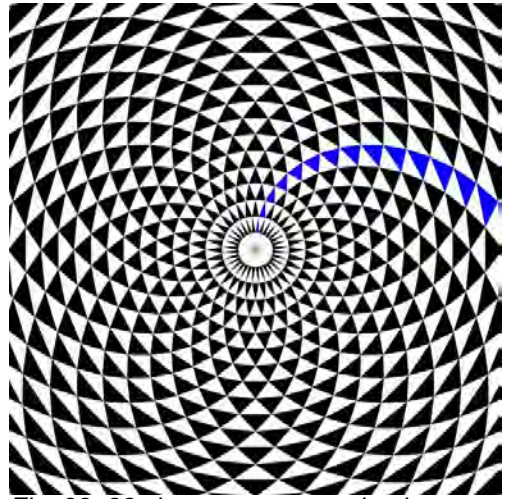


Fig. 33: 32 shapes, constant depth.

The same generalisation can be made with the quadrangles (all quadrangles are counted, both white and black):

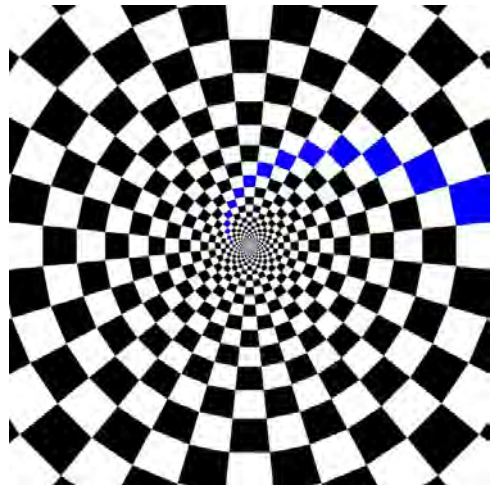


Fig. 34: 32 shapes, varying depth.

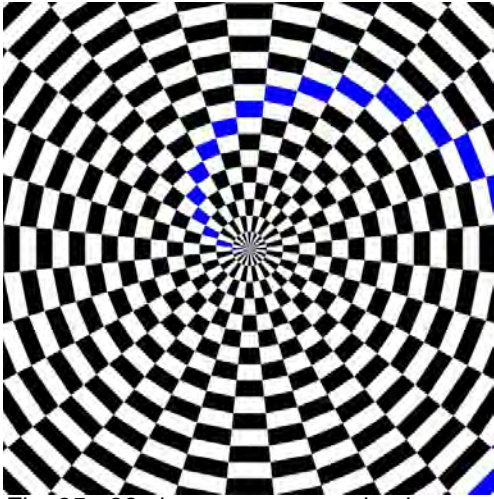


Fig. 35: 32 shapes, constant depth.

We can extrapolate our method to the other archetypal tiling of the plane, beside the triangular and orthogonal ones, the hexagonal. We need three colours in this case, and even without enhancing any spiral, they are rather conspicuous:

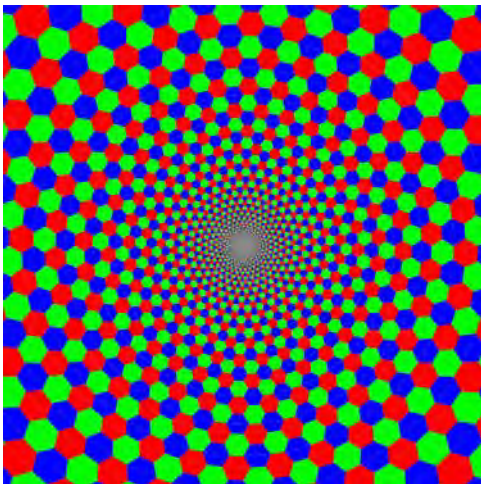


Fig. 36: 32 shapes, varying depth.

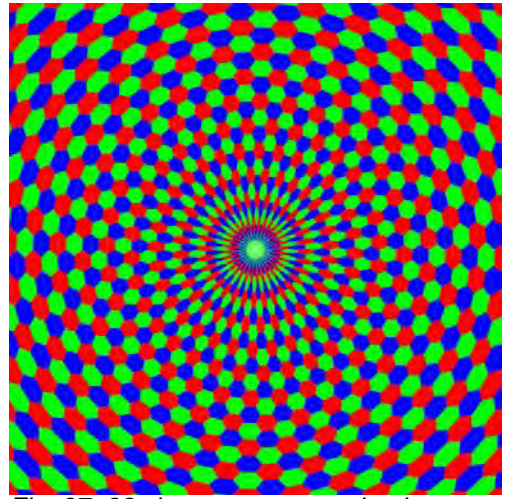


Fig. 37: 32 shapes, constant depth.

We must now return to our analysis of the mosaics with triangles and correct it. We had only considered the upward triangles, and observed that they were “in quincunx”. This assumption was in accordance with the mosaics, because the downward triangles, between the coloured ones, were left in a neutral colour, like a background. But for a more accurate analysis we must also consider the downward triangles. With a small number of (black) triangles we can see more clearly what actually happens, i. e. that the triangles lay on a hexagonal lattice:

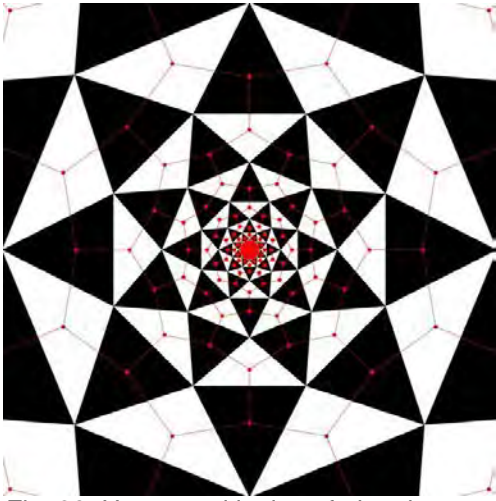


Fig. 38: Hexagonal lattice of triangles

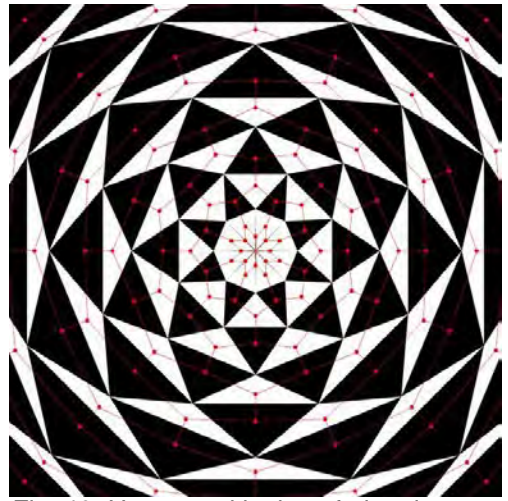


Fig. 40: Hexagonal lattice of triangles

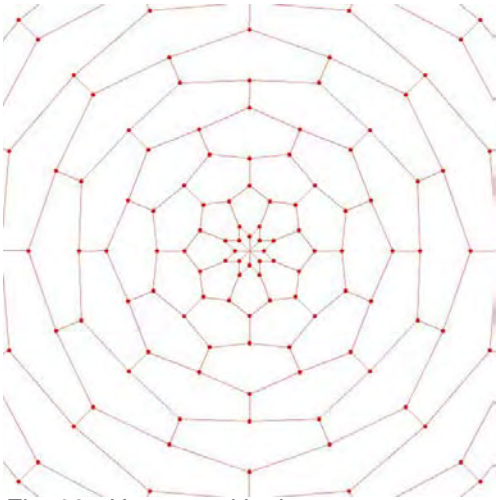


Fig. 39: Hexagonal lattice

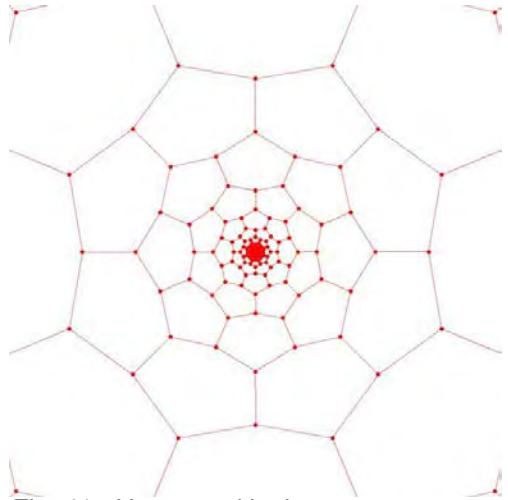


Fig. 41: Hexagonal lattice

We can now generate all particle patterns corresponding to possible tessellations, depending upon the type of lattice ("orthogonal", triangular, hexagonal) and the variation (dr) of the radius of the particle positions.

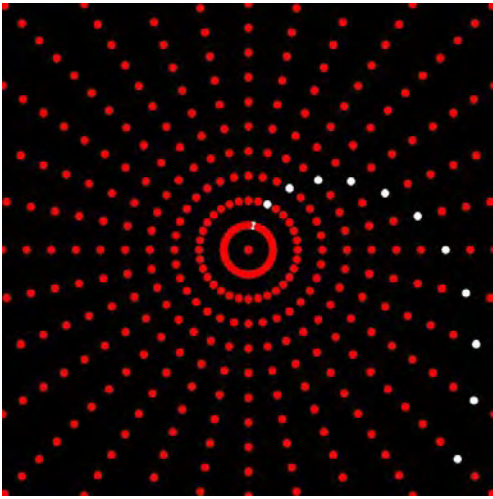


Fig. 42: "orthogonal", dr constant.

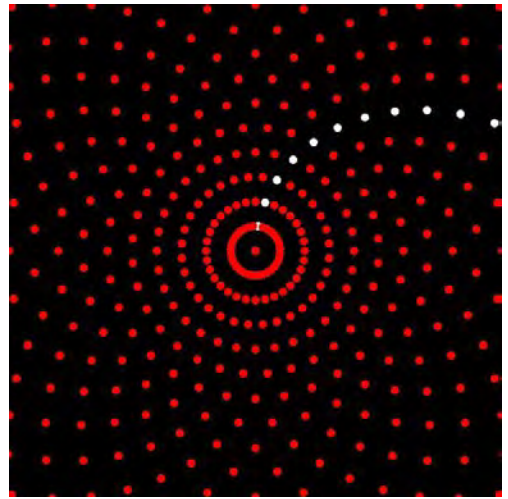


Fig. 44: triangular, dr constant.

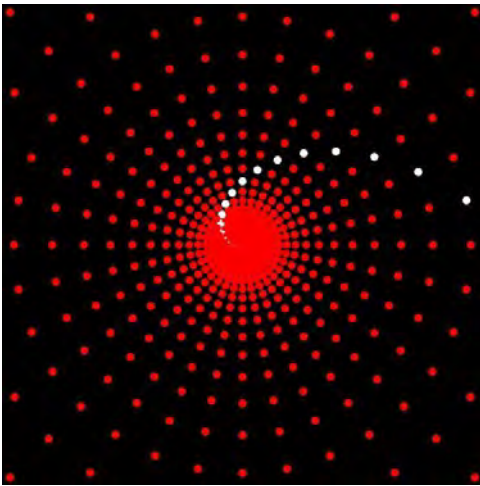


Fig. 43: "orthogonal", dr variable.

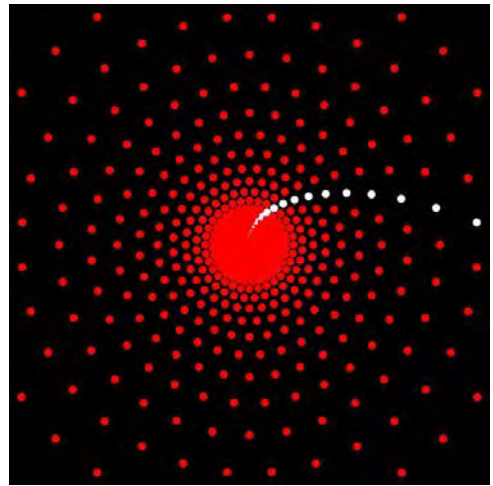


Fig. 45: triangular, dr variable

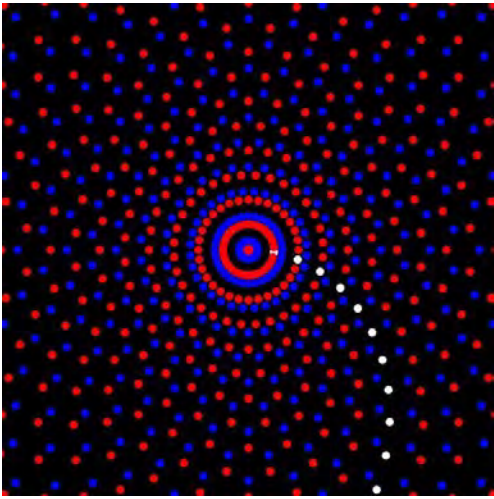


Fig. 46: hexagonal, dr constant.

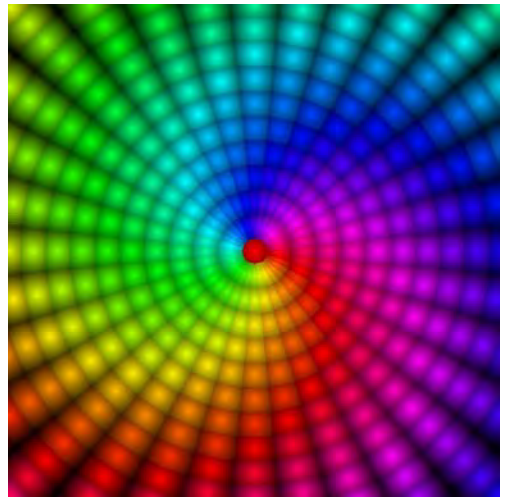


Fig. 48: "orthogonal", dr constant

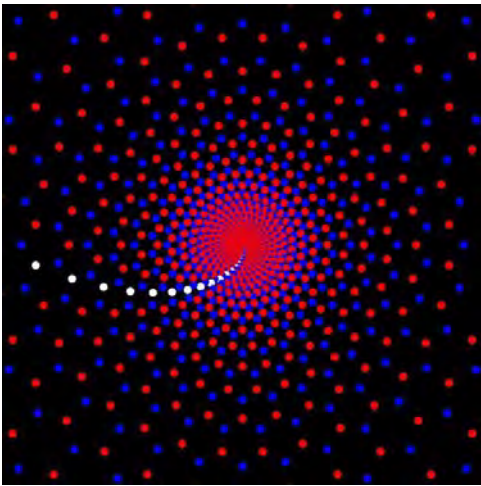


Fig. 47: hexagonal, dr variable

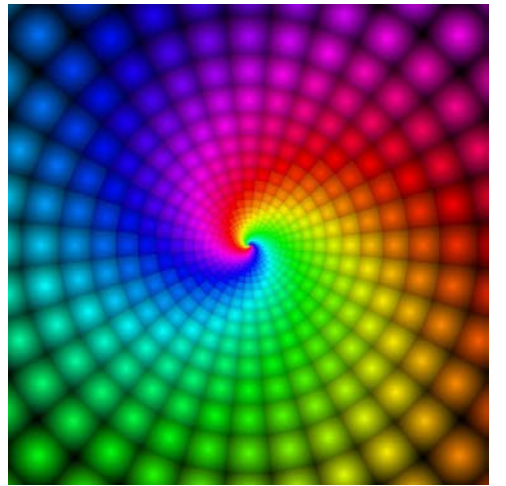


Fig. 49: "orthogonal", dr variable

Now let us use these particles as sites for Voronoi tessellations:

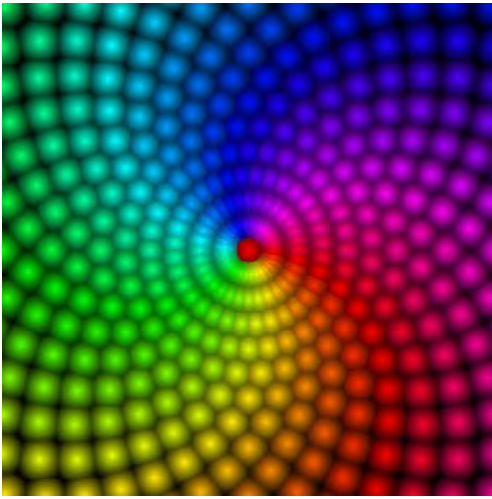


Fig. 50: triangular, dr constant

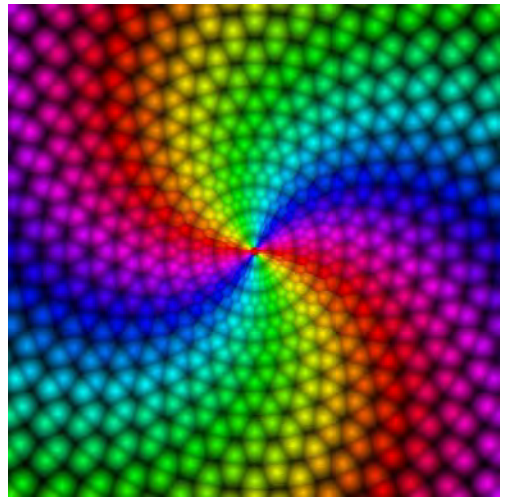


Fig. 52: hexagonal, dr constant

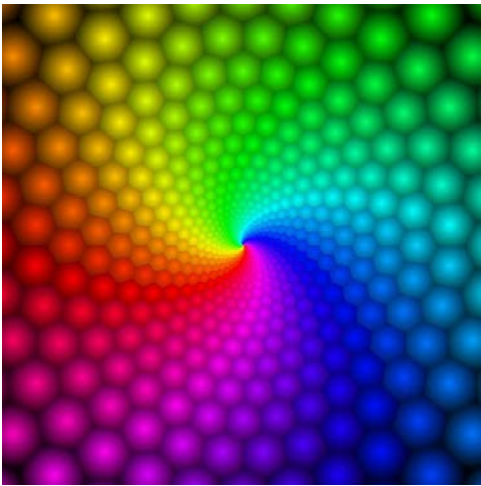


Fig. 51: triangular, dr variable

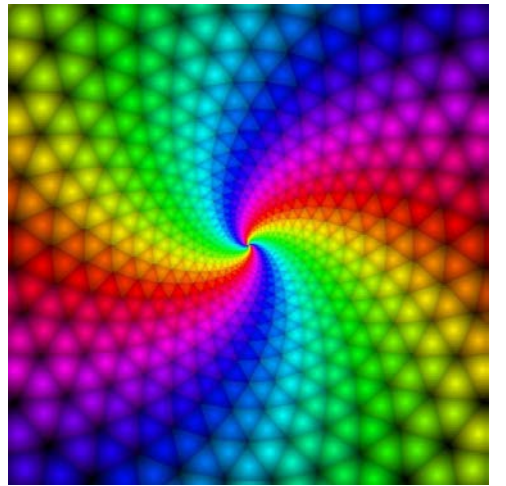


Fig. 52: hexagonal, dr variable

We notice that, in the case of the triangular and hexagonal lattices, while when dr is variable the tiles of the Voronoi tessellation are what we expect (hexagons and triangles, respectively) it is not always the case when dr is constant.

We could explore further this question, but it would lead us too far from our purpose, so in order to better explore the correspondence between our familiar tessellations and this new world of concentric tessellations, we shall make a little detour.

2.3 Cartesian to polar transformation

Tiling a disk is a task equivalent to tiling a rectangle, with a change of perspective, or, more accurately, of geometry.

We can imagine a very simple bijective, or one-to-one, transformation that goes from a rectangle to a disk, by taking the Cartesian coordinates, and considering them as polar ones (regardless of potential scalar factors) :

$$x \rightarrow \theta$$

$$y \rightarrow r$$

Applied to one of the most famous portrait in history, here is what happens to the poor Mona:



Fig. 53

Obviously there is more than one way to do that:

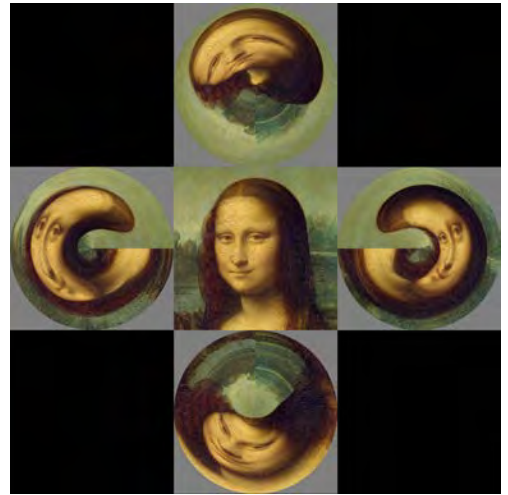


Fig. 54

but we shall stick to this first one.

This transformation turns vertical lines into radials, horizontal lines into concentric circles and oblique lines into one, or many spiral(s):

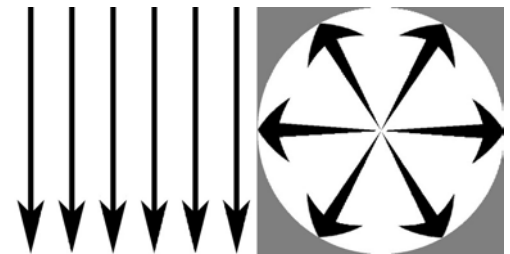


Fig. 55

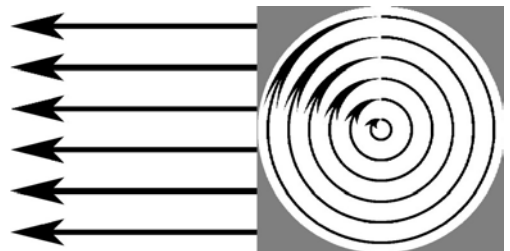


Fig. 56



Fig. 57

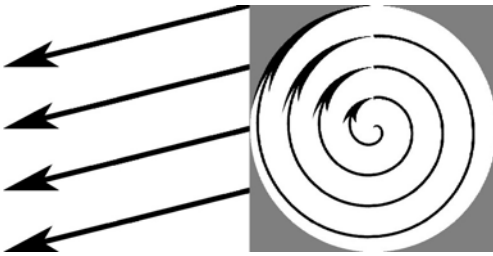


Fig. 58



Fig. 59.

We can now see what happens to classical tessellations:

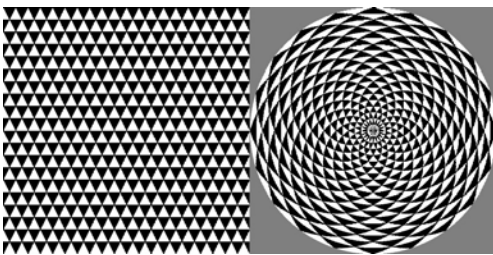


Fig. 60

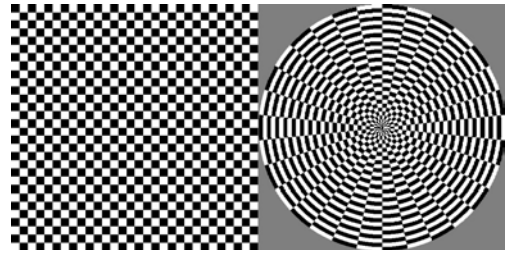


Fig. 61

Contrary to our generalisation of Roman mosaics, the tiles are rounded along concentric circles, which appears more clearly with a smaller number of tiles by layer:

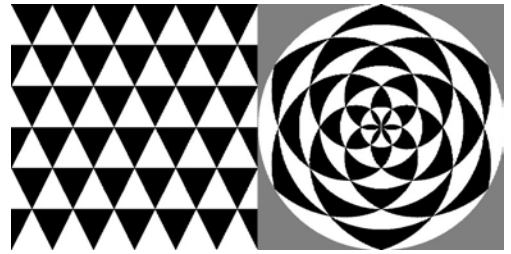


Fig. 62

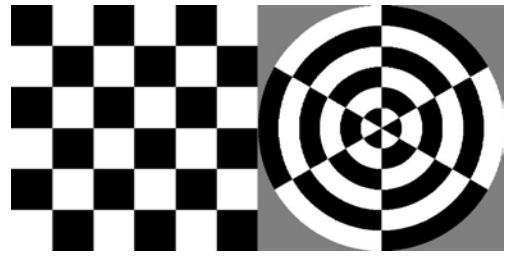


Fig. 63

But, transforming a regular tiling pattern from Cartesian to polar with the simple rule we have adopted, we get tiles that are not isometric, but rather have a constant height, because layers have a constant depth.

It is not the most logical way to tile a disk. It would be more satisfying to get tiles that are isometric. So I wrote another transformation that makes it (regardless

of potential scalar factors) :

$$x \rightarrow \theta$$

$$a^y \rightarrow r$$

Let us see how our new transformation acts upon the same images as before:

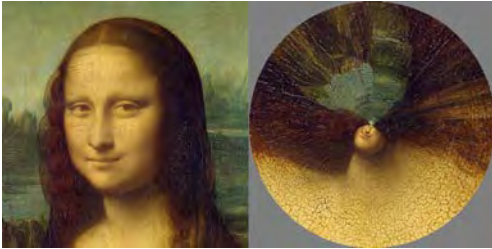


Fig. 64

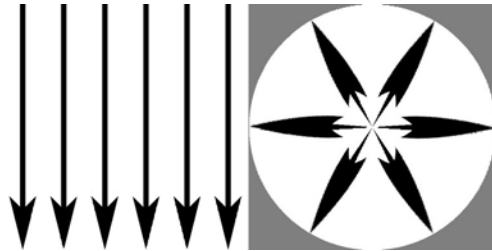


Fig. 65

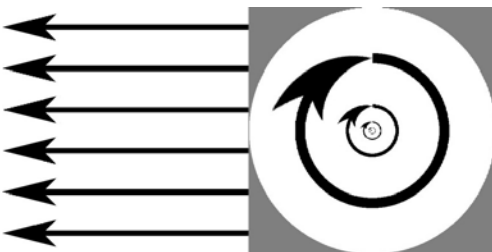


Fig. 66

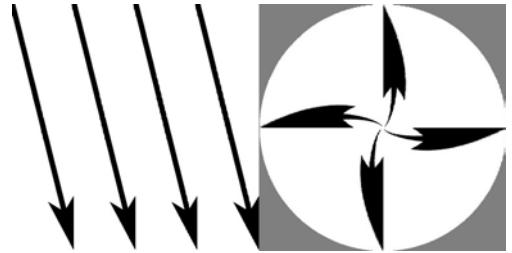


Fig. 67

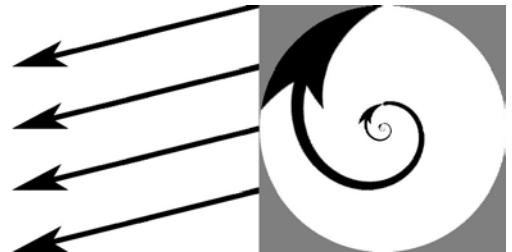


Fig. 68

And now, let us apply this transformation to classical tessellations:

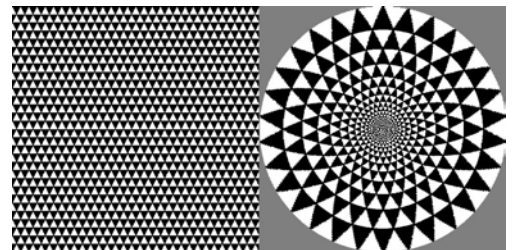


Fig. 69

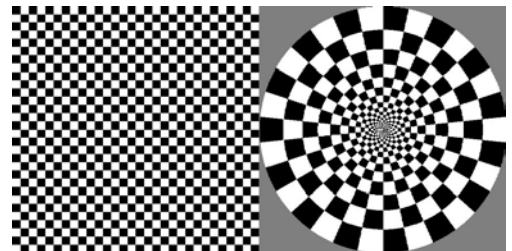


Fig. 70

As with the previous transformation, the tiles have rounded edges:

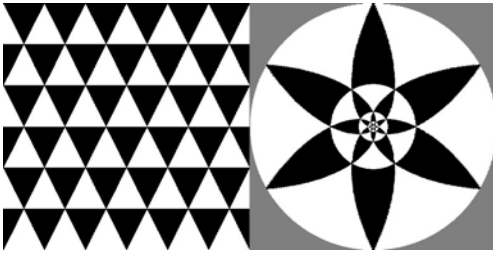


Fig. 71

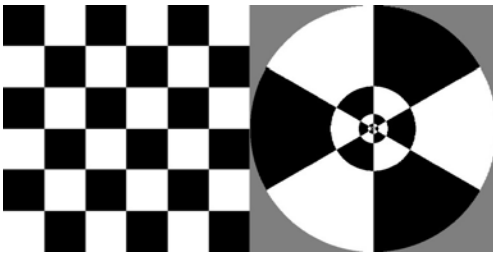


Fig. 72

What one may conclude, among other things, from this little detour, is that spirals are as natural for this geometry of the disk, as oblique straight lines are for our more familiar geometry.

3. Back to phyllotactic spirals

Phyllotactic spirals are phenomena that emerge when florets, or any type of plant organs, appear in a genetic, or generative, spiral. Our non phyllotactic spirals were visible although the basic tiles were arranged, not in a spiral, but in concentric circles.

As a transition, we can make a slight modification to our pattern of 32 triangles for each concentric circle, by converting each circle of tiles into a spiral such as the last tile of each spiral corresponds to the last triangle in the converted circle, but with a radius from the centre increased by the depth of the layer.

Putting triangles in such an arrangement, we could be fooled by the resemblance of the result with our generalisation of the mosaic pattern (see Fig. 33), though by looking more accurately at the centre we discover the truth, the genetic spiral:

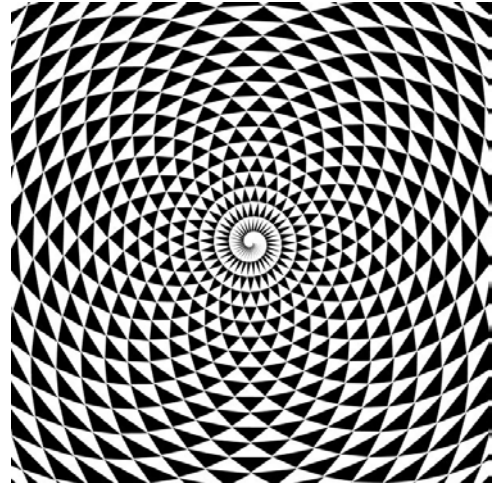


Fig. 73

We see conspicuous spirals as well. There are 32 spirals in the same orientation as the genetic spiral:

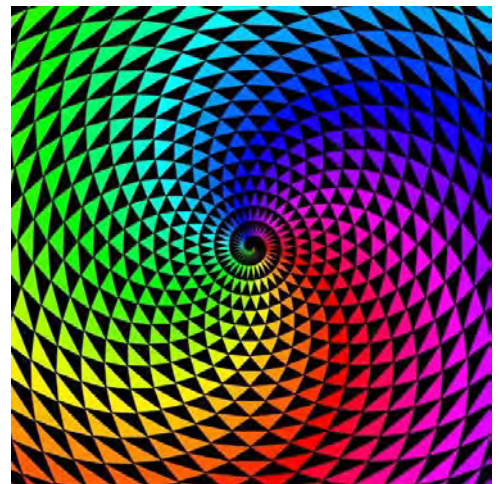


Fig. 74

But there are only 31 spirals in the opposite orientation:

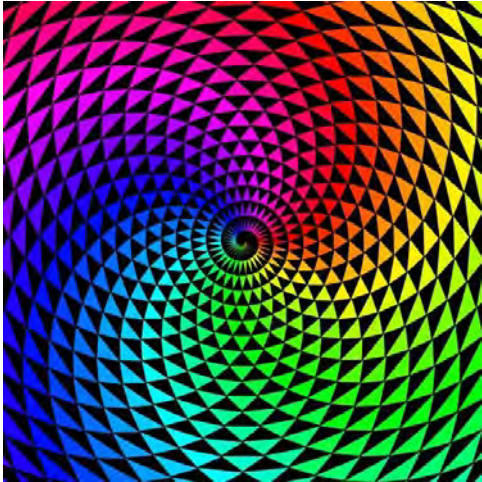


Fig. 74

though it is not perceptible with the naked eye...

We are now going to generalise this first experimentation and go closer to true phyllotactic spirals.

All spirals may be written as such:

$$r = a\theta^b$$

with some particular cases:

$$r = a\theta \quad \text{Archimedean}$$

$$r = a\theta^p \quad \text{logarithmic}$$

$$r = a \log b\theta \quad \text{exponential}$$

$$r = a\theta^{1/\varphi} \quad (\varphi = (1+\sqrt{5})/2) \quad \text{golden}$$

$$r = a\theta^{1/2} \text{ or } a\sqrt{\theta} \quad \text{Fermat or parabolic}$$

Let us note that, when referring to a mathematical function, the names weirdly

are the inverse of those functions...

As we are not interested in drawing whole spirals, but only in putting consecutive particles on a spiral, we take some divergence angle, i. e. the angle between two consecutive particles, as constant ($\theta_n = n \text{ div_angle}$), and compute the radius r_n given by the adequate formula.

By construction, our first experiment in this part was an Archimedean spiral, with a divergence angle of:

$$(2\pi + \pi/32) / 32 = 2\pi (65 / 2048)$$

Let us now display this pattern with simple particles:

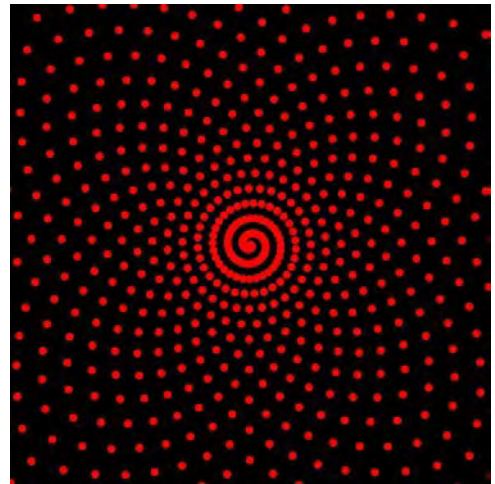


Fig. 75:

Archimedean: $\theta_n = n2\pi (65/2048)$ $r_n = 3\theta_n$

The pattern shows obvious spirals, and we could wonder why nature did not chose such a divergence angle... But if we take a smaller value for a (which is the same as pursuing the pattern further), we see that the pattern breaks at some point:

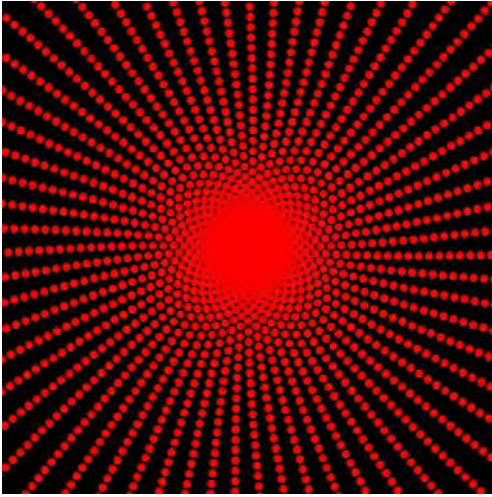


Fig. 76:
Archimedean: $\theta_n = n2\pi$ (65/2048) $r_n = \theta_n$

The spirals “degenerate”.

What is key here, mathematically, is the rationality of the factor of 2π in the divergence angle. Though 65/2048 is irreducible (65 and 2048 are co-prime), this number is undeniably rational.

Yet true phyllotactic spirals emerge when the divergence angle has a factor which is irrational, and among the irrational numbers, the one which is the “most irrational”, if we can say so, is the golden mean, or more precisely here, the factor of the divergence angle is most commonly $1/\varphi^2$ (or $1/(1+\varphi)$) where $\varphi = (1+\sqrt{5})/2$ is the golden mean.

Let us now use this divergence angle for the Archimedean spiral, and we see that the pattern produces phyllotactic spirals:

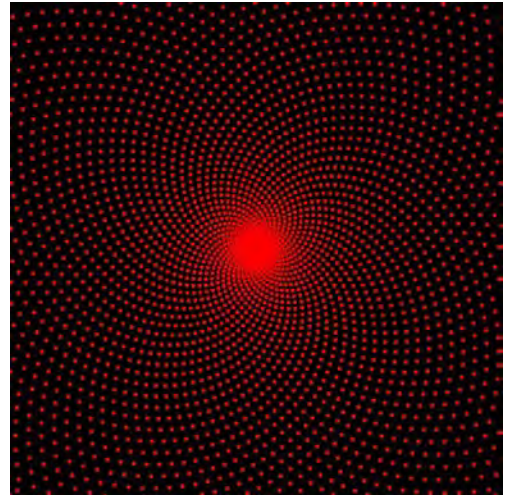


Fig. 77:
Archimedean, $\theta_n = n2\pi/\varphi^2$ $r_n = 0.05 \theta_n$

Now what about the other types of spirals?

In our non phyllotactic pattern, we used a variation similar to the logarithmic spiral. Let us try it, with the “noble” divergence angle:

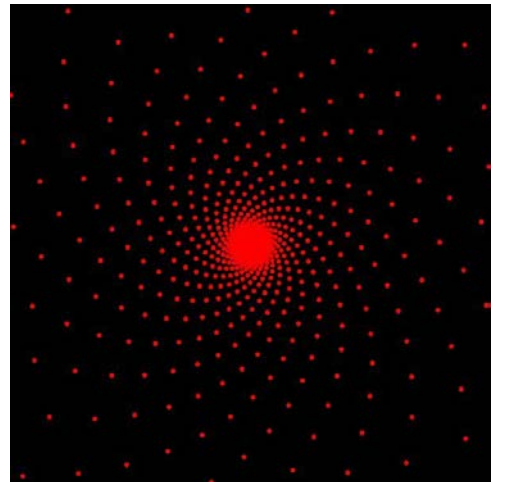


Fig. 78:
Logarithmic: $\theta_n = n2\pi/\varphi^2$ $r_n = 0.005 \times 1.0025^n$

The pattern is fine but by definition the radius grows exponentially, so it takes a long time to produce the particles in the centre, and they go further from it very rapidly.

Let us now try its reciprocal, the so-called exponential spiral. The phenomenon is inverse from the previous one, particles shoot out very rapidly at the beginning and then more and more slowly:

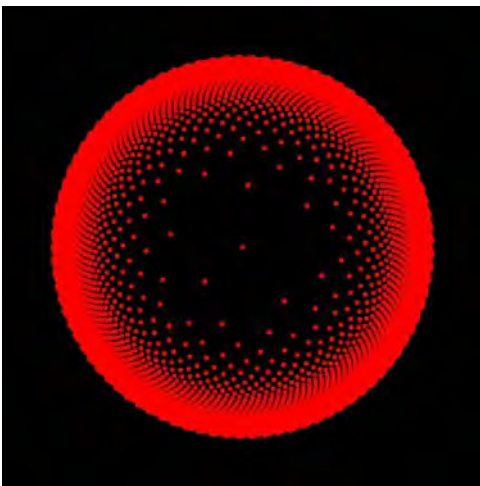


Fig. 79:
Exponential $\theta_n = n2\pi/\varphi^2$ $r_n = 20 \log(10 \theta_n)$,

In those two cases, conspicuous spirals may be hard to discern, though they are actually present.

Let us finish with the two most promising types of spirals, the “golden” one, whose name seems appealing, and then the parabolic or Fermat spiral:

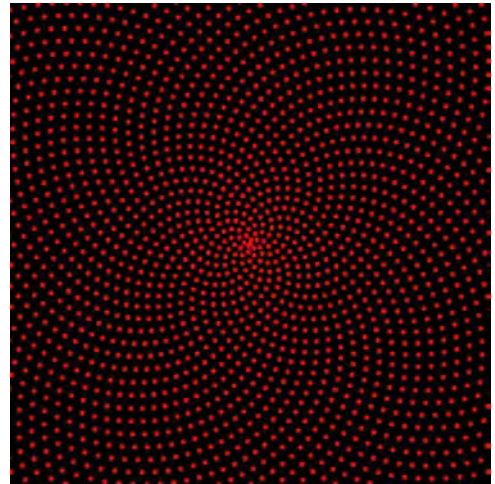


Fig. 80:
Golden: $\theta_n = n2\pi/\varphi^2$ $r_n = 2 \theta_n^{1/\varphi}$

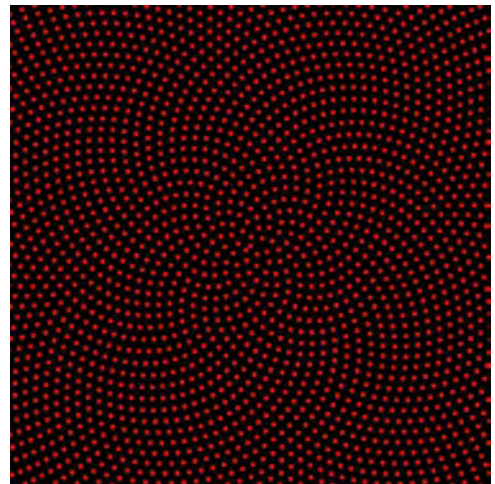


Fig. 81:
Fermat: $\theta_n = n2\pi/\varphi^2$ $r_n = 5\sqrt{\theta_n}$

The two patterns show obvious conspicuous spirals.

Mathematically speaking, all types of genetic spirals yield phyllotactic conspicuous spirals in Fibonacci numbers when the divergence angle is the so-called “noble” one, i. e. $2\pi/\varphi^2$. Our interpretation of the Douady-Couder

experiment yielded Archimedean spirals by construction, with the formula:

$$r = (\text{speed}/\text{div_angle}) \theta.$$

While the Archimedean, golden and Fermat spirals look a lot like patterns occurring in nature, the logarithmic and exponential ones seem far fetched, and corresponding to very weird behaviours. The golden one has a self-similar propriety, but it does not seem to be a requirement for the kind of behaviour encountered in phyllotactic patterns. Jean [3] does not insist on a particular type of spirals. It depends on a lot of particularities of the plant in question. However, there seems to be a consensus in the scientific community about the Fermat spiral being the type for the daisy and sunflower patterns (see for instance [4]), that goes back to a famous paper by Vogel [5], and like Dimitry Weise insisted upon [6]. The reason invoked in general is the packing efficiency of this pattern. But this efficiency supposes at least two prerequisites: first that the florets, or any shapes in question lie on a plane, secondly that the florets are all of the same size, or that we know of their rate, or rule, of growing, and those prerequisites are not so obvious.

In conclusion, spirals are inherent to the geometry of the disk. Though each type of spiral has its own characteristics, phyllotactic spirals emerge as soon as there is a genetic spiral of any type, and, most importantly, a particular so-called “noble” divergence angle.

Let us finish with enhancing the conspicuous spirals with the Fermat type:

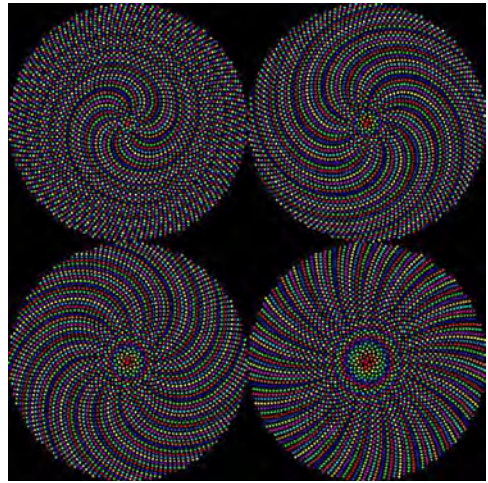


Fig. 82: 34, 55, 89 and 144 conspicuous Fermat spirals.

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- [1] Marie-Pascale Corcuff, “Distant Forces generating Forces”, *GA2018*.
- [2] S. Douady, Y. Couder, “Phyllotaxis as a Physical Self-Organized Growth Process”, *Physical Review Letters*, Volume 68, Number 13, 30 March 1992.
- [3] Roger V. Jean, *Phyllotaxis. A Systemic Study in Plant Morphogenesis*, Cambridge University Press, 1994.
- [4] Akio Hizume, Takamichi Sushida, Yoshikazu Yamagishi, “Voronoi Phyllotaxis Tiling on the Fermat Spiral”, *Bridges 2014*
- [5] Helmut Vogel, “A better way to construct the sunflower head”, *Mathematical Biosciences* 44 (1979), no.3-4, 179–182.
- [6] Dimitry L. Weise, “Phyllotaxis is not logarithmic”, *GA2021*.

Unreal Worlds a Study in 2d Wavetable Synthesis and Soundscape Ecology

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Abstract

In *Unreal Worlds* (2023) audio is processed by a 2d wavetable object in Max/MSP enabling radical manipulation of nature sounds recorded near my home at various times of day. Recorded sounds feature song sparrows (day), frogs (night), frogs and birds (day), and bird song (morning). Native species include sparrows, nuthatches, titmice, yellow chat, robins, cardinals, tree frogs; and sparrows figure significantly in the recordings.

Sound gestures in *Unreal Worlds* (2023) were composed to resemble the natural environment's densities and proportions, but the sound worlds themselves are fabricated. Effort was made during the compositional process to both emulate the natural world and, in some cases, leave in or enhance the artifacts of the audio processes used to transform the sound. Once known, these are easily distinguished; from pitch

transposing birds and frogs, the sounds of "wind," "water," and the ambient drones of the second half of the work.

There are several versions of the work the first is approximately thirty minutes long, with six minutes of silence interspersed throughout. The silence to enables patrons to perceive how sound transforms an environment (habitus).

During this paper presentation, I will discuss the creation of transition matrices from environmental recordings and demonstrate other versions of the work including installations, and user-controlled patches.

Unreal Worlds 2d Wavetable Synthesis Installation

Unreal Worlds (2023) was composed for an exhibition entitled, *Making Place*, September through October 2023 in the Carroll Gallery of the Marshall University's School of Art & Design. The work is a 30-minute loop capturing aspects of the local soundscape presented tongue-in-cheek to those who would listen critically. As a composer and nature lover, I am continually amazed by the beauty and diversity of ecosystems, and the richness of any sonic environment and though subsequent variations of *Unreal Worlds* will attempt to emulate nature more closely through the incorporation subtle biophonous proportions, and tonal variations; *the*

subtext is that these imitations are no substitute for the beauty and variety of the world that surrounds us. They are a pallid imitation; representations using sounds we perceive with only limited understanding of their function, purpose, or intent. As David Dunn stated: [We must]...*hear beneath the surface of our most familiar projections to what might be a more intrinsic understanding*, what Bateson called [the] mind in the natural world. [1]

Soundscape?

Bioacoustics often focuses on individuals of the same species implying that communication is a locked system that ignores inter-species interactions. It often refers to the **emission-propagation-reception paradigm**. Though this approach is useful, more recent work focuses on revealing networks of communication, or the sum total of acoustic elements occurring in a network, ecosystem, or **soundscape**. These studies focus on species interactions, and how they compete, or cooperate for limited acoustic space in the environment, and they have yielded models of sound transmission that focus on biophysical characteristics, the physical environment, and feedback mechanisms that give rise to changes in songs and calls. Species interactions are classified as-**biophony**, sounds of the environment-**geophony**, and human sounds-**anthrophony**. [2] These are the primary components of a soundscape of which we are generally aware. My experiences while making field recordings for this project highlighted that species in close proximity (2-10 meters) often times interacted like a group of improvisers, giving each other space to 'sound off' in the biophonous chorus (Acoustic Niche Hypotheses-ANH).

Continuous anthroponous sounds (machines) had little effect on biophonic interactions, while sudden loud anthroponous sounds, the presence of a predator, or my presence often silenced the group. After an interruption when the chorus resumed, if I remained, my presence was still 'felt'. These observations confirm what has been well known in the bioacoustics field, that human disturbance of environments reshapes geophony and alters animal activity, sounds, and interactions. [3]

Acoustic Indices

When addressing networks of communication, **Acoustic indices** may be used to account for acoustic diversity. Indices can be classified for a wide range of factors but many refer to amplitude, complexity of time/rhythm, frequency or amplitude, or take into account **biophony**, **geophony**, or **anthrophony**. [2] Figure 1 shows a sonic spectrum featuring three distinct species. During the analysis phase of the project, sounds were processed with broadband noise reduction to reveal individual species more clearly. The audio spectrum below demonstrates differences between three species in one of my recordings. The frog sounds had a quick rhythm at a lower frequency and amplitude than the Yellow Chat bird call that followed. This call was slightly slower, had a broader pitch range, and a higher amplitude intensity than the frogs or the American Robin whose call featured more pitch diversity, a lower amplitude, and short phrases separated by silence.



Figure 1: Audio Spectrum of Biophonous sounds recorded June 8, 2023. [1]

Day, Time, Season

Unreal Worlds employs sounds from different portions of the day; morning, midday, and evening. My observations of activity in field recordings mirrored research findings where there are distinct differences in the dawn and dusk chorus, midday and evening biophony. Field recordings were made at my home, a .33-acre lot containing wooded and grassy areas, and ample food and water for our local animal residents. Further, these recordings were made in summer, which has the greatest animal activity. [4] More recordings are being collected and analysed to map changes of season.

Unreal Worlds #1: fixed version, 2d Wavetable Synthesis

In the first version of the work, I collected sounds from field recordings and modified them using the mc.2d.wave Wavetable Synthesis object in Max/MSP. In this object the audio file is divided into rows (e.g., 1 = the entire file), the length of the segment to be played, starting point for playback and range are specified. Inputs may also be modulated using continuous waveforms (e.g., phasor) or multichannel waveforms. Both are shown below, though only one can be used at any given time.

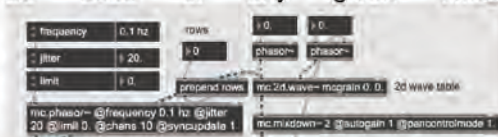


Figure 2: Max/MSP mc.2d.wave patch

Combinations of input variables enable changes to playback, speed, pitch, duration, forwards/backwards playback, radical modulations, and/or granularization of the sound file. [2]

Modified sound materials were then assembled and mixed in a DAW for the final version using roughly the same time proportions as the original source files. This version of the work plays off the notion that environmental sound recordings are representations of the original environment; a flattening of acoustic complexity which has been edited to be repeated and consumed. [4] My version takes this one step further using processed sounds to represent geophony (e.g., wind, rain, bubbling streams), and altered biophony creating 'new' species of birds, frogs, and insects from the original sound recording, as well as other ambient sounds similar in style to the work of Hildegard Westerkamp. [3] In this first version of the work, timing between iterations of single species were generally preserved, but the interactions between species were composed to create an imaginary soundscape, with imaginary creatures. To further the project and develop a more nuanced understanding of soundscape interactions, I built analysis patches to capture timing, amplitude, and frequency events from the original recordings. These became the basis for probability matrices and the beginnings of a second version. This process confirmed the cyclic nature of sound events, the relative consistency of frequency and amplitude for each species, and a clearer understanding of event variability in the realms of pitch and rhythm.

Analyses Patches

I analysed field recordings using the bonk~, sigmund~, and timer objects in Max/MSP. This generated tables of amplitudes, frequencies, and timings for each of the files analysed. [5] Amplitude of octaves in recorded samples returned predictable results with most biophonous sounds existing in the sixth and seventh

octaves of the spectrum analysed approximately 1.5 to 6 khz. [2] These amplitudes were then incorporated into the demo version of **Unreal Worlds #2**.

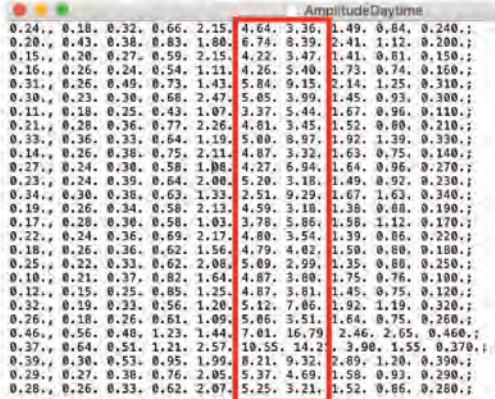


Figure 3: Frequency Spectra Amplitude Collection Output from Bonk~.

Timer output of attacks filtered through Bonk~ captured event timing. In these cases, audio that had been processed with broadband noise reduction produced the best results for analysing discrete rhythms and frequencies. The table below shows the timing of chirps from the Yellow Chat in Figure 1 with short pauses followed by 5-7 repeated chirps in rapid succession. The timing of events (short, or long) are variable, but the overall perception of long silences followed by short sound events are perceived as a regular and predictable pattern.

1536	4045	3996
103	92	103
95	157	106
103	122	122
129	141	130
109	78	109
111		
141		

Figure 4: Timer Analysis of Rhythms of the Yellow Chat bird.

Visual Analysis of Recordings

In addition to using Max to analyse recordings, I also analysed audio spectra visually to parse species activity and general proportions. All of this data informed the creation of sketches for **Unreal Worlds #2**.

Unreal Worlds #2: Probability Matrices

Sketches for *the work* use timing garnered from analysis patches and visual analysis of recorded spectra. The patch below triggers avian, and anuran sounds from the recording pictured in Figure 1 (e.g., Frogs, Robins, and Yellow Chat).



Figure 5: Max/MSP patch to trigger natural sounds.

Probability matrices created for each of the individual animal sounds incorporate timings between sound events into a transition matrix (middle of the figure).

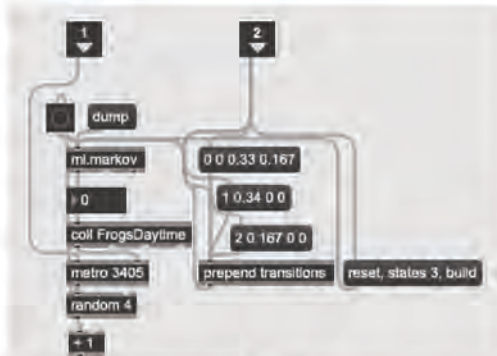


Figure 6: Probability Matrix

The sample analysed to generate the transition matrix was between two to three minutes in length, and though the sample length was short; the variation between entries of sounds from each species only generated between three to five states for each transition matrix attesting to the cyclic regularity of each species sounding in the chorus.

Conclusions

The *Unreal Worlds* project has been a fascinating journey of observation, aural perceptions, composing, audio analysis, and research in Bio Acoustics and Soundscape Ecology. *Unreal Worlds 1, 2* have revealed to me the potential for creating soundscape installations using samples triggered using probability matrices and the idea that a soundscape might be generated by assembling samples of its constituent parts. How many environmental recordings have been produced where the engineer waited to capture sounds absent the intrusions of ubiquitous anthropony? I propose sampling individual elements and reconstructing them as an experiment to yield information about environments with or without each of the constituents (e.g., biophony, geophony, anthropony). Further, I intend to continue gathering recordings in the

Appalachian region to gain a fuller understanding of the biodiversity of the region and/or experiment with soundscape recordings collected by others such as those in the Bernie Krause archive, or on Xeno-Canto. [4]

Notes

1. Bird call identification, **BirdNET** Sound ID. K. Lisa Yang Center for Conservation Bioacoustics, <https://birdnet.cornell.edu/> (accessed November 6, 2023).
2. *Unreal Worlds #1* https://drive.google.com/file/d/1V9Vkl0vzSC_hhM4gFNyhkJJ-dYU_o114/view?usp=sharing
3. Westerkamp examples: Beneath the Forest Floor <https://www.youtube.com/watch?v=n-U8iTyqKRA> Transformations: <https://www.youtube.com/watch?v=J5Aa-JskUY0>
4. Xeno-Canto wildlife sounds from around the world. <https://xeno-canto.org/>

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The Mariner Project: Generative Photomontage

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Abstract

The visual aesthetics of generative art are characterised by the wide-spread use of computer-generated imagery. The use of analogue imagery, such as photography, is relatively rare.

The *Mariner Project* helps expand the visual vocabulary of generative art by using photography as the principal visual material in combination with generative software processes to automate the production of photomontage artworks.

This research proposes that non-digital photomontage processes can be conceptually blended with generative computation in a holistic model of creative practice. This subsequent reduction in direct authorial engagement can enhance the production of novelty in surreal imagery.

The *Mariner Project*.

The *Mariner Project* is a series of art works, conceived as an exploration of Australia's colonial past, characterised by the alienation and existential terror experienced by Western European colonists on their arrival to the Australian continent.

This concept frames the horror of early European shipwrecks along the coast of Western Australia as a defining metaphor for a violent and destructive collision between European culture and Australia's landscape and Indigenous peoples¹.

The coast of Western Australia came to be known among Dutch sailors as the harsh and unforgiving end of the earth. It was to be avoided at all costs' [1].

The work featured in this paper uses visual material found in remote coastal environments of Western Australia to create a menagerie of monstrous creatures. These represent the visceral manifestations of colonial dread, and the dissipation of their humanity in an alien and annihilating landscape.

The conceptual goals of the project are realised via two techniques afforded by the generative system: (a) 'Authorial Distance' and (b) 'Defamiliarization'. This paper describes the digital and non-digital aspects of the generative photomontage system developed for the *Mariner Project*.

Authorial Distance

A key aspect of this work has been the use of generative computation as a strategy for exploring novel compositions. Generative systems, by reducing the author's direct engagement in granular decision-making, offer a form of authorial distance that can be equated to surrealist automatism.

The surrealists developed these automatic writing and drawing practices as a key device for by-passing conscious rationality in the search for novel imagery [2]. In this project I use generative systems in a similar way. Minimising direct authorial engagement allows for the use of randomness to subvert rational decision making, albeit via instrumentally controlling the balance between the two poles of chance and design.

Defamiliarization

Another key aspect of the *Mariner Project* creative process is the system's ability to make relatively recognisable and familiar source material, such as plant cuttings (fig.1), unfamiliar and strange (fig. 9).

The term "defamiliarization" was first coined in 1917 by Russian formalist Viktor Shklovsky in his essay "Art as Device" (alternate translation: "Art as Technique") [3]. Defamiliarization or 'ostranenie' (Russian: *остранение*), is the artistic technique/process the Russian formalists named of presenting common things in an unfamiliar or strange way so that audiences could gain new perspectives and see the world differently [4].

The *Mariner Project* uses formal processes of 'defamiliarization' to express the concept of colonial dislocation and alienation.

Stage 1. Location and material

The *Mariner Project* creative process started with the selection of geographic locations, relevant to the previously described themes and during a field trip in April 2023.

These locations included the coast between Perth and Cape Range National Park, and the Pilbara region of Western Australia. The locations were explored for objects to be photographed. Selection was based on formal properties such as shape, colour, or texture etc. that I considered aesthetically novel and evocative.

Because the collection of material is strictly limited to what is available in a location, the final aesthetics of the project are unpredictable, an emergent outcome of chance encounters when navigating and exploring the environment.

Characterised this way, the photographic procedures relative to the environment represents a form of analogue generative system in two respects:

1. Restricting photography to a fixed environmental location provides formal and thematic constraints analogous with rule-based generative software.
2. The unpredictable nature of what a location will provide reflects the key role that chance (pseudo-randomness) plays in the production of novelty and variation in a generative system.

Although the analogue and digital aspects of the generative system remain palpably different, they share a common level of conceptual abstraction in terms of how I develop creative strategy and working methods.

Stage 2. Select and photograph objects.

The visual components of the project's generative visual design system are derived from objects that are found and photographed on location.

This paper uses a pair of objects, two green shoots from an unidentified plant, found in the dunes of a beach in Cape Range National Park in Western Australia as illustrative examples (fig.1).

The photographic process used in this project is informed by two central requirements of the generative image making process (A) Formal Modularity and (B) Formal Diversity.

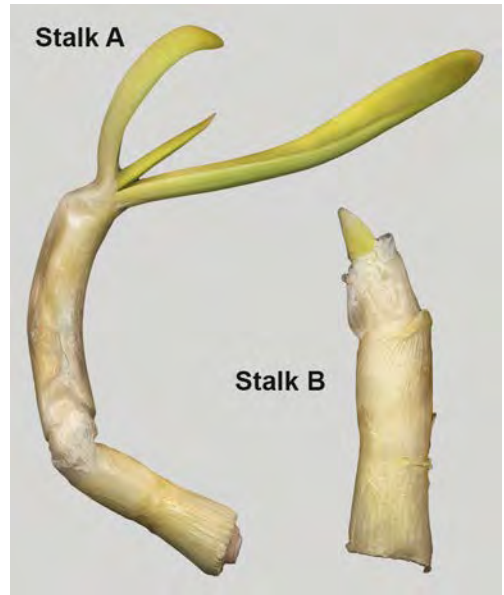


Figure.1. Two similar plant stalks.

A. Formal modularity.

The *Mariner Project* generative process requires many photographic elements to be seamlessly combined to form the image of a surreal face that retains the mimetic illusion of a real object (Fig. 8).

To achieve this, each photograph needs to share the same lighting conditions, and lens optical characteristics such as focal length, focus, light transmission (iris, aperture, and *f*-stop).

Maintaining this level of conformity is made more difficult by the necessity of photographing objects in the field. Removing natural material (objects) from Australian parks and reserves is prohibited and photography needs to be done on site. For this reason, objects were photographed using a portable flatbed scanner. This form of digital image capture produces images that have fixed lighting and lens optical characteristics and are thus suitable for seamless combination via digital imaging montage processes (fig. 1).

B. Formal diversity

The project's generative system creates images by combining and arranging a relatively small and finite number of photographic images (the 'image element library') into a potentially infinite number of final compositions.

Thus, the richness, variety and diversity of final compositions is enhanced by increasing the diversity of shape elements that are available in the image element library.

To increase a range of image elements available from the same object, each is photographed at vertical, horizontal, and perpendicular angles. Each plant stalk was photographed and then rotated forty-five degrees and re-photographed until eight separate images were produced (fig.2).

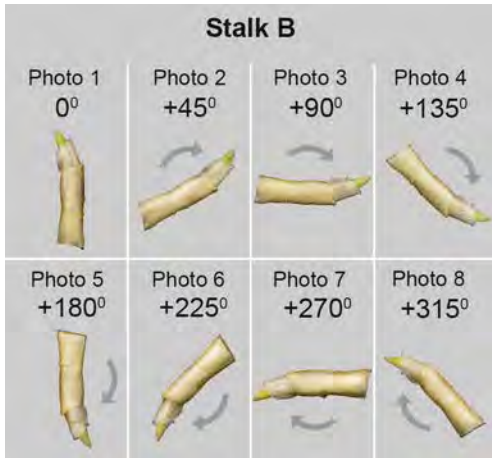


Figure 2. Stalk B photographed at eight different angles.

Because flat-bed scanners have an internal light source that is 'above' the scanning array, the images produced have a distinctive, directional lighting and so the same object, angled differently, will produce an image with different high lights and shadows. This variation adds diversity to the library of image elements.

Also, an object can be turned over and photographed from its opposite side if this provides an aesthetically pleasing result. The process of rotation is repeated, and another eight images are produced.

Stage 3. Create a diverse image library.

As outlined in the above, each discreet object is photographed at least eight times. However, because the images are of the same object at a different orientation, there is very little variation in terms of overall shape within the image set.

This next step uses image manipulation software to create a more extensive and varied library of image shapes. Adobe Photoshop 'Actions' (software macro) are used to automatically chop and distort (bend) each original image into fourteen different shapes (fig 3.).

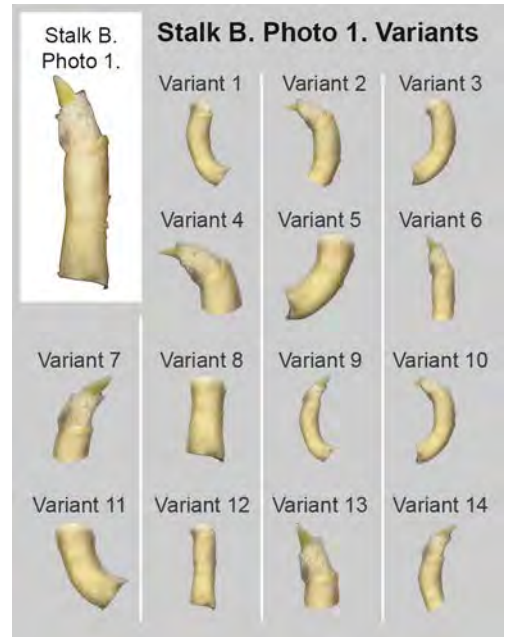


Figure 3. Stalk B chopped and distorted (bent) into a range of shapes.

These software macros are designed to be reusable and work on almost any scanned object image, accommodating variations in image size and shape. Applied as a 'Batch Process' from within Adobe Photoshop, this automatically produces a library of 120 image elements derived from the 8 initial photographs. Thus, the two objects used in this example of the project resulted in a final image library of 240 shapes (fig.4 & fig.5).



Figure 4. Stalk A photographs produce a library of 120 'modular' image elements.

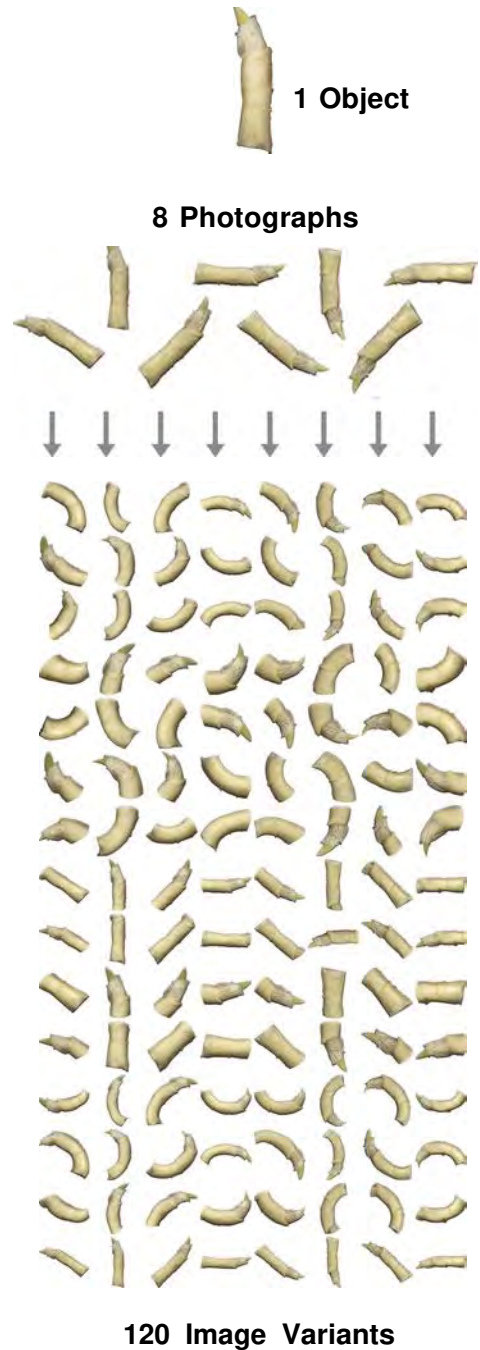


Figure 5. Stalk 8 photographs produce a library of 120 'modular' image elements.

Stage 4. Final image assembly and selection

Following the preparation of a library of 240 'modular' image elements, the next stage of production (composition) is carried out with an off-the-shelf version of Adobe After Effects, an industry standard visual effects software package. In very simple terms, this software could be described as *Photoshop* + time. *After Effects* is usually associated with the production of motion graphics and visual effects content in video sequences².

After Effects has 'Composition' spaces based on a timeline where video and animation footage are composed and edited in layers like those used in *Photoshop*. The *Mariner Project* uses each frame in the timeline as a discrete image space.

The first composition in the project is five thousand frames in duration. This number is not arbitrary. The generative system is a single After Effects document composed of multiple nested composition spaces and each one has the same duration of five thousand frames. The final output of the system is a sequence of five thousand images. Each one is a separate character design and a final artwork. This number of images represents the 'search space' I will explore to find the project's final range of exemplars. The number is chosen because five thousand images can be comfortably reviewed within an afternoon of work.

The library of 240 image elements (fig.4 & fig.5.) is imported into this first composition as a sequence of images, one per frame, and the sequence is looped so that the 240 images will repeat across the five thousand frames. Whereas the playback of a composition would usually move through each frame

sequentially at a prescribed number of frames per second, the *Mariner Project* uses a time remapping script that moves the playback marker to random frames in the compositions at the prescribed frame rate (e.g., 30 frames per second). In this way the system chooses image elements randomly and this technique is used for numerous random selection processes throughout subsequent composition spaces in the project.

The first level of image composition occurs when the randomised image sequences (usually no more than two or three) are imported into a composition space and combined to form a range of more complex visual elements (Fig.6).

The size and position of each image sequence is a mix of (1) fixed rules and (2) semi-random variables.

1. Fixed rules.

The maintenance of fixed rules for certain operations continues throughout all levels of the work's composition. For example, the image elements may be scaled or repositioned but never rotated. All the raw imagery in the work is initially photographed (scanned) with a light source from a similar direction (top down). If the orientation of each image remains unchanged then disparate elements can be seamlessly combined while still sharing the illusion of being lit by a common light-source within the picture frame. This ensures that the artwork maintains an illusion of optical reality despite being a fictional construct composed of a vast array of different visual elements.

2. Semi-random variables.

By contrast, the scale, position, and opacity of these image elements relative to each other within the work's frame

space is a semi-random function of the system. As with the selection process, randomness operates within parameters that I manipulate creatively³.

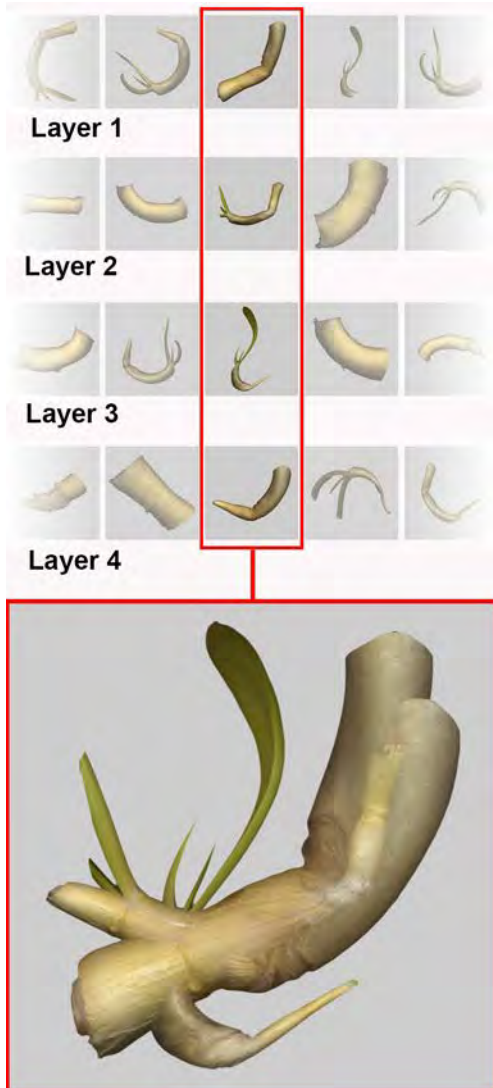


Figure 6. Primary visual elements combined to form secondary compositions.

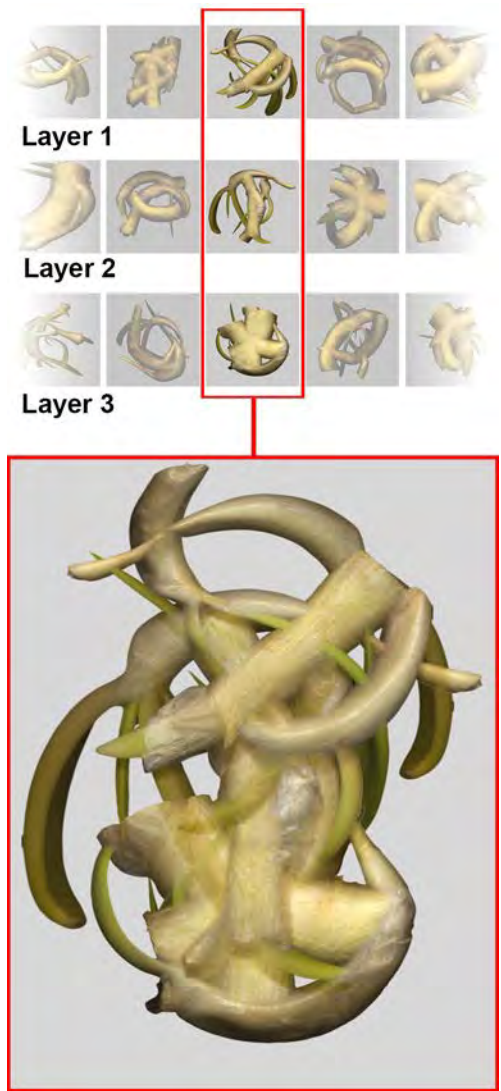


Figure 7. Secondary compositions are combined to form complex compositions.

The first level of image composition (Fig. 6) effectively produces a new library of elements from which the next level of combination randomly draws its raw elements. The same semi-random selection and organization rules of the first

level are repeated to produce new configurations of imagery (Fig 7).

This process of combination proceeds through several successive levels and the imagery grows in visual complexity. Key to this model is that even small degrees of random variation across as little as three or four levels of combination can produce vast and unpredictable populations of variety and emergent form.

At a basic level of abstraction, the structure for such a system is relatively simple to articulate and model in conceptual and computational terms. Any image that is recognizable as a face is essentially defined by a set of generic rules for the relative position, size and shape of a few key facial elements. For example, a 'smiley face' is simply two points, a line and a plane put into the correct spatial relationship (e.g.: **J**).

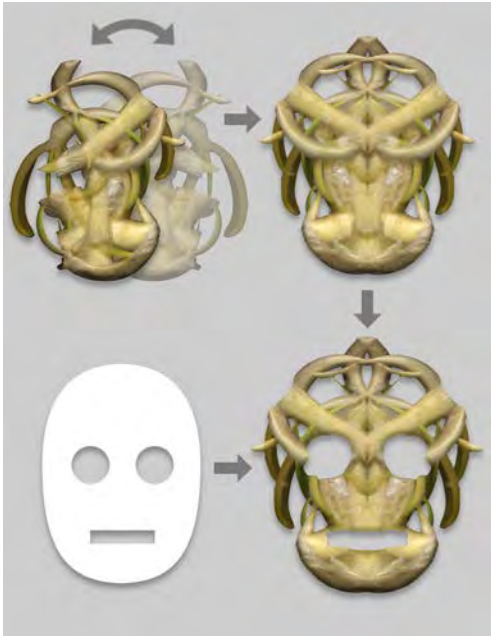


Figure 8. Complex composition with vertical symmetry & subtracted facial features.



fig.9. final compositions each contain up to sixty raw photographic elements.

Random variations of the facial element's Cartesian properties (e.g., size and position) can, if maintained within acceptable bounds, give rise to the endless diversity of new faces. Depending on the project, these photomontage compositions contain up to sixty raw photographic elements (Fig.9).

I then review the final population, evaluate the individual merits of its constituent artworks, and select a final range of exemplars for final use. The system produces a search-space population of five thousand discrete portraits. The possible number of variations is potentially infinite, but the number produced is based on the number of images I can comfortably review across a working day.

Discussion and conclusion

The above description intimates a linear and progressive construction process, but this does not capture the essential character of the process. An important factor in this method of working is that the software structure is not designed in stages but begins as a complete productive entity that produces a large population of finished compositions from its earliest inception. My part in the system's creative development is primarily via the calibration of random variables while viewing (in real-time) the results in a representative sample of the artwork population.

Via a process of review and adjustment, I work the software's 'rules' towards settings that produce an optimal richness of useful variation in the artwork population. This optimal state is generally a point where surprising and aesthetically pleasing configurations will emerge.

In this model of practice, 'chance' becomes a primary artistic medium and over the course of my research, I've learnt to manipulate it in the same way I previously learnt to use colour, form and tone etc. A key principle in this model is that the production of novelty via random variation is always mediated by the risk of losing coherence. Ernst Gombrich articulates how aesthetic pleasure is located at a point between order and disorder.

... how ever we analyse the difference between the regular and the irregular, we must ultimately be able to account for the most basic fact of aesthetic experience, the fact that delight lies somewhere between boredom and confusion [5].

An important virtue of this process is that I am never involved in the specific construction details of any discrete artwork or animation at any stage. My creative decisions are always conceptualised and made to the population via adjustments to the generative software's various levels of abstraction and rules. Each new adjustment effectively changes every member of the artwork population and subsequently my experience of individual works approaches that of 'the innocent eye' [6] of an audience's initial experience.

By reducing my conscious agency from the intimate details of the artworks production, I significantly improve the potential for novel surrealism in the outcome. Another key aspect to achieving this is the system's ability to create a diverse range of photographic image elements from a restricted initial source and combine them in ways that defamiliarizes their initial visual identity.

A central role of the computer in the future of creative practice has been identified as that of a 'colleague.' [7]. To this end, my research has worked towards the development of personalized generative software that can be integrated into my daily creative practice at an intimate level. My research proposes that the formal and conceptual processes that manifest a personal visual style in a photomontage art practice can be codified as discrete software functions [8]. As such they can then be usefully deployed independently of direct human authorial agency. Via my studio-based practice, I have demonstrated the practical value of generative computation as a toolset complimentary and additional to traditional practices of field photography.

¹ On 4 June 1629, the Dutch sailing ship *Batavia* was wrecked on the Houtman Abrolhos, a chain of small islands off the western coast of Australia. Over a 2-month period before rescue, the survivors were subjected to a reign of terror by a group of mutinous sailors. 120 of the ship's passengers and crew, who survived the wreck, were murdered by the mutineers before a rescue ship arrived.

² Key to the viability of this project is the re-conception of how this software's linear production paradigm can be used as a non-linear generative system. Importantly, Adobe software products such as Photoshop and After Effects are widely used. Whereas dedicated generative art and design software and coding practices often require prohibitive levels of expertise, graphics software suites such as Adobe's offered my photomontage art practice a creatively intuitive and accessible path to generative practices.

³ This process of randomisation offers the first opportunity for parametric control. If the library of image elements is split in two separate folders based on, for example, fat and thin elements, then they can be imported as two discrete sequences into the first composition. If each sequence is made visible for each half of the timeline, then the random time remapping script will ensure that there is a 50% chance of either the fat or thin images being visible at any given time in playback.

The selection is semi-random in that controls can adjust the probability of certain image selections being made based on pre-defined formal distinctions. For example, if the images in the image element library have meta-data relating to

colour or shape etc., then they can be imported as discrete image sequences into a composition timeline. Adjusting parameters can manipulate the odds to favour the selection based on these properties. I can also calibrate the selection process to favour a thematic distinction such as that between manufactured or organic objects.

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Evolution of Generative Imagery During the Pleistocene

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Universal images in Nature | Flickr, Nbezruczko@thechicagoschool.edu



Abstract

Some Pleistocene images and artifacts are hundreds of thousands of years old and may have preceded stone tools dated over 3 million years old. However, archaeologists are conflicted about their evolutionary significance. Some attribute seminal generative cognitive functions to making rock images that contributed to literacy and technology. Others simply dismiss them. Present research conducted a hermeneutical inquiry into the generativity underlying Pleistocene images that inexplicitly now appear in contemporary human cultures. Sensitivity to events in Nature and expressive exaptation are the central hypotheses, and results suggest that natural selection for psycho-motor coordination and aesthetics may have been instrumental to their incremental advance.

1. Introduction

The Pleistocene era was a geological period in “deep time” that began about 2.6 million years ago (Mya) and ended approximately 10 thousand years ago (Kya). A period of dramatic ecological change, which was characterized by several migrations out of Africa into Europe, Middle East, and Southwest Asia. Some archeologists have long speculated that images and artifacts made by hominids and hominins during this period mediated cognitive advances that we now call generative art [1]. Somehow, human ancestors extended their native symbolic capacities that were already common among higher mammals [2] with complex semiotic sign capacity and spontaneous generativity [3]. These advances would contribute to an evolutionary trajectory that would ultimately separate hominins from archaic primates. Yet virtually nothing is known about these adaptations, but a long trail of rock images now leads to *Homo sapiens*.

An enigmatic aspect of Pleistocene imagery is their appearance in contemporary 21st century cultures. Inexplicitly, Pleistocene images now appear in early childhood scribbling [4], contemporary Western paintings [5], and commercial designs, and they are distributed across macro and micro levels

of scale in Nature [6-8]. While substantial research has examined production and refinement of stone tools, virtually none have been conducted of paleolithic imagery, which in fact promises even greater understanding of higher cognitive evolution. Consequently, research is needed to clarify the contribution of Pleistocene imagery to cognitive evolution, and the transmission of cognitive structures across millennia. The following sections outline a strategy to conduct hermeneutic phenomenology to address those goals.

1.1 Marks of consciousness

Though these old images are from art makers long dead, we can almost know them [hominins] through their art objects, feel the same processes operating in their minds, for those are not just marks made by hands but marks of consciousness, marks of developing brain synapses and circuitry in no large way different from our own, p.147 [9].

The objective of this research was to conduct a phenomenology of Pleistocene imagery. Prominent among several obstacles was understanding hominins' intentionality and consciousness, as well as conceptual continuity of images across time. They were addressed by "fusing" the horizons between hominins and humans [10] with an existential link abstracted from shapes and patterns in Nature (see Figure 1). Nine image fragments from Pleistocene culture represent a universal regularity of sun, water, and spirals in Nature. In the present research, they are primordial echoes that are believed to resonate in the contemporary Life-spaces of human

visual preferences through epigenetic DNA encoding [11]. Figure 2 presents their appearance in paintings and pottery, and they are common across cultures. In addition, their continuity across "deep time" is supported by an immense ontology appearing in biological cells but also celestial galaxies that is unchanged over millions of years. Arguably, their ubiquity is ingrained in the Universe, in insects, mammals, and humans defining a reality associated with survival [3, 6]. More specifically, those images are from the path that hominins took, and *Homo* followed.

2. Hypothesis

The hypothesis here is some hominids millions of years ago perhaps by chance perceived shapes and patterns in Nature and scratched images in the sand or on stones. A very rare event as primates in Nature do not spontaneously draw. Natural selection then conferred a reproductive advantage on this spontaneous expressive sensitivity, which was phylogenetically continued through the hominin line to *Homo sapiens*. Nine images are believed to represent abstractions of hominin perceptions of Nature.

3. Research questions

The central question here is how hominins and possibly earlier hominids initiated, maintained, and extended mark-making that is now widely interpreted in artistic terms. This remarkable advance has baffled anthropologists throughout the 20th century and remains unresolved.

Figure 1. Universal images in Nature and through time. Column A presents images from Hodgson [28], and some are hundreds of thousands of years old. Column B presents images from contemporary early childhood drawings originally identified by Luquet and rediscovered by Kellogg [4]. Column C presents abstracted images from their origins in Nature appearing at micro and macro levels of scale. This set of images also appears in contemporary visual art [29], and commercial design. The key point here is hominins are believed to have recorded their sensitivity to Nature in images, and this behavior was naturally selected. Preference for those images was assimilated over millions of years and is now in a collective human subconsciousness. Young children scribble them in drawings, professional artists paint them, and humans in general visually like them. In addition, the shapes are embedded throughout the Universe in biological cells to celestial galaxies, which suggest a fundamental affinity to ontology.

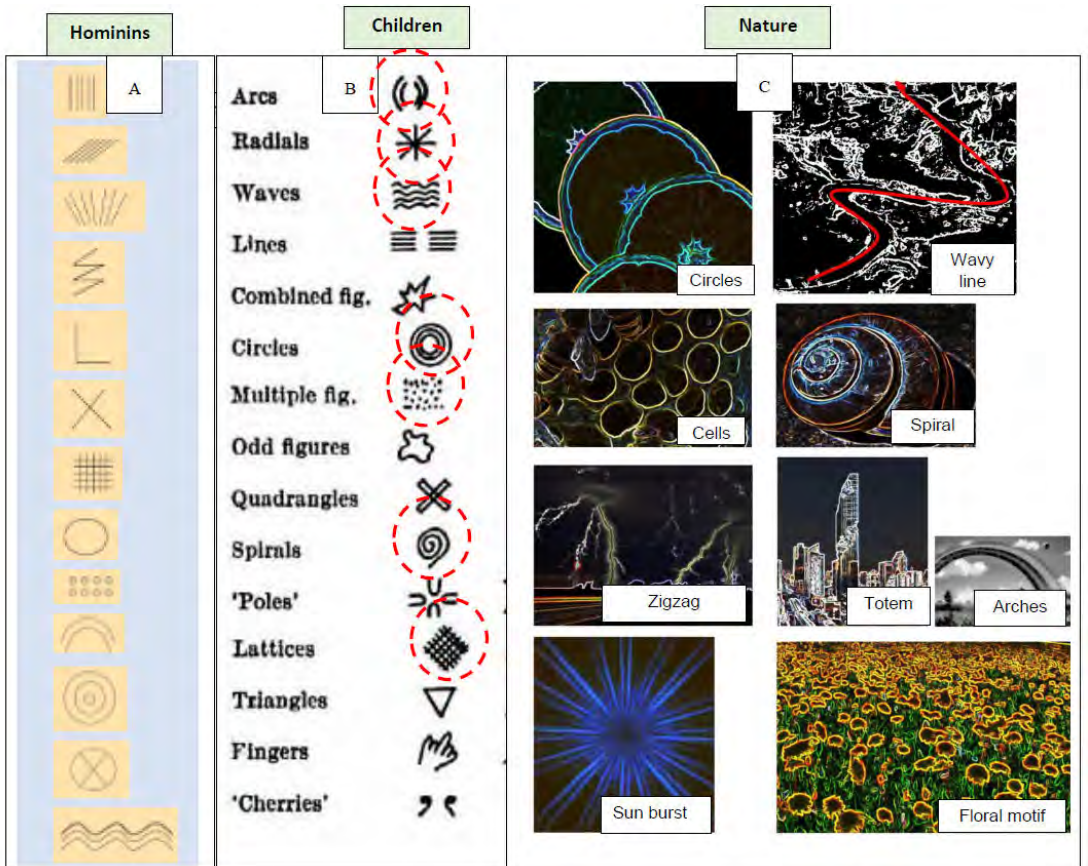




Figure 2. Universal images through art history. Among intriguing aspects of Paleistocene images is a subset called UIs that reappear throughout the history of visual arts but also in contemporary paintings and commercial designs. But even more surprising is the unawareness and sometimes overt scorn that viewers have for UIs despite obvious satisfaction seeing them in paintings. Consequently, we are forced to consider UIs as deeply ingrained in the human subconscious though viewers may be oblivious to them. In the present research, archaic hominins are believed to have abstracted images from Nature, which they preserved in drawings. Finally, hominins who followed

this path of graphic expression were naturally selected.

Specifically, what does Pleistocene imagery embody about their makers that might help understand them better? Then what do apparent changes in the expression of images and artifacts over hundreds of thousands of years reveal about hominins' cognitive evolution?

4. Methodology

4.1 "Being in the world."

In looking at any phenomenon, one must place it within its possibilities, its variations., p.16, [16].

Following Heidegger's lead, we may legitimately ask about hominins, what was their "being in the world"? To understand them better, a primordial leap across hominin externalizations to contemporary *Homo sapiens* consciousness would be needed, which could enable a reflective shift "to the things themselves". That strategy was implemented here by linking hominins and humans together through common images in Nature that also appear among Pleistocene images and in contemporary cultures. They established a survival background for conducting a hermeneutic cycle of hominin externalizations. The philosophical foundations underlying this approach to understanding Pleistocene images was discussed by Merleau-Ponty in his account of "nested gestalts" [18].

In practice, conducting this hermeneutic cycle first centered on a hominin survival background defined by signs in Nature. Then a dialectal, iterative process interpreted a sample of Pleistocene images from the archeological record, which incrementally generated transcendent meaning revealing a coherent network of image themes. Moving in the direction of reification, a complex process of concrescence enacted a "tentative" reality for interpreting images and artifacts [12].

As Gadamer explains, 'It is a circular relationship. . . The anticipation of meaning in which the whole is envisaged becomes explicit understanding in that the parts, that are determined by the whole, themselves also determine this whole. [13]

While literally bringing images "back to the things themselves" is obviously impossible, a culturally enacted reflection of images conducted here projected inferences that converged in a harmonious collective "voice".

To make one more point concerning the 'voices' of evidence, harmonies are most likely to arise when there are convergences, p. 24 [14].

The legitimacy hence validity of phenomenological insights presented here was justified, first, by perceived directness. Clearly, hominins directed conscious intentionality to making externalizations and specifically mark-making. Secondly, conducting a hermeneutic cycle is a concrescent process that was informed and embellished by assemblages and fossils in a predator ecology [12]. Together they mediated an obvious gap in mentality between hominins and humans that ultimately justified understanding and Truth. Heidegger would describe this process as knowing externalizations for "what they are in themselves and on their own terms" hence better to know hominins themselves.

I suggest that we start by thinking of . . . the artifact, and the process of analysis . . . which includes perceiving and acting and interacting with the artifact . . . to be the complex concrescent process that enacts meaning, p.16 [12].

4.2 Method: Sampled images

This research required two sets of images. First, nine templates were abstracted from Pleistocene images that

are believed to represent universal events in Nature, which also appear in child scribbles and contemporary paintings. They constituted a background (see Figure 1). This abstraction represents a synthetic “reality” that joins horizons and accommodates limitations of examining the phenomenon of Pleistocene images.

Then a second image set was selected from the archeological record of tools, weapons, mobiliary art, cave art, and body ornaments, which represented the objective diversity of authentic hominin externalizations (n=30). This sample can be viewed online [17]. They were hermeneutically rotated against an abstracted background in Nature, which enacted meaning. An explicit manipulation of figure and ground that yielded a gestalt of the image sample.

4.3 Method: Implementation of hermeneutical cycle

Together, abstractions from Nature and Pleistocene images during a hermeneutical cycle established a “phenomenological epoche” in Husserl’s tradition, which created conditions for convergence. Notably, this process emphasized *prelinguistic* reflexivity [18], which differed substantially from conventional phenomenology. A method that typically depends on unique “lived” experiences as revealed during participant interviews. Yet, inert visual images also embody a latent, but prelinguistic narrative that is realized through recursive hermeneutic mediation and reconstituted through interpretation. This coherent reconstruction here yielded knowledge about hominins.

We are concerned with developing a methodology that is explicit . . . contributing to an understanding of the conditions under which phenomenological knowledge is produced, p. 35 [19].

The following procedural steps were implemented. First, hominin culture was contextualized during a conditioning phase by conceptually embedding externalizations in a predator survival environment – a consolidation of information referred to as *conrescence* [12]. During this step, abstracted images of Nature sensitized observers to concepts of survival and security. Then a second set of Pleistocene images followed, which were first examined individually to clarify unique attributes. Then they were collected and compared in pairs to identify shared properties until all possible pairs were exhausted. This procedure is frequently called the constant comparative method [20]. Finally, pairwise results were interpreted for commonalities, cohesion, and emergent trends. Results from this procedure described perceptual structures precipitated by systematic examination of embodied Pleistocene images presumably transcendent, hence independent of time and place. Phenomenologically, Husserl would have referred to these results as “essences”. Specific images, of course, would vary across these essential structures.

After hermeneutical interpretation, the collected images were arranged in hierarchical semiotic order as defined by Peirce’s Theory of Signification. Those externalizations that were clearly indexical were lower on the hierarchy, while those associated with arbitrary

abstract motifs were much higher. The method implemented here was pragmatic intending to understand the images in the context they were expressed, and these results pointed to differences in semiotic properties.

5. Results

Many qualitative structures emerged during hermeneutic reflection, and a pragmatic philosophy emphasized material expressions, which were reduced to a small set of shared dimensions. Following structures were identified in all externalizations:

- **Perceptual awareness:** Degree of conscious perceptual mediation that was required to physically produce an externalization. Simple smashed rocks do not require as much conscious deliberation as a figurative narrative.
- **Ideation and proximity:** Every physical object and image displayed a conceptual distance from an idea. This distance was minimal for concrete objects such as tools and weapons, which are directly linked to physical ideas. Mark-making was typically a representation of animate or inanimate objects mediated by an idea, sometimes unknown. This issue of object proximity to ideas appears in all externalizations.
- **Psychomotor coordination:** Visual motor coordination is required to render an image, which presents a practical challenge. Difficulty is further increased as explicit intentions such as concrete, representational image, narrative content, and design properties become prominent.
- **Spoken language origin:** Externalizations varied in amount of relative spoken language that would have been necessary to produce them. Less spoken language would be needed for concrete objects versus representational figurative images. For example, more narrative content presented in visual images would suggest a more significant presence of spoken language.
- **Aesthetic sensitivity:** Externalizations displayed qualities reflecting preference. Contemporary visual arts authorities consider visual preference an indication of personal aesthetic values. Hominin's expression of uniformity, balance, simplicity, striving for perfection, and consistency in images are several recognized qualities that can be objectively identified without attributing cultural functions or importance.
- **Written notation and symbolism:** Evidence of arbitrary rules imposed on production of images. For example, syntax among images was documented in drawings [21-25]. Likewise, lunar calendars and counting devices presented evidence of rules and order. Construction of complex tools also demonstrated procedural rules.

6. Discussion

When one moves . . . into the Lower Paleolithic [2.6 - 1 Mya], assumptions regarding . . . meaningfulness must

be questioned. Rather than asking what something meant, we must ask whether something meant anything at all. We cannot assume that *Homo erectus* thought in the same fashion as *Homo sapiens* p. 63-66. [26]

The things at stake were originally acts of intentionality across an evolutionary span of over 3 million years, and their meaning now is hopelessly obscure. Indeed, no matter how similar images from the Pleistocene and 21st century may seem to be, that they had comparable meaning is highly unlikely. To accommodate this concern, three pillars of philosophical phenomenology -- essence, meaning, and understanding guided this interpretation of externalizations. More specifically, a method was embodied with what is believed eternal in the Universe to bridge an immense gap between hominins and humans, which yielded results surprisingly coherent. In addition, hermeneutics in the context of a pragmatic semiotic signification theory provided additional insights into images and consciousness within a time-invariant framework. Altogether, they point to an ontology, which, arguably, constitutes objective knowledge [15].

Those structures identified here point to much stronger semiotic pressure in Nature on hominin evolution than commonly recognized, which complements contemporary models of hominin cognition and tool making aptitude [27]. Hominin perceptual sensitivity to semiotic pressure likely led to natural selection.

In general, the structures identified here raise questions about the cognitive adaptations that would have been needed

to maintain effective hominin interactions with Nature for over 3 million years. For example, the cognitive leap from earliest symbolic conceptions needed to generate metaphorical insights associated with tools to the generation of notation devices and literacies was enormous. Clarifying those adaptations that made that trajectory possible remains a challenge.

6.1 Summary and conclusions

Results here suggest that hominin externalizations differed along at least six transcendent dimensions. Despite variation across deep time, all images can be represented to some degree on them. Surprisingly, the shared dimensions identified here were not chaotically organized or random, and, in fact, were well-defined pointing to separate pathways for image-making, aesthetic sensitivity, and notational literacies. The simplest externalizations (rock smashing) only required perceptual awareness of natural events and capacity to mimic them. More complex externalizations demonstrated ideation, and psycho-motor coordination, which incrementally improved over thousands of millennia. Aesthetic sensitivity presented an unexpected and separate pathway with existential implications. This semiotic progression culminated in arbitrary symbolic expression that was eventually characterized by notation and syntax in the Middle Stone Age (280 to 50 Kya).

The results here also showed that sampled Pleistocene imagery defined a pragmatic semiotic hierarchy, which provided insights into the complexity of cognition needed to produce them. For example, the lowest level of semiotic function was direct ideation of an object

without graphic mediation such as figure or shape. Those results suggest hominins already had substantial symbolic capacity more than 3 Mya making primitive rock implements called Oldowan choppers. They are the earliest evidence of a generative image by an ancestral human that would have required concrete conceptualization of a functional tool, and a metaphorical capacity to foresee its usefulness. In other words, possibly hominids and certainly hominins had the capacity to infer simple cause and effect relations. In addition, present research asserts that hominins had a semiotic response to perceived forms that were like other mammals but with a unique aspect, arguably, related to metaphorical insight. They perceived patterns in Nature and decisively preserved images of them. These results suggest that visual thinking preceded tool making.

In general, these results suggest hominins engaged in more symbolic functioning during Lower Paleolithic than archeologists commonly believe. In fact, assertions that hominins “leaped” into modernity and became anatomically modern humans only about 50 Kya, a distinctly European-centric claim, was probably more associated with fine motor coordination than significant advances in cognitive capacity. The brilliance of their visual art, notably at Altamira and Lascaux appears to have prompted a myopic jump to conclusions. Results here suggest cognitive trajectories and adaptations preceded contemporary *Homo sapiens* by millions of years.

A conclusion reached here is much published discussion about Pleistocene imagery is distorted by motor

development, which conflates images and tool making. While physical finesse producing beautiful images and refined tools is recognized relatively late in the archeological record and garners enormous attention, present research suggests that aesthetic and cognitive advances had appeared much earlier. Arguably, hundreds of millennia before motor coordination differentiated tools and aesthetics.

Finally, the identified structures here are excellent candidates for future empirical analysis. Any of them could be empirically parameterized and associations examined with prospective ecological influences or other parameterized forces. Statistical models would be logically possible.

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Prosthetic Godhood and Lacan's Alethosphere: The Psychoanalytic Significance of the Interplay of Randomness and Structure in Generative Art

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Abstract

Psychoanalysis, particularly as articulated by figures like Freud and Lacan, highlights the inherent division within the human subject—a schism between the conscious and unconscious mind. It could be said that this suggests that such an internal division becomes amplified in the context of generative art, where technology and algorithms are

used to generate artistic expressions that meant to emerge from the depths of the unconscious. Here, we encounter the tension between the conscious artist and the generative process itself, which may yield unexpected, even uncontrollable results.

This paper, therefore, seeks to address this division within the modern subject and its relationship to technology, wherein the division within the living body is revealed through the presence of prosthetic elements, which mirrors the division brought about by the incorporation of language as a signifier. I argue that the amplification of this internal schism does not necessarily lead to a more fractured subject. Instead, generative art, bolstered by advancements in AI and machine learning, offers a unique opportunity for individuals to externalize and explore their minds in novel ways.

By examining contemporary works such as Hal Foster's *Prosthetic Gods*, which stands as a pivotal exploration of the convergence between modernist art and psychoanalytic theory and Isabel Millar's *Psychoanalysis of Artificial Intelligence*, this paper elucidates the profound implications of Freud's vision of modern

subjectivity as Prothesengott (Prosthetic God) and address the questions concerning this technological imbrication of the human mind and body through the Lacanian framework. Although for Freud, Man does not become a real God, rather, the potential to transcend one's limitations ascribes us to God-like qualities by seeking to generate new forms of life that go beyond merely reproducing nature — a transgression of the natural. Millar emphasizes that Freud observes that this is evidenced by the fact that these additional organs remain distinct from the organism and can never assimilate into it. One continually falls short of realizing the fantasy he envisions, opting instead to use his supplementary artificial organs to endlessly revolve around the objects of the drive.

This evolving relationship that the drive has with its technological objects, resounds in Lacan's conception of "lathouse" which allows extimate objects to convert interiority (unconscious) into exteriority (conscious) and exteriority into interiority. The thesis of this paper seeks to employ this underutilized concept to understand the nature of human subjectivity and its bodily and structural relationship to generative art. Therefore, this paper emphasizes what really happens when we enter into this relationship with the lathouse, whereby this artificial object has effects in the "real of jouissance", where these Lathouses create a network, namely the Alethosphere. My goal is to argue that generative art as a technological development, can be seen as an extension to the development of the drive. Conclusively, I make the for generative art's potential to externalize the human creative drive by emphasizing

the interplay between randomness and structure, and how it offers a means to surpass our inherent limitations by presenting an avenue for self-expression that transcends traditional modes of art.

1. Introduction

In psychoanalysis, the exploration of the unconscious and its inherent drives is integral to understanding the construction of the "self." Sigmund Freud's seminal work introduced the notion of the human self, revealing an inherent split (Spaltung) within the subject, notably between the ego and the id [1]. This division delineates the intricate negotiations between internal and external realities, as the ego grapples with the complexities of mediating these conflicting forces.

Jacques Lacan further expounded on this internal division in his influential works [2-3], positing it as a fundamental characteristic of subjectivity itself. This division, originating in the processes of individuation during infancy and the subsequent entry into the symbolic order of language, is epitomized by the concept of the barred subject (\$). This symbolic representation signifies the subject's entry into the symbolic order, marked by a lack due to castration and the loss of original unity, resulting in a perpetually divided subject. Lacanian psychoanalysis, recognizing that lack constitutes subjectivity, strives to elucidate this absent component through the subject's engagement with the symbolic.

This paper endeavours to explore the contemporary manifestation of this internal division within the modern subject, particularly in its interplay with technology. The division within the living

body becomes evident through the presence of prosthetic elements, echoing the division induced by the incorporation of language as a signifier. Both phenomena contribute to a disruption of unity and the introduction of lack or absence. Prosthetic elements, functioning as external additions, symbolize a form of supplementation or compensation for bodily deficiencies.

Similarly, language operates within a system of differences, signifying meanings and continually underscoring the absence of a fixed, unambiguous signified [4]. In this context, prosthetic elements and language act as mediators, unveiling the underlying division within the subject. They facilitate a perpetual negotiation between unity and fragmentation, presence and absence, within the individual's experiential domain.

This paper posits that the amplification of this internal schism in the case of generative art, could indicate a more fractured subject, ensnaring its subjectivity in yet another domain of extensionality. However, it argues that while language and prosthetic elements introduce division through different means and operate in distinct realms—language in the symbolic, and prosthetics in the tangible, corporeal domain—prosthetics such as Artificial Intelligence do not induce the same division as the signifier. The paper therefore contends that AI has the potential to reconcile the pleasure principle and the reality principle within Lacan's underused concept of the "alethosphere," wherein individuals can externalize their minds in innovative ways.

Hence, this project seeks to interrogate the intricate interweaving of technology with the human mind and

body within a Freudian-Lacanian framework. More precisely, it formulates two essential inquiries that probe into the nexus of human subjectivity and technological advancements, particularly focusing on Generative Art:

1. In what manner does Freud's concept of prosthetic godhood find relevance in the context of generative art?

2. How does generative art function as an extension of the drive circuit, especially considering the inherent randomness and structural aspects within its composition and its relationship to the alethosphere?

In pursuit of addressing these inquiries, a comprehensive exploration will be undertaken, delving into contemporary works such as Hal Foster's "Prosthetic Gods" [5] and Isabel Millar's "Psychoanalysis of Artificial Intelligence." [6]. Foster's work stands as a significant exploration at the crossroads of modernist art and psychoanalytic theory, offering invaluable insights. Meanwhile, Millar's contribution specifically dissects the ramifications of Freud's conceptualization of modern subjectivity as Prothesengott (Prosthetic God). This investigation aims to illuminate the profound implications of Freud's vision and engage with inquiries regarding the intricate entwining of the human mind and body with technology within the contours of Lacanian psychoanalysis.

The exploration of these contemporary works serves not only to enrich our comprehension of the intersection between art and psychoanalysis but also to underscore the persistent struggle individuals face in realizing the fantasies associated with adopting supplementary artificial organs. Rather than attaining fulfillment,

individuals often discover themselves caught in an unending orbit around objects of desire. This paper thus examines enduring relationship between the human drive and its technological artifacts, as it resonates with Lacan's concept of the "lathouse," wherein extimate objects facilitate the transformation of interiority (unconscious) into exteriority (conscious) and vice versa. Fundamentally this concept allows us to locate the drive within the alethosphere of technology and situate it beyond the object cause of desire (object a).

2. Freud's Prosthetic Godhood

Man has, as it were, become a kind of prosthetic God. When he puts on all his auxiliary organs he is truly magnificent; but those organs have not grown on to him and they still give him much trouble at times. [7]

The exploration of Freud's concept of prosthetic godhood serves as a critical entry point into an analysis of contemporary perspectives on technology, embodiment, and human desire. Freud's skeptical perspective on the extension of the body into utopias, manifested in the idea of a prosthetic god, challenges the notion that contemporary individuals find fulfillment in this god-like character [7]. This skepticism is rooted in the recognition that the desire for a technologically driven transcendence mirrors an unattainable future, coupled with a nostalgic yearning for an equally unachievable infantile past, as articulated by Andjelkovic [8].

Deriving inspiration from the classical representations of gods and goddesses in Ancient Greek statues, crafted to propagate an idealized bodily

form, Lacan [9] and Sloterdijk [10] emphasize a connection between cultural ideals and representations that can function as mirrors [11]. In this vein, Lacanian psychoanalysis discerns an intertwined evolution between technical artifacts and human desire, positing that technologies, far from satisfying pre-existing biological needs, increasingly generate new desires [11]. Consequently, technology assumes the role of a conduit for the imperative to attain this cultural ideal, correlating with the ego-ideal of the symbolic order.

Within this cultural milieu, the concept of "playing God" undergoes a nuanced reinterpretation, shedding some of its negative connotations. The idea of human transformation assumes a central role in various cultural sources, notably in the thoughts of Friedrich Nietzsche. Nietzsche's foresight concerning the emergence of the "masters of the earth" resonates in contemporary discussions surrounding posthuman and transhumanist trends, where the posthuman replaces the traditional deity.

In the aftermath of the "discontents" arising from the technological entanglement of the human mind, I envision a technological future where generative art does not merely serve as a prosthetic extension endowing us with god-like technology. Instead, it should refrain from supplanting but rather supplementing the human body, thereby relinquishing the outdated notion of a human as a mere worker whose expertise allows the use of prosthetic elements [12]. The true peril of technology lies not in its inherent nature but in how our actions implicate us, not nature. This apprehension and fear of technology correlate with the Lacanian lamella—a "fear of the asexual

reproduction of Life, the fear of a life that is indestructible, constantly expanding, reproducing itself through self-division" [12].

Hal Foster's work, "Prosthetic Gods," skillfully employs psychoanalytic theory to delve into the trauma experienced by European artists. Prostheses, including the act of art-making, empower individuals as subjects to engage with the world, safeguard themselves from external threats, and compensate for the imagined castration. However, Foster also critiques mainstream modernism for presupposing an intact ego capable of expressiveness, vision, or transgression [5]. He underscores the potential of art to offer redemptive meaning that neither undoes loss nor fixates on trauma:

No wonder, then, that Guber wanted to escape this paranoid fascination with enigmatic signifiers, this melancholic cult of traumatic loss; so did many other artists and critics (hence, again, the recent turn to Beauty and Spirituality). But between riddling and redeeming, between an aesthetic of missing parts and a dream of wish-fulfillment, there are other paths; and Guber intimates one third way: neither a fixation on trauma nor a faith that magically undoes loss, but the fabrication of scenes for a working-over of trauma and loss—a working-over, not a working-through in the sense of having done, a narrative closure, a redemptive meaning. [5]

To guard against succumbing to the potential horrors of technology on our psychic apparatus, I argue that genuine self-expression through generative art is a tangible possibility. This can be achieved by structuring, utilizing, and fostering prosthetic gadgets (or lathouses) in the alethosphere in a manner that does not pose a threat to the

human subject and its composition, yielding outcomes with a humanistic orientation. Andjelkovic [8] contends that the relationship with technology can serve as a backdoor to the sacred:

Technology is the expression of an unconscious fantasy – and thus a 'back door' to the sacred – in the same way that notions of gods and spirits pointed to an abrogated ideal of omnipotence desired by the human subject, cast-off and projected onto objects, figures, and forces found without, in the external world. [8]

In "Lacan and Religion," Dunlap posits that a teleological direction in response to the alethosphere is crucial, emphasizing the significance of the drive that locates the essence of what already exists, rather than engaging in the arbitrary creation of desires and meaning [13].

We might expect Lacan to turn, at this point, to the realm of the real, to perhaps present us with a matheme – a little package of purely formalized and meaningless truth – to emphasize the impossibility of navigating ourselves out of this impasse from within the symbolic. It is therefore curious that Lacan would instead turn to the category of meaning (sens) and religion as the properly human response to life in the alethosphere. In his other works meaning is almost always associated with the imaginary and accompanied by a warning ... It would perhaps be best to connect this strange (for Lacan, at least) use of meaning to his understanding of Aristotle's fourth cause – that of teleology, or, for our purposes, the "direction" that is another meaning of sens – which modern science has had to jettison in order to pursue the purely mathematical, and therefore meaningless, truths that function as its gold standard. When Lacan tells us that, "what is at stake when what we are dealing with is the divine dimension and generally that of the spirit, turns entirely

around the following: what do we suppose to be already there before we discover it" (1967–8: 15/11/67)...this for Lacan functions not as a symptom – a problem to be overcome – but as *sinthome*, both sickness and cure; for it is woven into the very fabric of the alienating *alethosphere* while yet providing the best hope that the rising tide of modernity has only served to sharpen what is "true" about religion: that it gives meaning to life, but not a meaning that is tacked on to arbitrarily turn a tragedy into a comedy, but one that was there all along, a *telos* reigning from "before the foundation of the world" (Eph. 1:4)." [13]

2.1 The Transvaluation of the Death-Drive: A New Future

Foster [5] delves into Marinetti's anticipation of the Freudian hypothesis, influenced by Lamarck, which posits that each organism evolves a protective shield (*Reizschutz*) against stimuli. Freud, in *Beyond the Pleasure Principle*, asserted that this protective shield "is an almost more important function for the living organism than reception of stimuli" [14]. Marinetti suggests that this extruded shield has evolved into a technological organ, functioning as an auxiliary organ that has become integrated into humanity. Consequently, Foster illustrates how Marinetti envisions a transformative dialectic where the traditional distinction between shield and shock collapses, and technology serves both as a protective shield and a stimulus for shock [5]. Foster further elaborates on a transvaluation of the death drive in Marinetti's perspective.

As we have seen, Marinetti was fascinated by the breaching of the body ego. Again, for Freud the response to this breaching is a binding of the body ego, a binding that develops through

repetition; but this repetition cannot be easily controlled: it might conduce to a becoming-inorganic not only of the protective shield but of the entire being—at least to the degree that it is gripped by the death drive. In his double move to reify the body and to vitalize things, "to substitute for human psychology, now exhausted, the lyric obsession with matter" (M 87), Marinetti seems to intimate this same process. More radically, he seems to embrace it, to transvalue the death drive as the very principle of self-preservation, indeed of self-exaltation ... On the one hand, this is to accept a kind of death; on the other, it is to stake a new future for "life" in a technology (in or beyond mere death). [5]

In Foster's chapter on the Return of the Real, there is a pronounced emphasis on the notion that art within this context seems to desire the gaze to illuminate, the object to assert its presence, and the real to manifest itself in the splendid horror of its pulsating desire. Essentially, the artwork aims to evoke a sublime condition, either by directly embodying it or by eliciting a response that resonates with the intense and pulsatile essence of the real [5].

3. The Generative Drive and the Alethosphere

It is in this context where the lathouse takes on significance as a different form of object. Based on this reading if object *a* is on the side of the metonymy of desire, then the lathouse is on the side of the drive and the body. [6]

Isabel Millar, in her work "The Psychoanalysis of Artificial Intelligence," contends that a conceptual shift from Lacan's 'object *a*' to the 'lathouse' is essential for grasping the often-overlooked concept of enjoyment. This

'lathouse' represents a contemporary form of the object, situated within the real as a synthetic creation resulting from technoscientific advancements such as Artificial Intelligence. According to Lacan [15], understanding the implications of entering into a relationship with the lathouse is crucial. He emphasizes that the lathouse occupies the position of the 'real,' and its effects within this realm are significant and impossible to fully encapsulate [15]

Millar [6] elucidates that Lacan introduced these neologisms to speculate on the growing importance and implications of these technological devices on forms of enjoyment and the broader sphere of 'formalized truth' to which they belong [15]. Lacan's central point is not merely that these objects cause desire but that they encapsulate elements of the drive, serving as impossible objects attempting to capture the *jouissance* of the body. These objects, therefore, seek to record the truth of our enjoyment within the Other, known as the *alethosphere*. Millar believes that because technoscience effects the real, it warrants us to consider them to be more than just "consumer pests" [6]

Millar's [6] discussion also looks at Veronique Voruz's [16] exploration of these non-natural objects of technoscience, emphasizing their production in the *alethosphere*. Voruz distinguishes lathouses as objects of the real of science, in contrast to the more traditional guises of *object a*. Freud's concept of prosthetic godhood, driven by an inherent lack, involves the use of auxiliary organs to orbit around the objects of the drive. Millar [6] also delves into Stiegler's *What Makes Life Worth Living?* [17], which is an exploration of

the changing relationship between the drive and technological objects, with the lathouse serving as an external non-natural object that administers *jouissance*. In this context, the lathouse takes on significance as a different kind of object, where 'object a' aligns with the metaphor and metonymy of desire, while the lathouse aligns with the drive and body [6]

Therefore, there is a shift whereby lathouse as an extimate object, converts interiority to exteriority and allows for the circulation of drive around the "ab-sex-sence of *jouissance*" [6]. Therefore, Miller's project serves as an interrogation of the relationship between knowledge and enjoyment, as she quotes "The philosophical question of truth is thereby supplanted by the psychoanalytic question of enjoyment, where metaphysical knowledge becomes sexual knowledge." [6].

Nonetheless, the disruptions ushered in by contemporary scientific endeavors, driven by the pursuit of knowledge but increasingly severed from meaningful contexts, result in an environment saturated with nothing beyond an assemblage of gadgets [13]. Lacan formulated the concept of the *alethosphere* as a myth, portraying truth as estranged from our grasp. He articulates this idea by stating, "if you have a little microphone here, you are plugged into the *alethosphere*" [15] underscoring that each gadget (termed 'lathouses') effectively connects individuals to this ultra-modern mythical space. Copjec says

In Lacan's new ultra-modern myth, there is no heavenly sphere, naturally; it has been demolished. All that remains of the world beyond the subject is the 'alethosphere', which is a kind of high-tech heaven, a laicized or 'disenchanted'

space filled none the less with every technoscientific marvel imaginable: space probes and orbiters, telecommunications and telebanking systems, and so on. **The subject is now a 'terminal' subject**, plugged into various circuitries, suited with wearable computers and fitted with artificial, remotely monitored and controlled organs, implants. In this alethosphere (alethosphere because this space and everything in it is built on the demonstrable truths, rigorous and mathematical, of modern science) the prosthetically enhanced, plugged-in subject does not need to flee reality in order to indulge his pleasure principle, for he is now able to remould reality in accordance with it. In other words, in the ultra-modern, advanced capitalist world, the pleasure principle and the reality principle are no longer in competition, but have merged to form a kind of corporation. [18, 13].

4. Implications for Generative Art and Conclusive Remarks

As I conclude this exploration into the psychoanalytic implications of technoscientific progress, particularly within the realm of generative art, a fundamental question surfaces: What role does randomness and structure play in reshaping the mythical expanse of the alethosphere?

Our investigation leaves us pondering the prospect of new desires emerging within the alethosphere, potentially giving rise to increased self-alienation and loss. Amid these uncertainties, however, we discern a potential potency within lathouses, influencing the authentic drive of the real and transcending the boundaries of the pleasure principle to construct meaning. Žižek, positioning gadgets beyond the realm of pleasure, introduces an element of Kierkegaardian anxiety rather than a

mere enhancement of pleasures and abilities [12]. This prompts reflection on whether technological control over prosthesis might extend to controlling the core of our self-experience, a concern articulated by Žižek [12].

In this attempt to formulate responses to life within the alethosphere, I turn to contemporary works, notably Isabel Millar's "Psychoanalysis of Artificial Intelligence" and Hal Foster's "Prosthetic Gods." These sources guide this exploration as we grapple with the challenges inherent in the journey toward individuation. This psychoanalytic anthropology, rooted in acknowledging disparity, provides a foundational understanding for a philosophy of technology informed by psychoanalysis. It is important to understand how randomness and structure operate in the context of generative art. The collaboration between the conscious artist and AI reveals unforeseen potentials, specifically for the expression of categorical meaning (sens). While we anticipate challenges in the technological future, our inquiry envisions a scenario where technoscience authentically impacts jouissance. The conscious subject, navigating generative art, autonomously expresses its drive toward individuation, safeguarding subjective experiences within the alethosphere. Acknowledging technology as a reflection of unconscious fantasies unveils a potential backdoor to the sacred, fostering humanistic goals. Emphasizing the conscious utilization of tools, like lathouses, becomes crucial to prevent compromising individuality. Investigating how individuals approach technology in creating generative art is imperative.

In this exploration, I acknowledge that we might not have all the answers.

Nonetheless, we assert that technoscientific advances need not lead to a future of self-alienation. Generative art emerges as a medium for authentic creative expression, potentially immortalizing the creative drive. This parallels the Lacanian myth of the Lamella, attempting to replicate an indestructible digital lifeform, signifying a potential future of self-exaltation with technology. The recovery of an indestructible, eternal essence within the subject may remain an impossibility, but the exploration of the transvaluation of the Death-Drive hints at a future where life with technology becomes a form of self-exaltation.

Lastly, the comprehensive exploration of psychoanalytic implications within the realm of technoscientific advancements, particularly in generative art, unveils profound considerations for the future intersection of human psychology and technology. Several key implications emerge from this inquiry:

1. *Reconfiguring the Alethosphere:*

The examination of randomness and structure within the alethosphere prompts contemplation on how these factors reshape our understanding of truth in the technologically mediated world. The potential emergence of new desires and the transformative influence of lathouses on the real drive open avenues for reconfiguring the conceptual boundaries of the alethosphere.

2. *Beyond the Pleasure Principle:*

Žižek's positioning of technological elements beyond the pleasure principle underscores a paradigm shift. Rather than enhancing pleasures, these prosthetic components induce anxiety and fear, aligning with

Kierkegaardian notions of apprehension. This challenges conventional views on the role of technology in human experience, urging a reconsideration of its impact on our core selves.

3. *Technological Self-Expression and Individuation:*

The exploration emphasizes the potential of generative art as a means of technological self-expression. By navigating the intricate path toward individuation, individuals can confront challenges and concerns within the alethosphere. The paper envisions a future where the conscious engagement with generative art ensures the preservation of subjective experiences and facilitates autonomous individuation.

4. *Backdoor to the Sacred:*

Acknowledging technology as a reflection of unconscious fantasies opens a conceptual backdoor to the sacred. The interplay between psychoanalysis and technology provides a unique lens through which individuals can achieve self-realization and transcendence. This suggests that the conscious utilization of technological tools, such as lathouses, can potentially lead to humanistic goals.

5. *Immortality of the Creative Drive:*

The examination of the Lacanian myth of the Lamella and the replication attempts by the prosthetic god introduces the notion of the potential immortality of the creative drive. Generative art, as a form of self-exaltation, signifies a departure from the original loss, offering glimpses into an indestructible digital form of life.

6. *Challenges and Responsible Utilization:*

The inquiry acknowledges the challenges inherent in the future of humanity entwined with technology. It underscores the importance of responsible utilization of technological tools, particularly in the creation of generative art. Conscious efforts to avoid compromising individuality become imperative in navigating the evolving relationship between humanity and technology.

7. Transvaluation of the Death-Drive:

The exploration of the Transvaluation of the Death-Drive suggests a future where life with technology becomes a unique form of self-exaltation. By redefining the relationship between technology and our unconscious desires, this perspective opens avenues for novel interpretations and understandings in the ongoing discourse on human-technology interaction.

In essence, this exploration fosters a nuanced understanding of the intricate interweaving of psychoanalytic principles with technological advancements. The implications outlined here propel future discussions and inquiries, urging a continued exploration of the evolving dynamics between the human psyche and the ever-progressing realm of technology.

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Drawing While Black Aka Drawing Wit Nonbinary Light

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Abstract

These performance drawings and performance writings centers Practice as Research. Meaning, not only engaging with finished work(s) like Visual Poems i.e. text-based works and/or visuals, or the criticism about these pieces, but I argue with this work similarly when I create 2D, 3D, 4D, and text-based pieces that it is equally important to practice making Black Visual Poems due to there being a scholarly and/or artistic knowing/knowledge, that is derived from the very act of practicing itself. By not

considering drawing practices be they 2D, 3D, 4D, or text-based as research at the same level as finished works and/or the criticism in this field; what are we missing out on as creatives and/or scholars by privileging one form of research over the other? In otha words. For these new series of performance drawings and performance writings in this hybrid text, are part experimental films and Visual Poetry hybrid pieces came about because of the need for dis creatives navigating experimental mark makin exploring euphoria and dysphoria marks as a trans-nonbinary person navigating de art world. These visuals were created by incorporating elements of performance-drawing, performance writing, and binary code translators; to create immersive environments and engaging experiences relating to race, gender expressions, and gender identity coupled with black hxstories and cultural diasporic traditions in Amerikkka. As the work evolved, I continued to consider what digital, analog, and ephemeral marks do if we let them be themselves. Shout out John Cage! The marks in this series of works were created by engaging wit Beautiful Black Blackty Blk Bodies ody ody ody ody ody ody ody ody ies of all shapes and sizes in the Black and Queer diaspora. Next, I decided to put my foot in it, and infuse da werk with African American Vernacular/Gesture English (AAVE) Image/Visual/Gestural descriptions thereby further expanding

queer mark making. Moreover, I am drawing with vocabularies, sources, bibliographies, scripts, image descriptions, remixing past drawings, collaging visuals/texts, and incorporating queer Black theory to create these new experimental marks. In otha words! Catch A Glimpse Into De Latest Top Bottom Side Switch Vers Secret Projects From One Of De Worlds Mos Queertorious Femme Makers!

Clapping While Black (feat. Pan-African flag)

tRigger wArning

Art Pages

FRFR Flashing Lights

Queer Euphoria

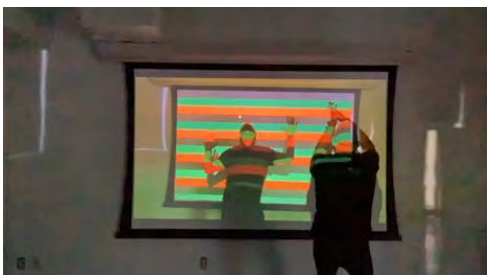
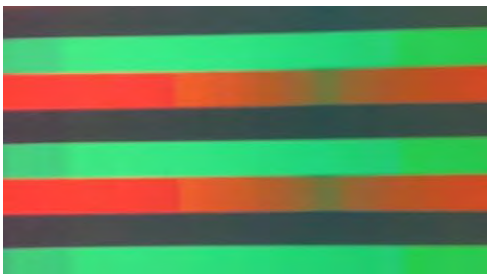


Still from marks 00:03, 00:12, 01:59, 02:34 - Clapping While Black (feat. Pan-African flag), Directed by Maurice Moore, 05:02min, 2022.

Visual/Video/Audio Description

"Film pops-off wit a Blackty Pan-African flag Hunty! Jumpin n' glitching cross dat lovely silver screen! Silver like Labelle brought tah de table. Chu know Dat Gitchie, ya-ya Coco-la-da feel. What chu know bout dat? Ha Ha! Dis beez where de coolworld-ish animation com into dis work. Slow motion fo meh, Slow Slow motion fo meh! Move yo hips churen! Beautiful non-binary figures moving throughout dis film. Slow-motion stops! De film moves at queer speed. My bad, I always forgettah talk bout de goodt vibrations/sound/noise. Lewk at de ableism! Want-dat-Vibrations-Tea? Put-on-a-Bop! Tah experience de-sting n' euphoria of Clapping While Blk."

Non-Binary Rizz (Feat Dorian Corey)

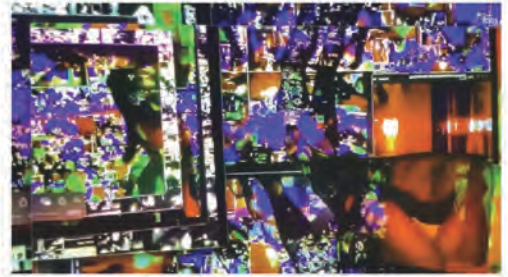


Tri**er Warning

Code

Flashing Lights

BLK & Yt



Still from mark 00:13 - Non-Binary Rizz (Feat Dorian Corey), Directed by Maurice Moore, 0:16 sec, 2023.

Visual/Video/Audio Description

And de category is 01001110
 01101111 01101110 00101101
 01000010 01101001 01101110
 01100001 01110010 01111001
 00100000 01010010 01101001
 01111010 01111010 Rizz, Rizz,
 Rizz, Rizz, Rizz, Rizz, Rizz.

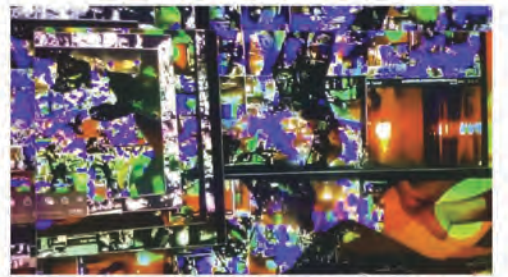
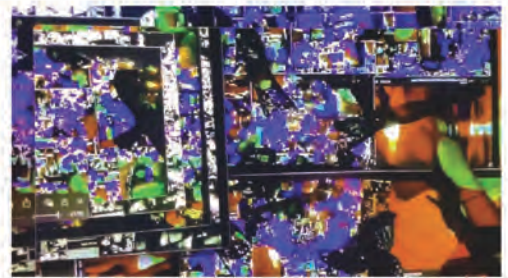
Queering Silhouettes

Trigger Warning

Queer African American Vernacular English

Flashing Lights

Thicc Thighs



Still from marks 00:01, 01:27, 02:01 - Queering Silhouettes, Directed by Maurice Moore, 02:27min, 2022.

Visual/Video/Audio Description

And De category is Marked Bodies!
 Yessssssssss! Where all my big beautiful Black Blackty Blk non-binare folks at?! I see you babies! Keep Givin it tah dem! Yesssssss, we beez on som Queering Silhouettes visual poems ish tah day! Ain't doin nothin in de dark no mo! All done in Dark light now baby! Ohhh and dis non-binare has de nerve to be goin all high sadyty wit dat digital materials ish! Chu thank you bad Mx. Thang! Don't

forget where chu com from! Go on though! Keep doin de most! Keep makin de cis folks nauseous! Givin em those non-binary sickening vibes! Dem tryin tah make ya still, when chu was born tah move! We only give still on our own terms! Ohhhh lewk at those bout ten or fifteen hundet rectangular squareish shapes filling dat dis still and throughout the film. Chu has beautiful Black Blackty Blk body parts warmed by som tropical iridescent sunsety hues! Yes, de glorious parts be cropped but unlike som creatives “coughs” mapplethorpe; dis piece beez givin a narrative hunty! Shout out Essex Hemphill! These pieces from this series were created by incorporating performance, writing, and gesture drawing to create immersive environments engaging experiences relating race and gender identity with black hxstories and cultural traditions in America. Now dat audio! On de low. Som cutie said yo gurl’s werk was mesmerizing! Ohh ans dey beez som humming ans feedback from the digital equipment and such. But dat ain’t nun of yells business. Enjoy joy de rest of de film!

Marked Bodies Video 1



Still from mark 00:06 - Still from - Marked Bodies Video 1, Directed by Maurice Moore, 0:47sec, 2022.

Visual/Video/Audio Description

Oonts, oonts, oonts, oonts, oonts, oonts, oonts, oonts, oonts, oonts! Yesssssssss Darlings! Dey beez a big beautiful Black Blackty Blk non-binare person in all dey glory! Dey gettin down as de oldheads usta say! Now we jus say gettin it! Livin de ancestor wildest and wettest dreams! Lewk at dat juicy black body bending, crouching, lifting, twirling on yah! Ha ha! De pictureplane or video beez broken up in tah bout nine or ten rectangular windows/boxes. Two of de boxes one in de center and de one at the top left corner has the Press play and Pause bars overlaid on these two boxes revealing the timestamp. At de lower right corner blurry fingerprints or smudges wit a glare comes into view.

Marked Bodies Video 2



Still from mark 00:55 - Still from - Marked Bodies Video 2, Directed by Maurice Moore, 0:47sec, 2022.

Visual/Video/Audio Description

And de category is Black Blackty Blk non-binare Realness! In Six rectangular windows seven Nonbinarygenderqueerish figures be standing in various positions. These windows be overlaid on top/bottom of each other. Making the visual appear to cropped on dey own terms! Yes eat yo heart out Mapplethorpe! All tea all shade! We given narrative hunty! We given de

churen a story! We not just bout focusing on one type of beautiful part dat makes up Black Blackty Blk bodies!

Marked Bodies Video 3



Visual/Video/Audio Description

Lewq at Huh servin Nonbinary realness! Bout nine Black Blackty Blk genderqueer figures beez filling de screen wit dat juicy big body goodness. De picture window be overlaid on top/vers/bottom/switch of each othatha. De top/vers/bottom/switch of de image/video creates an upper case "L" shape wit a pair of gorgeous legs at de bottom appear to be runnin off de pictureplane. At de bottom/top of de right pictureplane dey be more creatively cropped figures jus revealing dey torsos and dey be some mo of dat beautiful blurry glare given the visual a dream like quality. I swear cis folks could nevh!

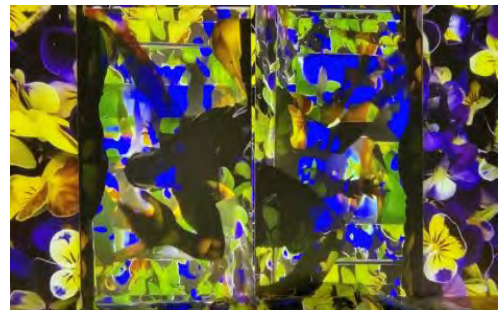
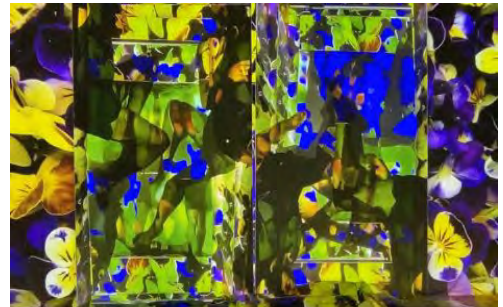
Marked Bodies Video 4

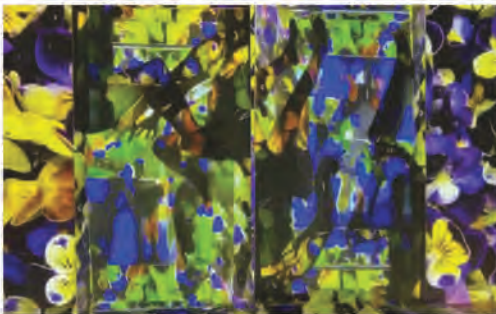
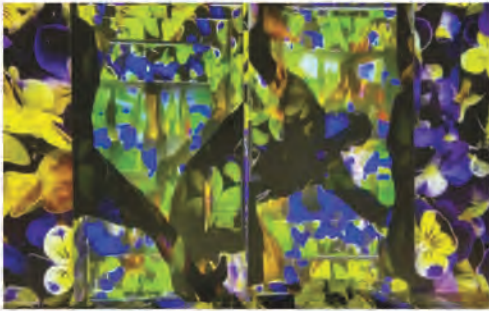


Visual/Video/Audio Description

Non Binaries outchea in Nature! Bout nine cropped Black Blackty Blk trans figures are moving dey marked bodies through out dis piece on dey own terms! Shout out tah Serap! Dis be our space hunty! De left part of de visual be in focus, and mos of de right part of the visual be given dat beautiful blurry glare! It's out of focus. Pops tongue! But dis reminds me of a painting.

Colored Silhouettes (feat Storme DeLarverie and Forget Me Nots)





Still from marks 03:59, 05:39, 05:41, 05:51 - Colored Silhouettes (feat Storme DeLarverie and Forget Me Nots), Directed by Maurice Moore, 06:04min, 2022.

Visual/Video/Audio Description

Forget Me Nots of are enlarged throughout dis digital werq along wit the de amazing Blk queer figure. Spinning out of control here. The horizontal black figure upper body reads as a solid silhouette and de hands and arms a blurry colored wit golden yella and blu hues.

It's as if dis figure beez surfing through a wave of Forget Me Nots. Hanging ten as dey say! Moving through a wonderous surrealist world made up of colorful floral arangments. Four vertical rectangle shapes make up de picture plane here. Wit de two on the outside being smaller den the two in de center.

Notes

1). Performance-Drawing Understanding how Performance-Drawing expands studio & performance arts research plus exists as a mode of critical inquiry intersecting with various mediums is what I have found engaging with making Performance-Drawings these past couple of year and using the 2020 text written by Foá Maryclare, Jane Grisewood, Birgitta Hosea, and Carali McCall called "Performance Drawing: New Practices since 1945," which defines performance-drawing as:

Importantly, drawing can now be understood as a performance when enacted in front of an audience either live or in anticipation of a future audience through a recording device. Drawing is concerned with process not product. It can be a score, a thought, a study, a map, a walk, an action within a performance, or the performance itself. Thinking about performance drawing encompasses several forms of art: visual art, theatre, dance, music. The ethos of performance studies that encompasses all activity as a form of performance has now been extended to the visual arts where the ontology of the line overwhelms every medium. (Foá Maryclare, Jane Grisewood, Birgitta Hosea, and Carali McCall p. x)

To reiterate, I now have come to realize that what I have been making is performance-drawings. And that many of my struggles with articulating my research in both critical essays and mark making practices; stems from me solely centering finished art objects over the process of drawing itself. All due to the assumption that finished art objects

made in two dimensionality with analog mark making with dry or wet media practices is the ideal (Foá Maryclare, Jane Grisewood, Birgitta Hosea, and Carali McCall p. x). This text allows me to consider that current drawings can be durational, spatial and not just fixed to one dimension (Foá Maryclare, Jane Grisewood, Birgitta Hosea, and Carali McCall p. x).

For example, I have been questioning the ease experienced when making say one dimensional (1D) or two-dimensional (2D) marks and/or drawings. Yes. But what about three-dimensional (3D) marks, and fourth-dimensional (4D) marks? Maybe? Let's take it further. What about 5D? or 6D...or 100,000D drawings?, and to infinity and beyonddddd!!!!!!! Drawings! Why is it so hard to imagine drawings with various lens in virtually any dimension? Moreover, could critical essays, or visual poems, or speculative fictions, or African American Vernacular/Gesture English (AAVE) infused Image/Visual/Gestural descriptions, or experimental queer films etc. also be considered as other dimensions as well. Moreover, I thought I had to just focus on finished art objects not considering the process of mark making as a finished art object in and of itself. I did not understand that by not allowing the of blurring between mediums to occur, keeping my pieces isolated just referring to my works as just drawings or just performances was hindering my artistic growth. Not showing or finding ways like I am now, with my Practice as Research (PAR) of not only just documenting the work, but to also show how engaging with performance-drawings through various lens and practices has continued to expand both

the act of drawing, and the finished art objects as well. Expansion by using other lens/fields/theory/expressions/senses etc. to get to experience and/or question the various dimensions drawing can take.

2). The use of African American Vernacular English (AAVE), and creating vocabulary to expand the Lexicon of Mark Making. Helped with channeling Black and Queer aesthetics. Not so much helped to make these aesthetics, but to have a space where I could play with Black and Queer aesthetics. In other words, the ability to sample other Black and Queer creatives aesthetics plus make up my make up words, concepts, and marks. Has been both affirming and empowering. Finding researchers thinking outside/inside/over/under/through this box we are always bringing up. Folks who like me even question if the shape used should even be a box. You will notice as you engage with these works and notes, African American Vernacular English (AAVE) is sprinkled throughout. This includes gestures such as "Eye rolls," the "Snap!," or the "Pops Tongue." Please fight the urge to correct grammar and/or spelling. Understand that the audience for this text is meant to be folks not usually centered in critical essays, notes, the arts, such as the Black/Blackty/Blk/Disabled/queers to name a few. If you don't identify with these ways of being. Know that you are welcome to engage with the text. However, you might have to do some Black/Blackty/Blk/Disabled/queer 101 werq. I am asking that you try to suspend disbelief and accept African American Vernacular English (AAVE) as a visual/gestural/sonic signifying language. And in this case signifying marks that

flow in both text and visual forms. No Tea, No Shade. Asking yourself if you're struggling. What -isms are getting in the way?

3). Part of the play & fun in creating these pieces, was being able to use this notes section as I would drawing materials and/or drawing concepts. Think of notes as a tool for art making. Like a piece of paper, a pen etc. to scribble, to sketch, to doodle, to render; and find marks that are not worried about being part of some binary focusing on good or bad techniques. But marks that are nuanced and exist on their own terms. Creating some marks that make sense and some that marks that don't make any sense to me. The notes section in this text exists as a low stakes space. Like a piece of scratch paper for notes where you use to test out materials or jot down and work through ideas. I don't know how to explain the notes. It's just a space that I don't think people really pay too much mind when reading a text or art object. In the notes space, I don't feel like I have to code switch, or mask, or be on, in any fixed way shape or form. The marks I make here in notes are indifferent. The notes are a space where I am not worried about being seen as some sort of arts researcher making prolific strides in the field. I am free to be messy in the notes. It may sound silly. But when I make the notes; it feels like I am frolicking in this section.

4). My relationship with drawing research has not been a linear one. I wish I could say that I found Foá Maryclare's, Jane Grisewood's, Birgitta Hosea's, and Carali McCall's text called "Performance Drawing: New Practices since 1945," way back in 2001 when I began my Practice

as Research (PAR) journey in the arts. Or that I even put on that there is a knowing that comes from Practice as Research (PAR). "Performance Drawing: New Practices since 1945," text introduced me to the likes of John

Berger, John Cage and also had me searching out creatives who pushed boundaries of research such as Marlon Riggs, Fred Moten, Lynda Barry, and Robert Morris. Researchers in many ways, be it through their criticism and/or creation of art objects have all influenced me to question, broaden, challenge, make up and break so called rules; many unspoken, pertaining to research practices involving studio arts. Questions never asked during any of my formal training. Why am I never asked for a bibliography or citations for my drawings when exhibiting? How do critical essays serve studio artists? What sources, or materials, or documentation should studio artists use when citing their works? Can critical essays, citations, frameworks, and notes be used as materials or to create art objects? Being in this position of not knowing has been scary, but it also grants me, and I hope other creatives more freedom in our field. Freedom to continue to explore nuances in art making and practices as legitimate academic research. So, no one ever really explained to me how to cite my sources, and who I was thinking with as I created/researched during my formal training. And I always hear from people who research how horrible and tedious research can be. Made me wonder if there is any room for play and/or fun in one's research? My answer to that question is Yes! Also, when you're Black, people tend to focus on our pain, our Blues. However, the Blues is not the only hue or mark to make with.

5). Text used for Visual Poems and/or Experimental Films Not trying to make my Visual Poems or Experimental Films situation into a verses battle. No one is forcing me to pick and choose between the two artistic frameworks. However, trying to decide which artistic framing of these visual works incorporating text to find if one works better than the other. Yes, I was questioning that; also, what happens if I leave the text out of the film? Am I being ableist? Because the text in these works were meant to function in part as image/films descriptions. To consider disabled audiences and also the usage of African American Vernacular English (AAVE) was added to center Black and queer audience. Not to mention just by using (AAVE) has been empowering and I have so much fun making marks using this black aesthetics. Also, the usage of text descriptions why can't this process be a creative one as well? Overall, I have been thinking about how the usage of artistic framing used in these pieces has an effect/affect how the work is engaged with. Well, duh! It's ok that I can't answer these questions now, but it seems important to bring them up in these notes. It's like I get to expose my many insecurities making these drawings here in the notes section of this critical essay. Maybe what I am ultimately asking is can the feel/felt sense what it feels like to draw and make these marks. Can this feel/felt sense also be part of typographical design? If these works in part are going to be considered visual or concrete poems.

6). Naming and [Not]knowing Balancing and Negotiating

[Not]knowing is a great opportunity, in that it creates space for centering

different kinds of knowing. Maybe a knowing that is just out of our grasp as creatives. A low stakes knowing. A knowing or [Not]knowing that I can freely admit that I don't know why I just don't call these damn works performance-drawings and call it a day. Instead of saying these works are African American Vernacular English (AAVE) infused image descriptions text-based visual concrete poems speculative performance writings that are a mixture of analog, digital, and ephemeral materials intersecting at multiple artistic dimensions. I guess in part for me there is power in naming and there is also power in not naming. Or naming on my own terms. Sidenote: This note is not supposed to answer any questions or make any big revelations. It's just meant to voice the swirling lines and marks of my [Not]knowing can take when allowed to wonder in space.

7). Audience as Makers - Experiences, Responses, and Reactions to the Works. I want it to be clear here that Audience as Makers or vice versa, that questioning this can be a space for play. To be messy and not have order. To continue to question various roles of Audience, Makers, Readers when gaining clarity through engaging with Practice as Research. Me as an Audience, Maker, Reader; sometimes I care about others outside of myself engagement with my creative research, and other times I don't. As a creative researcher it is important to question what drives me or us to know the similarities and differences between do work and/or werq. Because we feel we have to, or supposed to, or want to, need to, expected too etc. For my creative research as I continue; engagement with the similarities,

differences, and nuances of what is traditional, alternative, and nuanced inside and outside of creative research. This questioning, and not making sense of the creative research, like knowing where me or the work will end up is part of what drives me to continue fluid way of knowing and/or not knowing when making. I want readers and audiences to also be free as I am through being and becoming creative researchers. This is another reason why establishing boundaries, and challenging expectations of what an art object and/or critical essay. Moreover, the maker roles as being both audience or makers the Experiences, Responses, and Reactions to or various works I am experimenting with through play.

8). In William Kentridge's, "William Kentridge Anything Is Possible," documentary by Art21. He states that multiple iterations of an idea be it through a drawing, or a text, or opera, and/or a tapestry brings about clarity. Moreover, these disciplines don't have to be hierarchical or turned into a pissing contest (my words) in order for people to become enlightened. (William Kentridge: Anything Is Possible Art21 mark 34:48-35:25)

9). "Where are the Podcast Blaccents?," was a 2019 panel discussion that brought together various Black voices who spoke of some of the code switching and meshing Black creatives have to implore in order to subvert White supremacy. What this podcast showed me about code switching and/or meshing is that turning on or off one's Blackness i.e., our aesthetics can take place in various iterations: writings, non-verbal movements and voice. Moreover, I think

there are instances where code switching and/or meshing take place in my performance and the form used in this text. This podcast also gave me inspiration to use AAVE and/or Blaccent(s) to experiment with the form in the text. I will also add that the turning on and off one's Blackness correlates with Langston Hughes text "The Negro Artist and the Racial Mountain," balancing and negotiating one's blackness.

10). Moreover, if drawing can be expanded and clarity gained by using various lens such as from experimental writing forms (free writing), textured papers, installations, digital or virtual interactions, practices and/or scores, incorporate audio & braille for the visually and hearing impaired, include letter correspondences, journals, and field notes. Then why can't the critical essay or notes in this context also be used as a lens and/or material to gain clarity? This notes section here puts into practice some of the pedagogy gained from engaging the works created by John Berger, Lynda Barry, Marlon Riggs; to create a critical research that is composed entirely of performance-drawings. One that serves both creatives and non-creatives alike, in that the essay challenges the traditional form a critical essay or notes sections can take, being that the materials used in its creation implore various analog, digital, and ephemeral forms/marks/expressions drawn from African American Vernacular Gestures English (AAVE), and callout some of the ableism and gatekeeping involved with critical research and/or art objects in this context where writing and/or mark making are expected to uphold the so-called standards involving English and/or grammatical correctness

in arts scholarship. This work gives both creatives and non-creatives alike a choice in deciding the various forms a critical research can take, thereby allowing expansion involving creative arts scholarship. To reiterate, this text object and/or art object was created in the same vein of many John Berger's and Lynda Barry's works, so it doesn't have to be engaged with in a linear or even a circular fashion. And you can take more than one pass at reading it. With this stated, consider starting with the Performative-Drawings or Performance-Writings pieces before engaging with the critical essays. Or just challenge yourself to think of Performative-Drawings and/or Performance-Writings in this text as critical essays. One way I have found useful at reading marks be they lines of text or lines in a drawing; is to consider how my queerness and/or Blackness informed many of the lines rendered be they spoken, typed, handwritten, danced, scribbled using various analog, digital, and ephemeral methods/materials expanded to engage the nuances of drawing. Also, consider that the mark maker is centering certain audiences with these pieces, speaking directly to them. In other words. The gurls who get it, get it, and the girls who don't, don't. Snap!

11). Lexicon of Mark Making

Mortality lines "Drawn To That Moment," read as a critical reflection that articulates how using Practice as Research (PAR). Understand that Berger's usage of critical reflection and PAR practice helps to explain the feel/felt sense dealing with the author coming to terms with mortality and the urgency to render his dead father's corpse with what I call mortality lines Berger's account over dealing with

the lose of his father. Yes, there is a 2D rendering of his father's corpse, but Berger's account here this experience; I would argue that these lines are just as impactful in the article as the 2D rendering. Bill T. Jones and his collaborators conceptualize in the Still / Here performance and documentary. These lines were evoked by the reckoning of balancing and negotiating ones impending death and/or mortality.

Theatrical Toxic or Violent lines - John Berger in "Drawn To That Moment," goes on to explain the lengths an educator Oskar Kokoschka went to, to get their students to draw with more verve. Prompting the Model to faint, to get the students to draw with more urgency.

Aliveness Lines - Aliveness Lines... these electric spook house lines Linda Berry spoke of during an interview; Stating that these thrilling lines are created by the wonder of not knowing when making marks; And goes on to state; Aliveness lines is what some creatives my lose and desperately are trying to get back after their formal training may have killed this feeling.

Text-Based lines AAVE infused Lines Visual Poem Lines - In an attempt to combat some of the ableism in the arts, and center People of Color POC. African-American Vernacular English (AAVE) in fused lines could be used in Text/Image/Audio/Visual descriptions to make drawing and other visual media more accessible. These works could also function as visual poems too.

Queer lines - Both documentaries one based in fictional citations and the other non-fictional citational marks; both

function as records which provide marked bodied creatives with evidence, links, traditions, expressions, rituals, aesthetics, i.e., marks that still give a number of Black queer folk's glimpses into communities that not only creatively supported each other, but also these films serve as a

record/citation/marks/lines that helps fight the violence brought on by the erasure and whitewashing Black queer folks still face in the 21st century. These factors lead many diasporic folks to not know or be able to articulate the connections, traditions, hystories, and relationships to their BIQPOC ancestors to the standards and expectations set in many academic institutions. Second, in Levington's documentary *Paris is Burning*, a Black queer person could be read as a citation/record that our Black & Latinx queer ancestors used to pass on the wealth of knowledge and/or aesthetics through performance i.e., the dances, the sites such as drag balls, reading & throwing shade, queer houses, Family structures the House Mothers & the Fathers. Therefore, Dunye's fictional citational marks in the film i.e., the staged photographs, mock interviews with the films subject, her characters comedic ventures in archives, and testimonies I would argue function/mirror many of the marks made the ancestors in Jenny Levington non-fictional documentary *Paris is Burning*. Where Dunye's & Levington's work fits into this drawing research involving questioning expectations and/or assumptions around mark making. Both documentaries one based in fictional citations and the other non-fictional citations both function as records which provide evidence, links, traditions, expressions, rituals, aesthetics, i.e., marks that still give a

number of Black queer folk's glimpses into communities that not only creatively supported each other, but also these films serve as a record/citation that helps fight the violence brought on by the erasure and whitewashing Black queer folks still face in the 21st century.

12). FRFR. Jus a lil bit. Just a wandering thought about practicing or receiving euphoria and/or dysphoria. Marsha's Plate : Black Trans Talk, Created by Diamond Stylz. This Black Blackty Blk trans podcast has been inspiring me for years. To have queer content dat centers Black people is amazing! This podcast has inspired me to instead of think about joy as a maker i.e., my piece "Drawing While Black aka Non-Binary Joy" formerly known as "Drawing While Black aka Black Boy Joy." Moreover, makes me consider what brings me euphoria and dysphoria about art making as a trans-nonbinary person navigating the world.

13). These Image Descriptions and Images in this essay were created by incorporating elements of performance-drawing, performance-writing, and binary code translators; to create immersive environments and engaging experiences relating to race and gender identity coupled with black hystories and cultural diasporic traditions in Amerikkka. As the work evolved, I continued to consider what digital, analog, and ephemeral marks do if we let them be themselves. Shout out John Cage! The Image Descriptions and Images here were created by engaging wit Beautiful Black Blackty Blk figures of all shapes and sizes for almost 3 months. Next I decided to put my foot in it, and infuse the work with African American

Vernacular/Gesture English (AAVE) Image/Visual/Gestural descriptions thereby further expanding queer mark making. Moreover, I am drawing with vocabularies, sources, bibliographies, scripts, image descriptions, remixing past drawings, collaging visuals/texts, and incorporating queer Black theory to create these new experimental marks.

14). Critical reflections are able to serve as a way to call truth to power, challenge, rebel, callout, and disrupt the so-called standard/formal/traditional/default aka the White Western European Capitalist etc artist work or processes (University Avenue West Waterloo). I argue that a standard mode of critical reflection as well as a Black quearing of the reflection process takes place when I am reflecting upon my work and processes used when demystifying a drawing and/or the drawing process along with black artist/activist Langston Hughes in "The Negro Artist and the Racial Mountain" takes place in their work as well. Meaning, we all use standard mode(s) of critical reflections to find ways to quare this concept which serves to better critique some of the complexities involved with Black identity and in my case Black quearing mark making

15). Dey beez an ongoing list of Black Vocabulary terms Below. That is compiled from my research and scholarship involving critical race theory, queer of color critique, reviewing Urban Dictionary, from films such as Paris is Burning, and Marlon Riggs' work both in his writings and in films. Ohhh And, yeah Karen! My vernacular also comes from just being Black and embracing Black aesthetics in multiple forms too. Snap! I adding to this list. Sometimes it come

from my millennial 80's baby interperion's of these words and/or gestures. All in all, it is just fun, playful, euphoric, and empowering to name marks and let them name you!

Vocabulary

Ayo - A greeting. Can also be a response to something negative.

Beez - How we say "be." I beez gon to the store.

Blackty, Black, Blk, #000000 - Different ways of referring to Black the color or the people in different ways.

Da - is short for the word, "The."

Da or De - is short for the word, "The."

Dat - shortening of the word That.

Dassit - Meaning: That is it. or Dat is it. As in "Dassit! Go do your own research! We ain't here tah do all dis AAVE Race 101!

Dey - is short for the word, "They."

Der - is short for the word, "There."

Dem - Short for "them."

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- Still from mark 00:13 - Non-Binary Rizz (Feat Dorian Corey), Directed by Maurice Moore, 0:16 sec, 2023.
- Still from mark 00:06 - Still from - Marked Bodies Video 1, Directed by Maurice Moore, 0:47sec, 2022.
- Still from mark 00:55 - Still from - Marked Bodies Video 2, Directed by Maurice Moore, 0:47sec, 2022.
- Still from mark 00:26 - Still from - Marked Bodies Video 3, Directed by Maurice Moore, 0:47sec, 2022.
- Still from mark 00:00 - Still from - Marked Bodies Video 4, Directed by

- Maurice Moore, 0:47sec, 2022.
Still from marks 03:59, 05:39, 05:41,
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Electronic String Art as Educational Algorithmic Art

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Abstract

Traditional string art creates curves from straight lines using nails, string, and a simple counting rule such as connect every 7th nail. Different counting rules or nail locations produce new images, but each change requires significant setup time. By contrast, *electronic string art*, ESA, images change instantaneously as parameters change. This allows users to rapidly adjust values and quickly test hypotheses even if those hypotheses are only incompletely understood. Such purposeful play can lead to learning, even if that learning is informal in nature.

1. The Four ESA Parameters

Electronic String Art is a suite of models, each based on a closed set of connected line segments using a simple counting

rule [1]. ESA has two image creation modalities, web and Excel, that complement one another [2].

ESA images are framed on regular n -gons or n, J -star. n and J determine the *vertex frame*, VF, shown in blue in Fig 1. Each line of the VF is subdivided into S equal subdivisions creating at most $n \cdot S$ possible subdivision endpoints (think nail locations), shown as red dots in Fig 1. The image is created by drawing a line connecting every P^{th} endpoint starting at the top. This process is repeated until the top is once again achieved in either $n \cdot S$ or fewer lines. The bottom row shows two 15-line ESA images using this algorithm with first line overlaid in red.

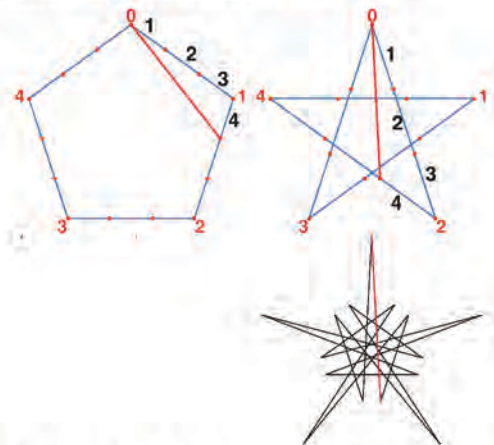


Fig 1. Examples showing ESA images created given $n = 5$, $S = 3$, and $P = 4$ for $J = 1$ left and $J = 2$ right. Top row shows VF in blue with 3 equally spaced

subdivisions per VF line and first line drawn (shown in red) based on counting rule that states: Draw a line connecting every 4th red subdivision endpoint. The bottom row shows the resulting images.

This simple structure allows wide latitude to explore ideas even if those ideas are incompletely understood. Users can rapidly test hypotheses and search for similarity simply by playing with the model. In the process, users are able to visually understand mathematics more deeply, even if that understanding is simply a by-product of such play. This purposeful play is consistent with Stein's *Triex: Explore, Extract, Explain* view of how to teach mathematics [3].

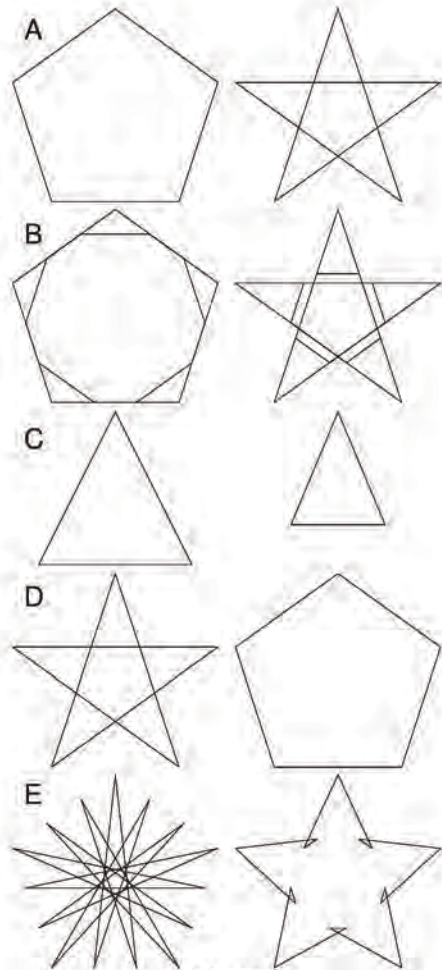
Images change as underlying parameters change and those changes are based on mathematical rules. But there is a second form of dynamism in ESA. It involves how a specific image is drawn, line by line.

2. Issues of Commonality

The completed image connects start of the first line with the end of the last line using a simple counting rule. As such, there are two ways to draw each static image. Additionally, the number of lines required, and how subsets of those lines relate to one another depend on commonality between the parameters.

2.1 Distinct Images

An ESA image has one line in and one line out of the top of the image. The values of n , S , P , and J determine how this first line (shown in red in Fig 1), and hence the image, is drawn. Therefore, there are two ways to draw any image. This is examined in Fig 2 which shows all distinct images given $n = 5$ and $S = 3$ for $1 \leq P < 15 = n \cdot S$. Between Figs 1 and 2, there are 10 distinct ESA images.



$J = 1, 4$ Left*

Fig 2 Row	$J = 2, 3$ Right		Lines in	
	P	$15-P$	Cycle	Total
A	1	14	3	15
B	2	13	3	15
A	3	12	1	5
C	5	10	3	3
D	6	9	1	5
E	7	8	3	15
Fig 1	4	11	3	15

*Notes: J and $5-J$ given $n = 5$.

P and $15-P$ given $nS = 15$.

(J_0, P_0) and $(n-J_0, nS-P_0)$ are drawn

in one direction and $(J_0, nS-P_0)$ and

$(n-J_0, P_0)$ are drawn in the other.

Fig 2. Distinct ESA images; $n = 5, S = 3$.

We see that one may restrict $J < n/2$ and $P < n \cdot S/2$ because larger values of J and P only alters the direction that the image is drawn. We also see that if P is a factor of S , then the image is simply the VF although note that if $P = 1$ or 14 the VF is drawn in 15 connected segments, but if $P = 3$ or 12 , the VF is drawn in 5.

2.2 Vertex Common Factor

The first form of commonality is in the VF between the number of vertices, n , and the number of jumps between vertices, J . This is called the *vertex common factor*, $VCF = \text{GCD}(n, J)$ where GCD is the greatest common divisor function. The number of used vertices and lines in the VF is n/VCF .

The simplest example of $VCF > 1$ is a 6,2-star whose VF is an equilateral triangle because the circuit is complete once the even vertices are connected with one another. A 6,2-star with 6-points cannot be continuously drawn. $VCF > 1$ is also the reason that a 12,5-star is the only distinct ESA star with 12-points (as noted above, a 12,7-star simply draws the VF in the reverse order). In general, as mentioned in the Fig 2 notes, an n, J -star and an $n, (n-J)$ -star simply differ in the direction in which the star is drawn.

2.3 Subdivision Common Factor

Given n/VCF used vertices in the VF and S subdivisions per VF line, there are $S \cdot n/VCF$ possible subdivision endpoints that can be used in the image. The second form of commonality is the *subdivision common factor*, SCF, where $\text{SCF} = \text{GCD}(P, S \cdot n/VCF)$. The number of used endpoints (and lines) in the image is $S \cdot n/VCF/\text{SCF}$. In Fig 2 Row C, the images are both isosceles triangles connecting subdivision endpoints 5, 10,

and 0 since $\text{SCF} = 5$. $P = 3$ creates Row A connecting subdivision endpoints 3, 6, 9, 12, and 0 and the image is the VF but $P = 6$ connects endpoints 6, 12, 3, 9, and 0; a pentagram results if $J = 1$, and a pentagon results if $J = 2$. In each case, this happens because $\text{SCF} = 3$.

2.4 Cycles (Cycle Generator)

The image will have rotational symmetry equal to the number of polygonal vertices included in the final image. Given this, in order to understand an image, one need only consider that part of the image spanning from the top of the image (the start of the first line) to the next time a polygonal vertex is encountered using the counting rule described in Section 1. For simplicity we call such a sub-image a *cycle*. [It is worth noting at the onset that it is mathematically more accurate to call this a *cycle generator* because the entire image is a cycle.] In Fig 1 the first cycle ends at vertex **4** for the left image and vertex **3** for the right image if $P = 4$. The next cycle ends at vertex **3** at left and **1** at right, and so on. As noted in Fig 2, the same static image occurs given $P = 11$ in which case the first cycle ends at vertex **1** for the left and vertex **2** for the right.

In general, the number of lines in a cycle is $S/\text{GCD}(S, P)$. As a result, given $S = 3$ in Fig 2, $P = 3, 6, 9$, and 12 produce one-line cycles; all other P have 3-line cycles.

3. Searching for Similarity

From an educational perspective, the best question you can ask is: *Can you find similar but not identical images to an image you find interesting?*

Suppose, for example, that you like the spiky 5-needle image in Fig 1, (n, S, P, J) of $(5, 3, 4, 2)$. You might quickly find similar images such as $(7, 3, 4, 3)$, or $(7, 3, 5, 2)$, or

(11,3,4,5). In each case this involved changing just 2 of the 3 parameters n , P , and J from their Fig 1 values while maintaining $S = 3$. If one allows larger S values then the images become more complex, nonetheless, some nice spiky images are still possible as Fig 3 shows. The key is to find a subdivision endpoint that is very close to the vertical diameter.

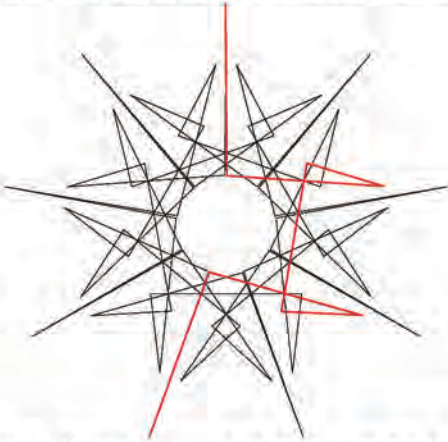


Fig 3. Image given $(n,S,P,J) = (9,7,17,4)$ with 7-line first cycle overlaid in red.

In Fig 3, the 3rd subdivision endpoint from each end of every line of the VF is very close to another endpoint on the VF. The pair that are very close to the vertical diameter are $P = 17$ and $P = nS - 17 = 46$. The version shown is the 3rd point of the 3rd VF line (since $17 = 2 \cdot 7 + 3$), just to the right of the centerline. The end of first cycle is at vertex 5. The other drawn version, $P = 46$ is the 4th point on the 7th VF line (since $46 = 6 \cdot 7 + 4$), just to the left of the centerline and the first cycle in this case would end at vertex 4.

4. Some Interesting Images

Playing with these parameters produces a wide range of images. Here are a few examples. Fig 4 is a 138-line spinning needle star that uses all its vertices but

only 1/5th of its 690 subdivision endpoints since $SCF = 5$. These endpoints and the first line are shown in red. Given this first line, it is clear the image is drawn counterclockwise, \cup . If you want to see it drawn clockwise, \cap , change to $J = 17$.

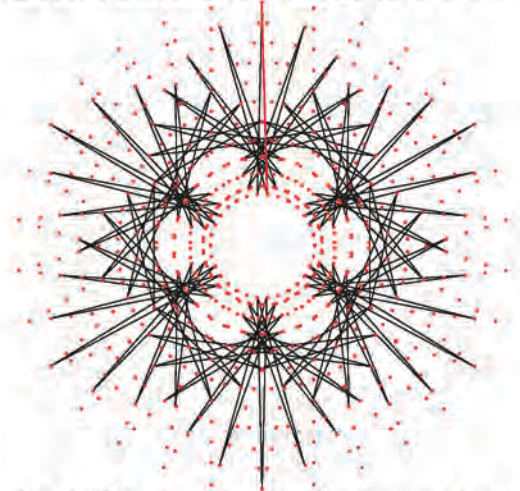


Fig 4. Spinning Needle Star image given $(n,S,P,J) = (30,23,265,13)$.

Figs 5 and 6 show images with first cycle overlays in red. They differ by a single subdivision per VF line ($S = 11$ vs. 12).

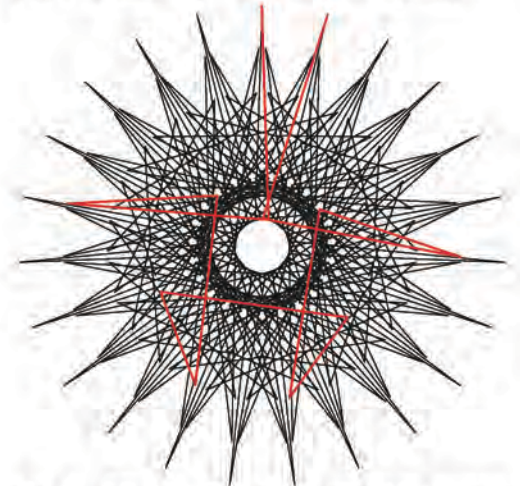


Fig 5. Needle Star with Shields image given $(n,S,P,J) = (23,11,71,12)$.

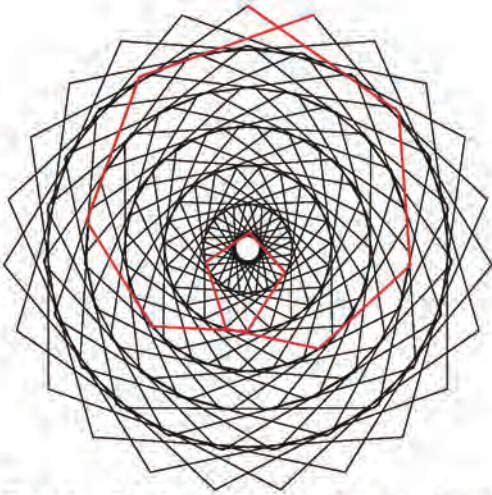


Fig 6. Stacked Circles image given $(n,S,P,J) = (23,12,71,12)$.

Because the first cycle ends at vertex 1 in Figs 5 and 6, both are drawn in a \cup 1-time-around fashion. The same would be true for other values of S because P and J are modular multiplicative inverses (MMI) modulo n meaning that $71 \cdot 12 = k \cdot 23 + 1$ for some k (here $k = 37$). This is like the Ticking Clock images in [4].

The 570 line Fig 7 provides a very different visual interpretation of MMI. Here 7 and P are MMI mod $n \cdot S$ ($7 \cdot 163 = 1141 = 2 \cdot 570 + 1$) meaning that the end of the 7th image line is the 1st subdivision on the 1st VF line, just beneath and to the right of the top of the image at the end of the 7th red line. I call such sub-images *single-step*. Given this, the 14th endpoint is the 2nd subdivision endpoint, and so on. The image is completed after about 81 steps (since $81 = 567/7$). Note that J is not part of this MMI calculation so that changing J creates additional single-step images (try $J = 7$). These images are best viewed dynamically using links in the **Notes** [2].

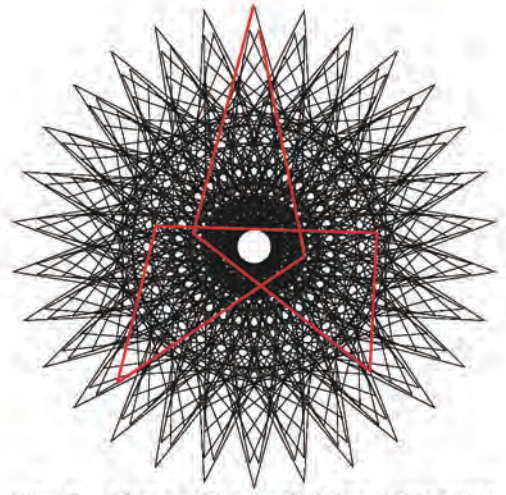


Fig 7. Three Shape-Shifting Triangles image given $(n,S,P,J) = (30,19,163,13)$.

Fig 8 is a divisible star. This 250-line image uses every vertex, $VCF = 1$, but only one 248th of possible subdivisions, $SCF = 248$, because $n = P$. The first 3 lines, shown in orange form an "almost-equilateral triangle" the peak of which rotates \cup , and is a *smallest-step* [1].



Fig 8. An example of the illusive 6,2-Star given $(n,S,P,J) = (248,250,248,83)$.

The entire image is created by 83 of these almost equilateral triangles rotating \cup plus 1 line ($250 = 3 \cdot 83 + 1$) which is why the last triangle ends at “vertex 4” of the “6,2-star” so that the final line brings us back to the top and completes the circuit. This description is best understood using the web link to watch it get drawn dynamically. To see a virtually identical image get drawn \cup in 248 lines, change to (250,248,250,83), since $248 = 3 \cdot 83 - 1$.

5. Jump Sets

Jump sets are an extension of the basic model that creates a more complex VF. The easiest way to explain jump sets is to set $n = 12$ since then we can talk in terms of hour jumps. $J = 2$ produces a hexagon connecting 2-4-6-8-10-0 (read - as connect) since $VCF = 2$. A jump of 4 produces a triangle connecting 4-8-0 since $VCF = 4$. But what if a jump of 2 is followed by a jump of 4?

5.1 VCF with Jump Sets

The VF of the two-jump set, $J_1 = 2, J_2 = 4$ is 2-6-8-0. If $J_1 = 4, J_2 = 2$ the VF is 4-6-10-0. If $J_1 = 5, J_2 = 1$ the VF is 5-6-11-0. All three VFs are quadrangles (in fact all are rectangles) since the circuit is completed once the top is achieved *at the end of a set*. If $J_1 = 6, J_2 = 3$ the VF is 6-9-3-6-0-3-9-0. The 8-line 4-leaf clover VF uses only 4 vertices because each used vertex is used twice. If you draw the VF, you will note that both diameter lines are drawn twice, once from one end, and once from the other.

Consider $J_1 = 3, J_2 = 4$. Individually, these produce a square and a triangle, but together their $VCF = 1$. The first few lines of the VF are 3-7-10-2 The VF has 24 lines with all vertices used twice. Fig 9 shows a four-color example of this image

based on Chapter 17 of [1]. If you look carefully, you can see that the VF has 3 squares and 4 equilateral triangles.

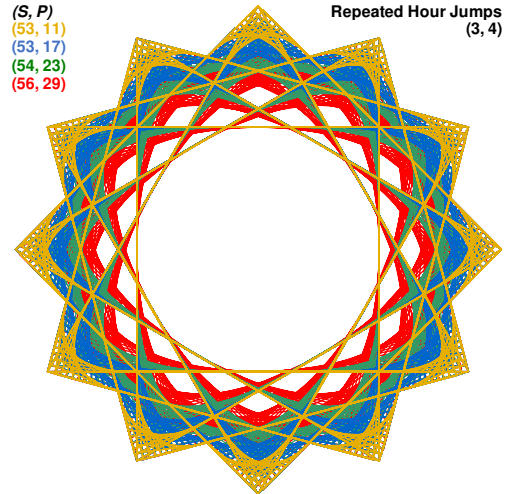


Fig 9. Image based on a double jump set.

This same idea works with different n and a larger number of jumps in the jump set $k > 2$. The general rule for lines in the VF in this instance is $k \cdot n / VCF$ with $VCF = GCD(J, k \cdot n)$ and set sum $J = J_1 + J_2 + \dots + J_k$.

5.2 Zero Jumps

The swirling wreath around the picture on the first page is based on the three-jump set (3,4,0). Compare that image (minus the picture, of course) with Fig 9. The end of the second jump is at 7 in both cases. In Fig 9, the next jump is to 10 which is why you can see a curve spanning vertices 3-7-10 that is absent in the three-jump version. The third jump remains at vertex 7. This is most clearly seen by the red and white swirl and by the white triangular areas like the one bounded by the line from 5 to 8 and the 15° angle, 10-7-11. This 15° - 75° - 105° triangle is formed by $J_3 = 0$. The second set of curves in the swirl is from 7-10-2 but that is the third set of curves in Fig 9.

Suppose we say that the swirl image on the first page is \cup going toward the center. If you want to change to a \cup swirl going to the center then simply change to a three-jump set of (4,3,0). These swirls point to the fact that jump set images need not have the vertical symmetry that exists for single jump ESA images. It is worth noting that the four-color models are not available on the web version and a zero jump is attained in the web version by setting $J = n$ [1,2].

5.3. Fibonacci

Larger jump sets are only available using the web version [2] and are discussed in Chapter 18 of [1]. Among these, many images using Fibonacci numbers as jump sets are beautiful as static images, but are particularly compelling to watch get drawn for those that are single-step.

The first two Fibonacci-based images have a $k = 7$ jump set using the first 7 Fibonacci numbers, 1,1,2,3,5,8,13 so the set sum is $J = 33$. Each is also single-step of length 3 and each shows the first 3 lines in orange.

560-line Fig 10 sets $n = 132 = 4 \cdot 33$ and $S = 20$. The VF has $28 = 7 \cdot 4$ lines and $560 = 28 \cdot 20$ subdivision endpoints. $P = 187$ because $3 \cdot 187 = 561$ (therefore 3 and 187 are MMI mod 560).

2401-line Fig 11 sets $n = 231 = 7 \cdot 33$ and $S = 49$. The VF has $49 = 7 \cdot 7$ lines and $2401 = 49 \cdot 49$ subdivision endpoints. $P = 1601$ ($3 \cdot 1601 = 4803 = 2 \cdot 2401 + 1$ so that 3 and 1601 are MMI mod 2401).

Other single-step images are, of course possible. For example, if we start from Fig 11 and change to $P = 1334$, a 7,3-star is formed that is single-step of length 9 ($9 \cdot 1334 = 12,005 = 5 \cdot 1601 + 1$). Other MMI pairs are found by backtracking

Euclid's Algorithm as discussed in Chapter 24 of [1].



Fig 10. A Fibonacci-7 Cross.



Fig 11. A Fibonacci-7 7,2-gram.

The values used to create Fig 11 were chosen to highlight a way that you can create "flickering videos" from images such as these. Note that $2401 = 7^4$. This means that every 7th P value has lower line density because $SCF = 7, 7^2, \text{ or } 7^3$ and all other P have $SCF = 1$. Put another way, you can watch the image

change in waves by scrolling across P values and 6 out of 7 will be at full density. How many distinct images are there? Set $P = 1,200$ and change to 1,201. Both are the same static image; the only difference is the direction in which the image is drawn (see notes to Fig 2). ($P = 1200$ is a porcupine image [1] as is the $J = 1$ Row E image in Fig 2.) There are 1,199 distinct images in this situation (since 1 and 7 both produce the vertex frame as discussed in Fig 2).

The bird-beak in Fig 12 is created by setting $n = 13$, the size of the 7th Fibonacci number. The beak is created with the last half of the set listed backward (with last jump removed) 1,1,2,3,5,8,13,13,8,5,3,2,1 so that $J = 65$ in 13 jumps. Since J is a multiple of n , the image is completed in a single jump set. This image is also single-step of length 2 because $S = 13$ and $P = 85$.

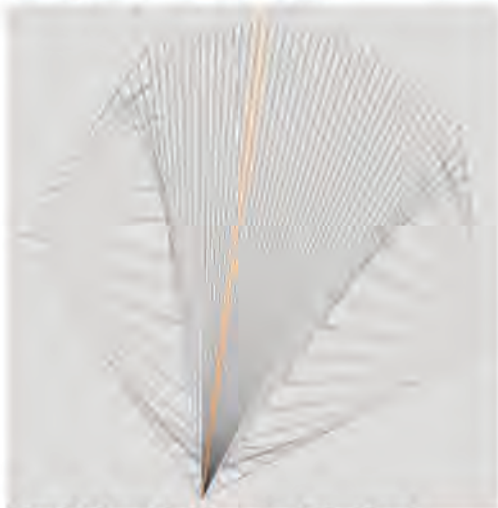


Fig 12. Double Fibonacci Bird-beak.

It is instructive to work through the jumps involved in Fig 11. The point of the beak at vertex 7 is at the end of the 4th jump. It is also the location of the pair of 13 jumps

(zero jumps). The bird-beak is another example of a porcupine image.

6. Non-Polygonal Vertices

One benefit of working with regular polygons is that users need not worry about where the vertices are located in the (x, y) plane. Users can explore as soon as they can point and click, and they can watch images change as n or J change.

Users can create ESA images with vertices of their own choosing, but the mathematical bar is higher since the user must place those vertices in the (x, y) plane. This is based on [5] which is expanded on in Chapter 19 of [1].

6.1 How V replaces n and J

S and P work just as in the polygonal model but a new variable V (for *Vertices used*) replaces n and J . The key to this version of ESA is that the vertices must form a closed loop. With the vertices of a regular polygon this is true but went unsaid; here it must be explicitly noted in order to understand how the image emerges from the vertex frame. The easiest way to explain how this works is to show how an image like the $V = 20$ cube in Fig 13 is created from the dashboard shown in Table 1.

After the last used vertex, the next vertex is always vertex 1, here the point $(10, 0)$. Given this, a triangle results if $V = 3$. When $V = 5$, the comma could be the start of the right side or the top. By $V = 8$ we see that the top is complete and by $V = 12$ the right side is complete as well. One might think that by $V = 16$ the image is complete but that does not happen until $V = 20$.

As you examine the progression of Fig 13 images, you may wonder why $V = 9$ looks less complete than $V = 8$. The reason is straightforward – vertex 9 is the same as vertex 1; the result is a zero jump like discussed in section 5.2 and also at vertex 7 in the Fig 12 bird-beak.

20	19	11
V , # of vertices used. $V \leq 21$	S , # of subdivisions per side	P , # of subdivisions between Points
You can change the yellow cells		
<i>Note</i> : Keep $V * S < 1000$ (or pattern will not repeat)		
Vertices	X	Y
1	10	0
2	0	0
3	0	10
4	10	10
5	14	14
6	4	14
7	0	10
8	10	10
9	10	0
10	14	4
11	14	14
12	10	10
13	0	10
14	0	0
15	4	4
16	4	14
17	4	4
18	14	4
19	14	14
20	10	10
999		

999 above means "vertex not used"
 Table 1. Dashboard for creating images based on user-determined vertices.

6.2 Creating your own Initials

For students who are just learning about Cartesian coordinates, asking them to create their own initials in string art, provides an exercise that can spark excitement and creativity.

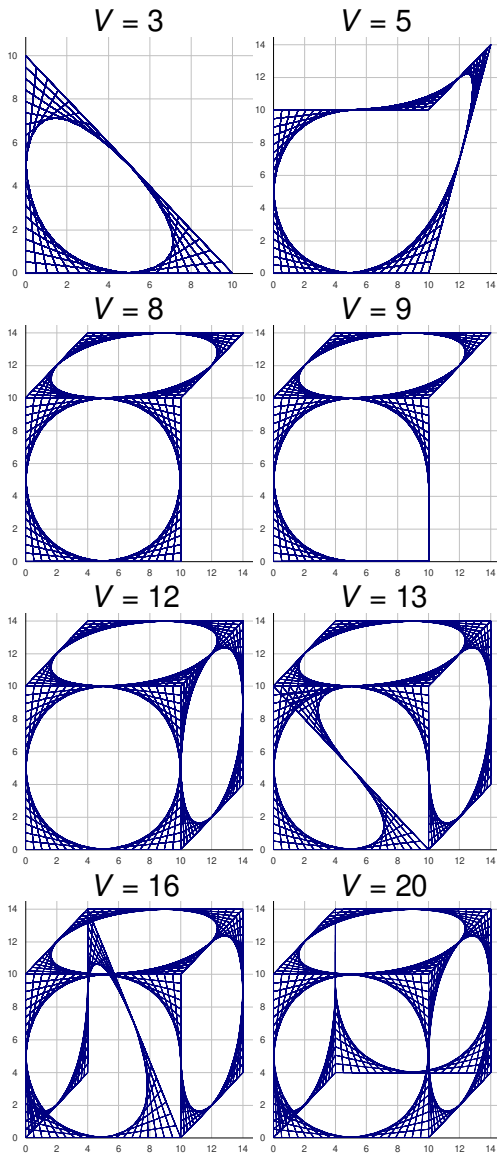


Fig 13. Creating a cube based on Table 1. Images for various values of V.

Section 19.6 of [1] provides suggestions for laying out initials. Among them, the most important are to start in the middle, use graph paper, and cell reference vertices that are used multiple times. The GA shown in Fig 14 used 33 vertices as

noted beneath the image. The image started at the connection between G and A and returned to that vertex four more times at vertices 19, 20, 28 and 33. The 19, 20 (after G was created) and 33, 1 pairs of vertices form zero jumps. This ensures that there are no curves connecting the G to the A (since $S > P$). The Excel file used to create this image allows up to 40 vertices and those vertices need not coincide by color [1].

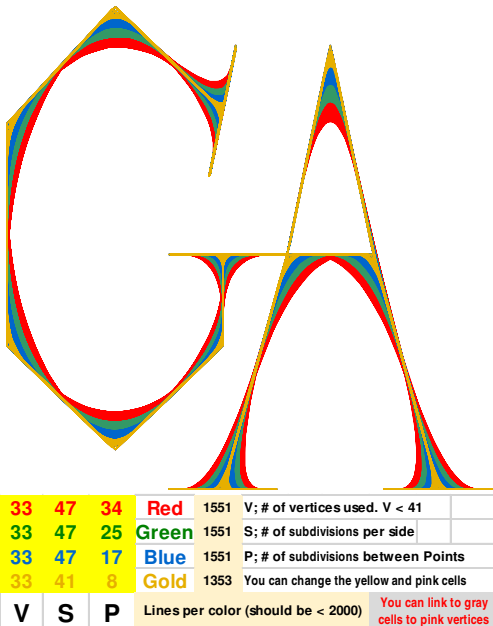


Fig 14. An example of creating initials using ESA.

7. Summary

Electronic String Art combines art and mathematics in a way that allows users to learn mathematics more deeply, simply by adjusting parameters and watching what happens. ESA was created for independent explorations but it is useful in more formal K-12 classroom settings to support teaching of various topics in a visually appealing way.

Notes

The links below take you directly to the web version [2] set to that figure. There are various *Drawing Modes*, start with *Fixed Count Line Drawing*, FCLD, and set *Drawn Lines*, DL, as noted then adjust drawing speed to your taste.

- The web version of [Fig 4](#), set DL = 2.
- The web version of [Fig 5](#), set DL = 11.
- The web version of [Fig 6](#), set DL = 12.
- The web version of [Fig 7](#), set DL = 7.
- The web version of [Fig 8](#), set DL = 3.
- The web version of [Fig 10](#), set DL = 3.
- The web version of [Fig 11](#), set DL = 3.
- The web version of [Fig 12](#), set DL = 2.

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Generative Explorations into Baroque Helical Columns

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Fig.1 Interlocking 3D printed fragments

Abstract

This abstract presents a series of fragments of 3D printed ceramic elements that are to be considered architecturally informed artworks, based on baroque Solomonic columns.

The pieces came out of discarded elements from another project aiming to create a 3D printed ceramic skin for structural steel that used parametric and generative processes to develop the geometry for the column.

When working on the original project, I noticed the beauty in the ruinous and unfinished quality of the rejected pieces when they were assembled as fragments.

This work is a result of these observations and is the embodiment of the failures, successes and quirks of translations of generative geometries into real materials. It represents the gap between an original ambition, what is seen on the computer screen and unpredictability in the fabrication process.

The works are described as baroque due to the direct reference of the voluptuous geometries of the Solomonic column and the great potential of variations from both generative and parametric approaches.

Rather than copy these types of columns, I aim to interpret their geometries and rules and reproduce them through the medium of 3D printed ceramics. In this series I adopt a helical form and a curved cross section and generate print paths to be sent to the machine.

There is a selection process that happens on the screen once geometries have been generated, another after the prints have been made and finally, in how they are assembled.

These works embody aspects of both precision and the unknown, when working in the intersection of generative processes in architectural design, unruly materials and digital fabrication technologies.



Fig 2. Larger helical column fragment

At present, I have the works attached as photographs to this abstract that include one large piece 1.2 meters in length and several fragments.

As this is a project that is exploratory and work in progress, I am in the process of developing further large- and small-scale pieces over the course of the next few months that may also be ready for the conference.



PseudoGAN.

A conceptual software for generative art

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Abstract

Introduction

Generative Artificial Intelligence solutions provide astounding audiovisual results in digital art, illustration, videogames and more [1, 2]. But these achievements come with many challenges.

The first problem with generative AI is that issues arise from the lack of a proper connection between digital and traditional culture, the clash between Romantic aesthetics, and the drawbacks of AI systems, including biased training data, flawed model assumptions, and lack of transparency [3, 4, 5]. Furthermore, many esthetics, artistic, scientific, educational, and ethical question are still unresponded [6, 7]. These questions are related to computational creativity, computer science and digital divide issues. Leaving apart phylosophical positions, developing the pseudoGAN software project, I was interested in three specific topics: a) the aesthetic and educational limits of generative AI such as GANs; b) the drawbacks of the standardized solutions offered by IA monopolies; c) the importance of original technology development and Open Source Software,

making it available for use, modification, and distribution in artistic and educational contexts.

The hipotesis is that achieving an inclusive, sustainable, and creative use of digital media, in general but especially for generative art requires the development of original proprietary digital technology, grounded in cultural identities, without black boxes and the biases of data models. The main task was to emulate machine learning and neural networks' results, and the unpredictable morphological interpolations made popular some years ago by Google DeepDream (Fig. 1). Why to do all this? Basically, I do not like the idea of AI doing all the intersting work of artistic research and leaving the artstic experience to machines.

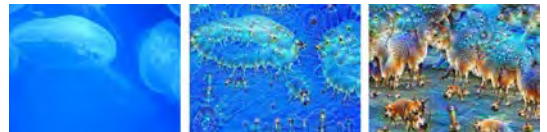


Figure 1. Google DeepDream interpolations.
Source:

<https://en.wikipedia.org/wiki/DeepDream>

This research is based on a literature review, software design, and artistic practice, and it highlights the importance of the humanities, ethno-computation, and analogical processes and materials. Starting from the images generated by AI

algorithms such as GAN, we investigated innovative solutions to interpolate images or generate morphing processes. To do this, during the research project were experimented alternative algorithms using only two source images, simple well known image processing techniques, without arcane mathematics or bigdata references. This application is a sort of conceptual software: even if it can be used for practical applications, such as creative image processing or video effects, it enlightens concepts about Artificial Intelligence art, creative software, digital art, inclusive education, and multicultural technological development.

1. PseudoGAN's software design principles

In the first place, my point is that the substantial contributions to artistic theory and practice are not images, animations or other audiovisual artworks, but software design and coding. The second important concept here is that the important learning process is the user's learning process, not the machines. This can guarantee real creative autonomy and originality, since the artist-user stays in full control of the process and its development. On the other hand, there are interactivity issues that should be revised, following Habermas communicative action statements [8]. Thus, I followed these guidelines to match technical and communicative action requirements (*in italic*):

- Clearly organize the interactive workflow (*achieving mutual understandings*).
- Explain every step of the process, without the need to open help windows (*feedback*).
- Help the user to avoid possible computational mistakes, like

divisions by zero, bad protocols, or improper data formats (*intelligibility*).

- Solve interactivity issues accomplishing, like transparency of knowledge with Open Source Software (*sharing knowledge, democracy*).
- Simplify the algorithms and resource demands, working only with 2 images a a time, no big data, no statistics, and almost no math (*intelligibility*).

I will enter into development details in the following chapters.

2. Interface and functions

Form the point of view of interface design and communicative action, the goal was to expose the processing sequence and making intuitive the connections between parameters. Standard interface componetes are designed to be similar to neural networks' nodes and weights (fig. 2), but clearly explained, parametrized, and visualized (communicative actions' transparency and equality requirements).

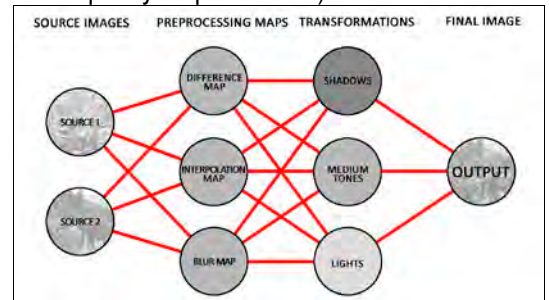


Figure 2. PseudoGAN neural network metaphor example. Work in progress.

To do this, the pseudoGAN software architecture was split into different modules and the elaboration process split into three main steps, organized in the proper sequence in the interface: preprocessing, morphing processes, and

postproduction.

I took great care to provide effective feedback to the user, this is necessary also when developing and experimenting with the software development.

I choose to forget the best efficiency, like speed, in favor of the legibility of code to facilitate editing, improvements and experimentation. The writing of code is an important part of multiauthoring and of the generative artistic experience.



Figure 2. Interface design basic design and concepts. From left to right: input and output functions, preprocessing, processing and postproduction. Still in development.

2.1 Preprocessing

The first task of the process is to prepare images that will be used as masks in different ways in the mixer module (fig. 3). The preprocessing process consists of three steps: 1) create a difference map that is a grayscale image mapping the differences between pixels of two source images, 0 means the pixels are equals, 255 100% different; 2) create the interpolation map blending the source images, values are assigned using percentuals of the sum of the values of the two source images, when the sum is 0, gets 100% of the first source image, when 128, 50% of source image 1 and 50% of source image 2, when 255 100% of source image 2. Pixels between these values gets different percentuals; 3) create the blur map, that is a sort of

antialiasing of the two source images. More maps can be added using different criteria. These maps are used as references for mixer's parameters modulation and act like neurons in a neural network, the learning process consists in adjusting interactively their weights (fig. 2).

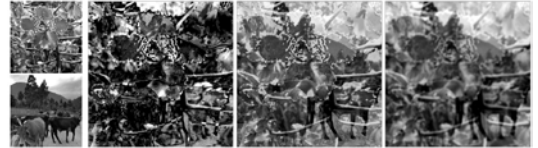


Fig. 3. From left to right: source images, difference map, interpolation map, blur map.

2.2 Transformations and morphing processes

The basic concept of the morphing process is to interpolate a selection of source images' similar pixels, filling the spare pixels with some interpolation between the 2 source images. This is done for shadows (Fig 3a) and lights (Fig 3b). Similar pixels expand in the bitmap like a wet into wet effect of watercolor paintings. Then lights are added to shadows (fig 3c) using different algorithms and parameters' values. Finally, a gray map (pixels around 110-138 brightness values) is used to refine details in the middle tones.

Maps and shadow-light interpolation have interactive menus to change the algorithms' behaviors. In this way is possible to generate different versions of the same process (functions can be programmed to generate animations, video effects and more). These images will be used in the mixer to get the final effect.

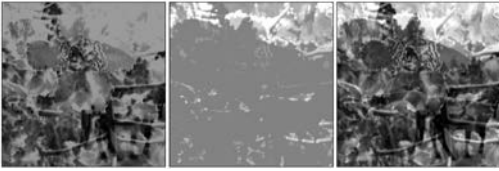


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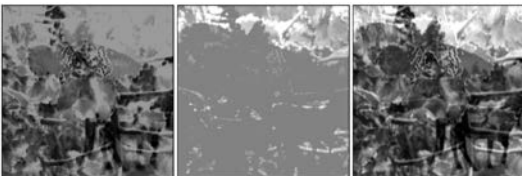


Fig. 3. From left to right: shadows and lights interpolation, union of shadows and lights interpolations.

2.4 Mixing

When interpolations are finished, the user has a set of different images that can be remixed like tracks in electronic music production. Using the mixer module, it is possible to equalize gray levels or colors, compress values, use masks (difference map, blur map, etc.), and apply filters with interactive parameters that can be animated modifying the effect parameters values in time. Frames will be automatically generated and saved in an Animation folder.

The user can apply neural networks feedback concepts adjusting the parameters (weights) or changing the order of the function in the interpolation sequence, until the right is achieved

2.5 Results

As explained before, the project's goal is to develop an application to create an image from source images which parts melts together to generate unexpected forms, like generative AI or GAN do using databases of thousands of images. Obviously, the final effect depends on the characteristics of the source images, AI does not understand the meaning of the images or of their parts; in fact, it is using statistic analysis that generative Ais can "select" the best matching forms and, adjusting the weights of the nodes (the "learning" process super or unsupervised), combine them realistically [9].

On the contrary, I purposely use only two source images, and decided to tune the parameters manually and without complex mathematics [reference]. This solution puts the artist in command of the weight tuning process [10]; the learning process then becomes something creative, since the user must experiment

to match images that can be completely different, as shown in figure 4



Figure 4. Details of source images and of the interpolation result. It is a nice surprise if images match in some ways.

A useful trick is to work some interpolations using a low-resolution copy of the images; this not only speed up the process but can improve the effects of the filters in many ways, like the sumi-e effect of the topo left image of figure 5. The interface design must provide enough flexibility and variety to let the user experiment freely and switch easily between images, maps and filters. The interpolations' sequences and functions' parameters can be changed anytime interactively; thus, the user can create his own processing scripts.



Figure 5. Gray scale and color images using different resolutions and sources. R, G and B channels are processed in the same way of grayscale values. The RGB's process is still under development.

3. Discussion and conclusions

To finish, I will resume the ideas and findings of the research developed in the previous sections, and terminate with some general considerations about software development, artistic practice, and generative art, computational creativity, education, and digital culture in general. It seems important to mention that academic literature seems not too much interested in cultural or esthetic issues of AI, with few exceptions [11, 12, 13].

Anyway, as said in the introduction, the starting point was to analyze and hack GANs processes, to get more computational creativity's freedom, under two main assumptions: first, that using AI the artist is the AI (or it's programmer or computer scientist), and not the user [10]; second, that, observing GANs results, it is clear that these are standardized combinations of existing materials, which in the long run always repeat the same formal characteristics.

Starting from the technical point of view, the differences with generative AI and GANs are the followings:

- a) Almost everything that generative AI and GANs do can be succeeded using standard image processing techniques.
- b) PseudoGAN's effect is not always realistic, since the interpolation statistics is just between two images, while machine learning checks thousands of images to catch the best matches between pixels.
- c) Parameters feedback and backpropagation between functions (like the weights of the nodes of the neural network) are in the user's hands, to trigger and stimulate his creativity.

- d) Algorithms are transparent, no black boxes of any kind, so interactivity is real, not just smashing buttons or playing with prompts.
- e) Instead of generic and global references based on big data, pseudoGAN's users can access local and contextualized information and processes; these assets include local cultural and technological assets, and artistic and natural environments references; these can be embedded in the algorithms and inspire the users' scripts.
- f) Concerning future developments and research, I will do more research to improve the interface and software architecture, refine color interpolations, develop more interpolation options, experiment with new algorithms for image processing, like textures, adding more pixel selection patterns, not just single pixels as done in this pseudoGAN version, and finally develop more macros and animation tools.

From the methodological point of view, we consider important to mention:

- a) Generative AI artworks are often formal exercises with little impact or even negative impact on real contexts, due to the limitations we have discussed. On the contrary, developing proprietary solutions can be significant in specific environments, because references relate to their cultural identities, and the solutions developed can be shared as educational processes designed

for the specific artistic research context [12].

- b) The development of proprietary and original digital technology is paramount for educational, digital divide and digital neocolonization issues [14]. It reduces the power of digital monopolies.
- c) Generative AI appears extremely flexible and unpredictable. This is an improper attribution, that is valid only speaking of the artwork as an object, that in the light of postmodern esthetics, overproduction, language saturation and so on is antiquated. And, considering processes and concepts, where hypertextual authorship develops, the AI's esthetic framework is repetitive and outdated.

And finally, I will pose some conceptual issues that are important to mention for education and artistic commitments. Some authors, critics or developers have doubts about the possibility that IA could find esthetic solutions that human can't imagine, but agree that AI can help study and develop human creativity [11] is false, since the model of IA is the human brain, its algorithms and criteria are human. Considering that, as Plato said, an imitation is always less than the original, AI's models are dangerous. For this reason, pseudoGAN software was developed keeping in mind the human artistic practice and creativity (even if in the scope of a specialized and small solution).

Considering all this, a fundamental question arises: why train and use AI when we can train and learn ourselves? The complexity of human artist

experience is something a lot more significant and creative, that AI technologies are stealing this from us. The abuse of IA reduces and turns off the efforts to undertake original research in generative art, and explore different solutions

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'Subversion' from the series 'A Theory of Universal Control'

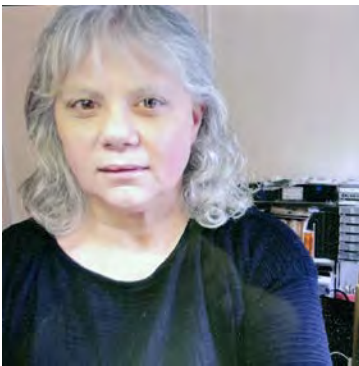
Angela Ferraiolo

New Genres, Visual and Studio Arts, Sarah Lawrence College

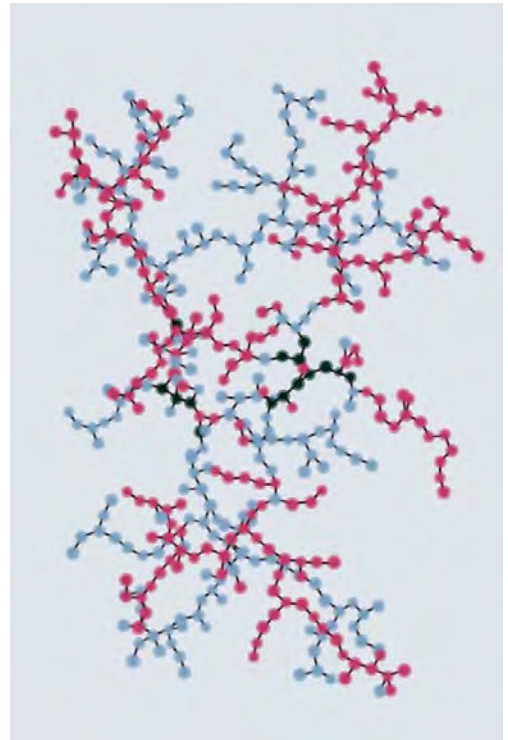
<https://littleumbrellas.net/>

https://www.instagram.com/angela_ferraiolo/

e-mail: aferraiolo@gmail.com



cultures of discipline towards cultures of control.



Abstract

This paper describes my screen-based art work 'Subversion', one work in a series titled 'A Theory of Universal Control'. The series uses computer models and adaptive systems to explore mechanisms of control and strategies of resistance in contemporary society. This particular work, 'Subversion', models subversion and disruption as a strategic response to a control strategy of forced conformity.

1. Overview

Thirty-years ago, the French philosopher Gilles Deleuze made a series of observations about the way power organized society. According to Deleuze, societies were shifting from Foucauldian

Fig 1. *Subversion*, Theory No. 4 from *A Theory of Universal Control*, 2023, Angela Ferraiolo, digital file from computational system.

The exercise of power was moving from institutional regimes of discipline towards mechanisms of logic and protocols of

information. Societies relying on institutions to establish social hierarchies would soon employ protocols of control to enforce hierarchies. Where disciplinary power had been based on surveillance, control power would be enforced through tactics like access and modulation. In control societies standards and benchmarks are actively shaped and reshaped as they are tested. Control shifts from reform and rehabilitation to influence and protocol. It's important to note that Deleuzian theory is highly nuanced and escapes simple dichotomies, but recent interpreters of Deleuze have observed that while societies of discipline sought to shape people and things, societies of control seek to generatively moderate what people and things are becoming or may become.

1.1 Rhizome as Metaphor

In their work, *A Thousand Plateaus*, Deleuze and Guattari use the rhizome as a metaphor to describe different modes of organization, control, and power. For Deleuze, the rhizome is non-hierarchical, interconnected, and lacking a central structure. It represents a more decentralized and dynamic form of organization, where power and influence can emerge from multiple points, with no central authority.

In *Plateaus*, the rhizome metaphor goes much deeper and covers a broad range of concepts and dynamics. The concept of 'rhizome' is introduced in a philosophical context to describe certain characteristics of organization and control in society. However, instances of this structure can be adapted and applied to computational models to represent similar kinds of organization. In *Subversion*, branching structures can be

seen as reflective of control structures becoming a visual metaphor that alludes to several aspects of control societies including:

Decentralization

The absence of a central authority and the presence of multiple interconnected nodes, which can represent individuals, data sources, or decision points.

Networked Control

The interconnectedness of nodes in the rhizome can represent how control and influence can emerge from various points within the network, rather than from a single, top-down source.

Fluidity and Adaptability

A rhizome structure can be visually dynamic, showing how connections can shift and adapt in response to changing circumstances or inputs, mirroring the flexibility of control in a control society.

While branching metaphor may not capture all the complexities of control societies, it can serve as a starting point for developing computational models and visualizations that shed light on the decentralized and networked nature of control in our modern, interconnected world.

1.2 System Design

Subversion and its larger series continues my work in adaptive systems that explores forces at work in post-capitalist societies. *Subversion* is made up of two factions of agents engaged in a struggle for power as expressed as their faction size. There are three factions active in the system:

Faction "a"

These agents follow a strategy of subversion, and seek to corrupt the agents they attack

Faction "b"

These agents follow a strategy of conformity and seek to copy themselves onto the agents they attack

Faction "c"

These agents follow a strategy of disruption and cause the agents they attack to switch factions regardless of their original loyalties

These factions are distributed over two 'agents' or sets of nodes. A sensor reads the amount of dissonance present in the world, and determines which faction will make the next move. Agents track the outcomes of individual competitions between nodes to evolve an overall strategy across their network. Agents also score the success rates of their constituent factions to evolve an overall agent or network faction population at each generation. On gaining majority presence in the system, factions can gain control of the sensor, though disruptors can reassign control of the sensor at certain times as well.

2. Discussion

Interpreting the metaphor of a system where factions attack and subvert each other in the context of a control society can carry a number of associations with various aspects of society and governance. Here are some ways to interpret this metaphor:

Power Struggles And Conflict

The factions represent different groups or entities within a society, and their attacks and subversion symbolize power struggles and conflicts that are inherent in human societies. This metaphor underscores the idea that competition and conflict for control or influence are common features of social and political systems.

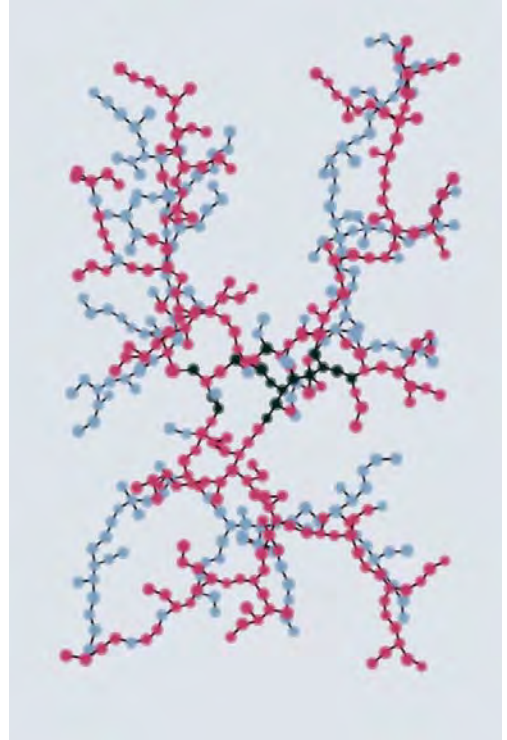


Fig 2. *Subversion, Theory No. 4* from *A Theory of Universal Control*, 2023, Angela Ferraiolo, digital file from computational system.

Authoritarianism and Surveillance The concept of a "control society" suggests a level of authoritarianism and surveillance, where those in power seek to maintain control over the population. The metaphor highlights the potential for abuse of power and the erosion of individual freedoms and privacy in such systems.

Dynamic and Adaptive Systems

The metaphor of factions attacking and subverting each other within a computer model represents a dynamic and adaptive system. In real-world societies, various groups and individuals constantly adapt their strategies to gain advantages or protect their interests. This metaphor

reflects the ever-changing nature of social and political dynamics.

Resilience and Vulnerability

The metaphor can also be interpreted in terms of system resilience and vulnerability. Factions that successfully attack and subvert the control system demonstrate vulnerabilities in the existing power structures. On the other hand, the control system's ability to withstand these attacks showcases its resilience and adaptability.

In addition to these primary readings of the system, there are several additional readings associated with the project:

Unintended Consequences

Factional conflicts and subversion can lead to unintended consequences and collateral damage. This metaphor illustrates how actions taken by different groups may have ripple effects throughout a society, affecting not only the targeted control system but also innocent bystanders.

Social Commentary

The metaphor can serve as a form of social commentary, raising questions about the ethical and moral dimensions of power, control, and governance. It prompts us to consider the trade-offs between security and individual freedoms in control societies.

Complexity and Interconnectedness The metaphor emphasizes the complexity and interconnectedness of systems. Actions taken by one faction can have cascading effects on other factions and the overall control system. This underscores the importance of understanding the interdependencies and feedback loops within society.

Modeling and Simulation

Finally, the use of a computer model to simulate these dynamics underscores the

role of computational modeling in understanding and potentially predicting the behavior of complex systems. It highlights the utility of such models for studying real-world societal phenomena.

The metaphor of a control society with factions attacking and subverting each other is intended to serve as a lens allowing the consideration of dynamics, challenges, and consequences of power, control, and conflict in human societies. It encourages critical reflection on these issues and the potential role of computer models in shedding light on complex societal systems.

Conclusion

This paper described an artwork titled Subversion, one system part in a larger series of works titled 'A Theory of Universal Control'. Subversion, and this series as a whole examines the dynamics of control societies and recent theories of control. Subversion consists of a set of agents representing distinct factions each with different strategies of engagement that compete for control across a branched structure of connected nodes. The design of the project draws on ideas from adaptive systems, critical theory, philosophy, and political science. The motivation for this project was to explore the branching structures as adaptive systems and as an expressive form.

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Radical Collaboration and Generative Practices for the production of *Labyrinth: Defining Humanity*

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Labyrinth: Defining Humanity
Beijing International Fringe Festival

Playwrights: Mei Ann Teo and Company, Lauren Yee, writer

Director: Mei Ann Teo

Scenic & Costume Designer: Melpomene Katakalos

Lighting Designer: Xingying Peng

Projection Designer: Tian Zhao

Labyrinth Working Statement

“Human beings are not born once and for all on the day their mothers give birth to them, but

... life obliges them over and over again to give birth to themselves.” GG Marquez In this work, we are inspired by the ways in which we have ability to reify our own origins through the process of reflection as an individual and communal act. How can we practice continual awakening and

renewal of perspective in this time of consumption and living for the sake of comfort? We believe that this process is one that comes only from deep personal reflection. As theatre makers, we revel in community and believe that profound connection is made when the meeting is made with individuals who have access to this practice of contemplation. Why is this theatre? The Greek word “theatron,” which the word “theater” is derived from, means A PLACE OF SEEING. What happens in most theatre productions is the process of modelling - where actors perform characters with whom the audience might have resonance. They play out their lives, and we watch their specific reasons for action. We see them as a model for us, as a stand-in for us, perhaps experiencing what we already have - or never will - as a way to connect us to the rules of human behaviour through observation. We are interested in the audience member having the creative power of SEEING WITHIN without the explicit models of characters and actors on stage. We wonder what are the possibilities for the human imagination when given prompts as opposed to model. We hope to inspire our audience to reflect deeply on their lives in order to be present in the now, and to face their future. We are collecting sources and impulses from our international community of family, friends, and acquaintances in order to build an ever-growing Collective Hive Mind that seeks to determine humanity’s history through personal memory. We believe in

the specificity of diverse experience as a component to understand the epic nature of the human being.

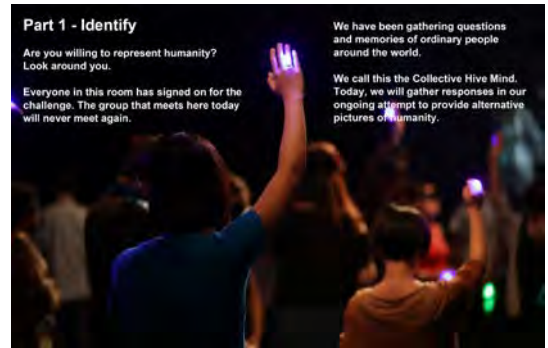
Preparation

Meng Jinghui, artistic director of the Beijing International Fringe Festival, personally invited our creative team to create a new piece for the 2014 season. Although we had very limited means, we looked at this unexpected offer as a chance to explore an idea we had for some time: What is the bare minimum we need to make theatre? At this point, we returned to our design-based method of creation based on the questions and nature of humanity. We worked within the principles of *radical collaboration* where all artistic identities are removed: EVERYONE is a maker, EVERYONE has a voice, ALL ideas and experiments are welcome.

Labyrinth is a unique piece where the audience makes the play. Before the performative parts of the piece were invented, we collected answers from a widely-distributed survey asking questions designed to take a person through the journey of their own inner life. We used the responses to create the basis for what would happen during the play. This piece asks the audience to become and make the play by inviting them to consider and act on their own humanity, both individually and collectively, by exploring a series of environments.

Part 1 - Identify

When the audience enters the space, they are surrounded by a low-lit white surround covered in video feed of questions and answers from the survey.



Part 2 – Activate Stations

As they acclimate to the space, they are then led in smaller groups through the “stations” for different experiences we called Sound, Map of Important Questions, Rice Hopes, Family Meal, and Wishes. Throughout all these experiences, there is a live feed camera roaming the space, broadcasting live on the surrounding walls.





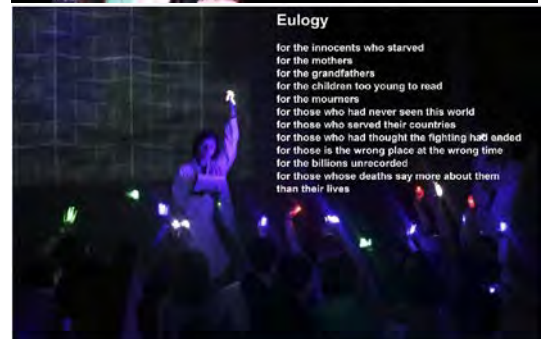
Part 3 – Interruption

As the audience groups cycle through the station experiences, an alarm sounds, and all activity is interrupted. All groups come to the centre of the space to play The Most Difficult Game. Individuals volunteer without knowing what the questions will be. They follow the rules listed below, and answer questions which can seem very difficult or impossible to answer, especially in front of a room of strangers. These questions were taken directly from the survey we created at the start of our process.



Part 4 - Apocalypse

Suddenly, and apocalyptic event occurs where audience members are eliminated from participation either voluntarily or randomly as they “die.” As they “die” and move into audience seating, they see that only a few are left underneath a parachute shelter. These survivors are left to consider the last question: What will you bring to help build humanity?





[Link](#) to an English translation of the television interview with China News

People's Daily Article: [English Translation](#), [Original Article in Chinese](#)

Review by Liu Fang: [English Translation](#), [Original Article in Chinese](#)



Press

This unique immersive experience garnered a lot attention from both audiences and press. *Labyrinth: Defining Humanity* was featured on the Chinese evening news as well as the Chinese national newspaper and a number of online news outlets. It was ranked in the top eight shows of the entire festival with over fifty productions adjudicated.

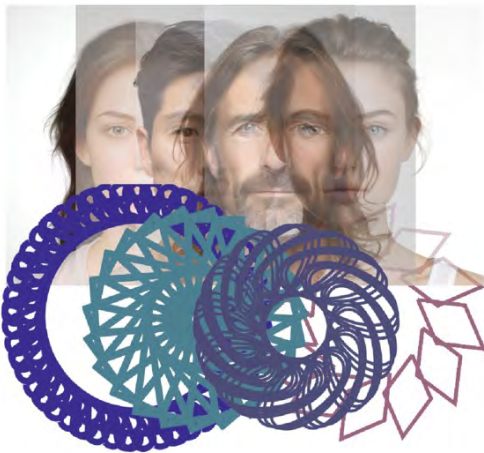
(Notional) Artworks for GA2023

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Abstract

Everyone is unique, especially their face. Even twins have more or less different faces. Faces are the most critical way for people to remember each other in their daily lives, so a face can be regarded as a unique ID of a person.

Notional aims to generate a unique pattern by collecting facial data of a person, such as face length and forehead width, to show that each person is unique. The final pattern can even be used as a form of identity in the context of the metaverse.

Statement of Work

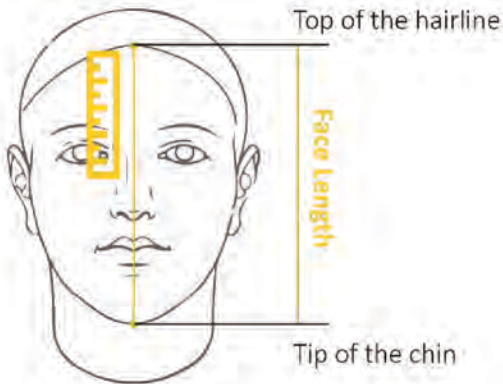
Notional mainly uses human facial features as reference data to generate exclusive patterns corresponding to human faces. Taking the recognised basic face shape as the starting point, map the data into the corresponding range so that the primary geometric figure corresponding to the face shape can be transformed and copied logically to obtain the final 2D figure. Since faces will not be 100% the same as any others, everyone's graphics are unique and can be regarded as the user's exclusive graphics and used on other occasions.

Initial Measurement & Input Processing

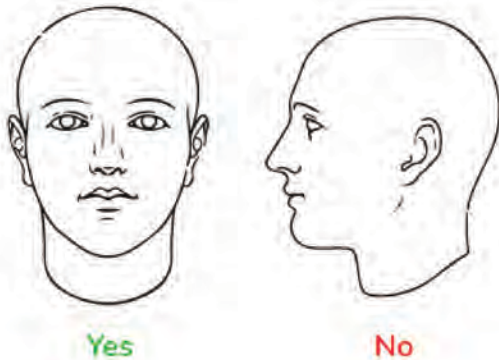
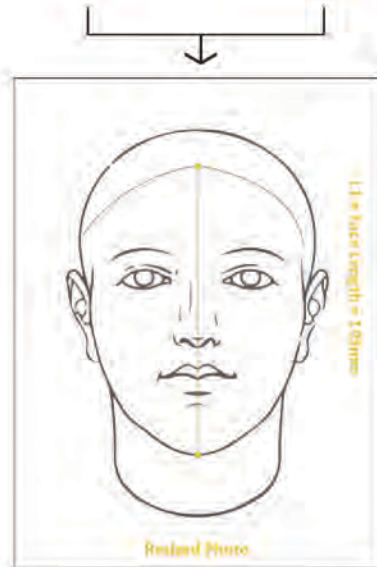
Grooming: Firstly, ensure the forehead is exposed as much as possible, and ornaments such as glasses and earrings should be removed to prevent the occlusion of the face from leading to recognition errors.

Measure Face Length:

Use measurement tools such as a soft ruler to determine the length of the face. The face length should start from the top of the hairline to the tip of the chin.



Take a photo: Then take a picture of the face from the front rather than other angles.



Resize the photo: When the **face length** is measured, the photo should be scaled to the same size as the reality to get almost exact facial feature data. The rest of the face data can be taken directly from the photo rather than measured individually in the real world.

Key Measurement

Length1(L1): Face length (px)

Starting point: The top of the hairline

Ending point: The tip of the chin

Length2(L2): Face Width (px)

Starting point: The left side of the cheekbone line

Ending point: The right side of the cheekbone line

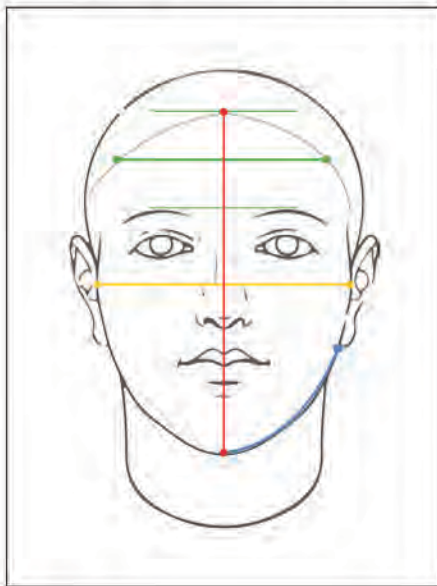
Length3(L3): Forehead Width (px)

Refer to the horizontal line passing the top of the eyebrow and the top of the hairline, take the middle point, then make a horizontal line.

Length4(L4): Jawline Width (px)

Starting point: The tip of the chin

Ending point: The root of the ear



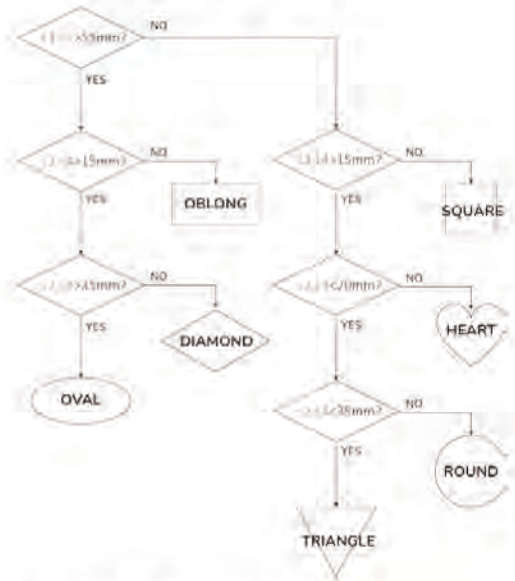
Caution:

In the demonstration prototype, these measurements are all from the resized photo, which means the unit is px(which is more universal in the digital area), and the variable "resize factor" controls the transition from px to mm, which is:

$\text{resizeFactor} = \text{measure data in real life(mm)} / \text{measure data from the resized photo(px)}$

Basic Shapes Definition

We classified face shapes by comparing the sizes of four key measurements so that each face could find its corresponding basic geometry.



The Basic References are from:

<https://www.omnicalculator.com/health/face-shape>

Shapes Transition

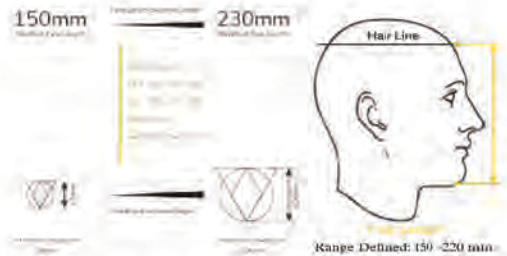
After obtaining the basic shape of the face, the primary process to get to the final pattern is to logically rotate and duplicate according to other facial data as a controlling variable and then map the average range of the facial data into the range of shape data.

Since the photo is adjusted to the size, data can be easily obtained from any other face part. The following table shows the total list of the transition of the basic shape and its depending control variable, and its detail will be shown in the next part.

Transition Steps	Reference Data
Shape Size	Face Length
Rotation Center X axis offset	Mouth Width
Rotation Center Y axis offset	Mouth Height
Rotation Number	Outercanthal Width
Rotation Angle	Intercanthal Width
Stroke Size	Nasal Width
Stroke Color -R	Left Eye Width
Stroke Color -G	Right Eye Width
Stroke Color -B	Pupillary Distance

Step1: Shape Size

Face Length is variable, which is the vertical distance from the tip of the chin to the midpoint of the hairline. It will depend on how big the user's basic shape is. The longer the Face length the user has, the bigger the shape is.



Equation: $\text{Shape Size} = \text{Face Length} * 0.625 - 43.75$

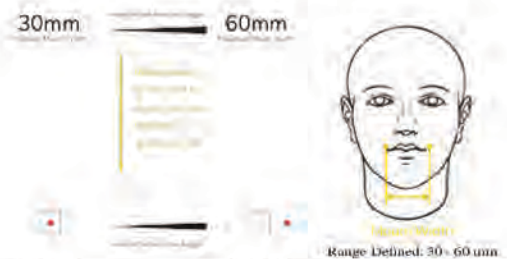
(Example: Face Length is 150mm)

$\text{Shape Size} = \text{Face Length} * 0.625 - 43.75 = 150 * 0.625 - 43.75 = 50\text{mm}$

The Range of the Face Length is sourced from:
https://en.wikipedia.org/wiki/Human_head

Step2: Rotation Centre X-axis offset

Mouth Width starts from the left side of the mouth to the right side of the mouth; take the horizontal data for the x-axis offset of the centre point. The longer the mouthwidth user has, the more deviation the shape moves from the x-axis.



Equation: $\text{X-Axis Offset} = \text{Mouth Width} * (10/3) - 100$

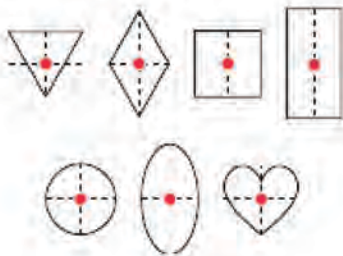
(Example: Mouth Width is 30mm)

$$\text{X-Axis Offset} = \text{Mouth Width} * (10/3) - 100 = 30 * (10/3) - 100 = 0$$

The Range of the Mouth Width is sourced from https://www.facebase.org/facial_norms/summary/#labfiswidth

(Definition: Shape Center Point Determination Rules)

Take the midpoint of both the horizontal line and the vertical line. The crossing point of the two-centre line is the initial rotation center point.



Step3: Rotation Centre Y-axis offset

Mouth height starts from the top of the lips to the bottom of the lips; take the vertical data for the y-axis offset of the centre point. The longer the mouth height user has, the more deviation the shape moves from the y-axis.



Equation: Y-Axis Offset = Mouth Height * 6.25 - 37.5

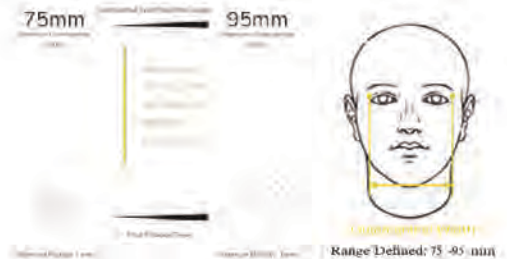
(Example: Mouth Height is 10mm)

$$\text{Y-Axis Offset} = \text{Mouth Height} * 6.25 - 37.5 = 10 * 6.25 - 37.5 = 25\text{mm}$$

The Range of the Mouth Height is sourced from https://www.facebase.org/facial_norms/summary/#upvermheight

Step4: Rotation Number

Outer canthal Width starts from the left side of the left eye to the right side of the right eye; take the horizontal data. The longer the outer canthal width the user has, the more the shape will duplicate.



Equation: Rotation Times = Outer Canthal Width * 2 - 114

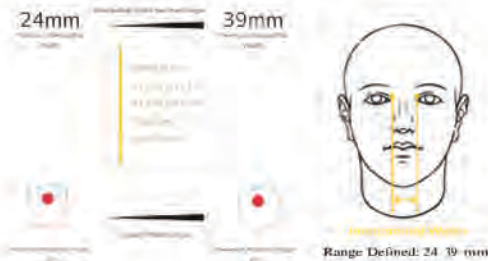
(Example: Outer Canthal Width is 90mm)

$$\text{Rotation Times} = \text{Outer Canthal Width} * 2 - 114 = 90 * 2 - 114 = 66\text{Times}$$

The Range of the Outer Canthal Width is sourced from: https://www.facebase.org/facial_norms/summary/#outcanthwidth

Step5: Rotation Angle

Inter-canthal Width starts from the right side of the left eye to the left side of the right eye, taking the horizontal data. The longer the inter-canthal width the user has, the bigger the angle shape will rotate.



Equation: $\text{Angle} = \frac{\text{Inter-canthal Width}}{4/3} - 22$

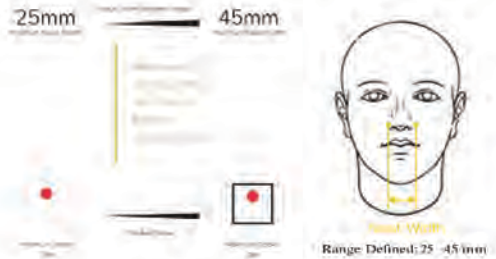
(Example: Inter-canthal Width is 30mm)

$\text{Angle} = \frac{\text{Inter-canthal Width}}{4/3} - 22 = 30 \cdot \frac{3}{4} - 22 = 18^\circ$

The Range of the Inter-canthal Width is sourced from https://www.facebase.org/facial_norms/summary/#incanthwidth

Step6: Stroke Size

Nasal Width starts from the nose's left wing to the nose's right wing, taking the horizontal data. The longer the nasal width the user has, the thicker the shape will be.



Equation: $\text{Stroke} = \frac{\text{Nasal Width}}{0.125} - 2.625$

(Example: Nasal Width is 30mm)

$\text{Stroke} = \frac{\text{Nasal Width}}{0.125} - 2.625 = 30 \cdot 0.125 - 2.625 = 1.125\text{pt}$

The Range of the Nasal Width is sourced from https://www.facebase.org/facial_norms/summary/#nasalwidth

(Special Case: Data out of range)

Since the Settings of the range are set according to the average human face size, there is a minimal probability that something will go out of range. To account for this concept, excess data is added to the stroke as additional data.

In any of the previous steps, data which is less than the minimum of the range is counted as:

EXTRA STROKE = (The difference from the range minimum) / Range Size

In a similar way, in any of the previous steps, data which is more than the maximum of the range is counted as:

EXTRA STROKE = (The difference from the range maximum) / Range Size

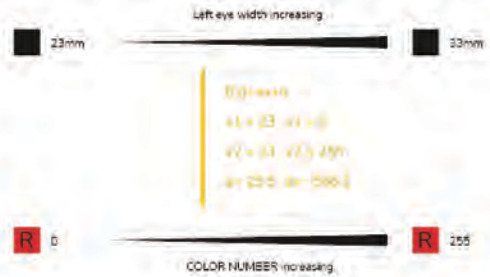
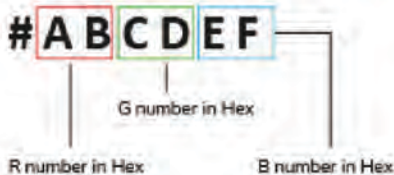
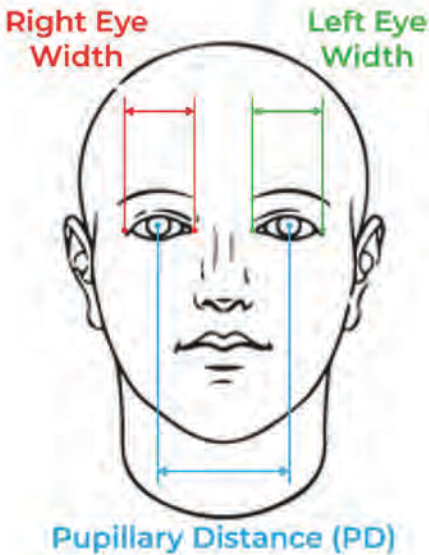
Thus, the final formula of the stroke is:

BASE STROKE = $y = 0,125x - 2,625 =$
Nasal Width * 0.125 - 2,625

FINAL STROKE = **BASE STROKE** +
EXTRA STROKE

Step7: Stroke Colour

Measure left-eye Width, right-eye width and pupillary distance to form 3 hex numbers, then find the corresponding RGB colour according to these three values.



Equation:

R Value = Left eye width * 25.5 - 586.5

G Value = Right eye width * 25.5 - 586.5

B Value = Pupillary Distance * 8.5 - 425

(Example: left eye Width is 30mm, right eye width is 28mm and pupillary distance is 80mm)

R Value = Left eye width * 25.5 - 586.5 = $30 * 25.5 - 586.5 = 178.5$

G Value = Right eye width * 25.5 - 586.5 = $28 * 25.5 - 586.5 = 127.5$

B Value = Pupillary Distance * 8.5 - 425 = $80 * 8.5 - 425 = 255$

Thus, the RGB value is (178,127,255)



The final stroke colour:



The Range of 3 Variable is sourced from:
https://www.facebase.org/facial_norms/summary/#palpfislength_r

https://www.facebase.org/facial_norms/summary/#palpfislength_l

Examples:



The Hallucinarium : Non-Linear Imagery Creation and Presentation in a Generative Arts Performance

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Abstract

In this system, a generative engine manipulates a set of images creating a non-linear visual experience: a representation of machine dreaming. The stimulation provided by this system-induced experience is aimed at the observer's emotive memories.

Description:

Presented in this sample performance are two main stylistic visual themes:

ONE: *Echo* – a set of images culled from the visual art of Beatriz Sampiano . With a live polytropic performance from members of the Electro-acoustic

improvisation ensemble Diaspora Focii Collective.

followed by

TWO: *River of Shadows* – an abstract shadowplay based on images from a set of pencil sketches of Arctic scenes by Kersti Abrams and palimpsestic collages of ink drawings juxtaposing Renaissance artists' work against a contemporary artist's neo-Renaissance pen work of Margret Schoerke. This yields a textural density eliciting the emotive nature of presentation.

(The sonic underpinnings of this piece comprise a complex computer-based electronic process applied to the physical manipulation of a set of seven or eight ocean-washed stones, capturing their surface texture and the chime-like resonance of them striking or scraping against each other during a simple act of picking up and dropping the stones together.)

Technique/Technical Approach:

A Complex Adaptive Systems (CAS) approach is followed in the technology implementation for this effort, where in a simple set of 2D images serves as the primitives of the Generative Engine system, and a small set of operations for combining (layering) and modifying

(affine transforms) these primitives facilitates the juxtaposition of elements within a set of transparent layers from background 'ground' images to increasingly transparent 'mask' images, forming a gauze-like quality over the overall solid 'Ground' forms.

The Chaotic nature of the motion and geometries of the overlaid primitives is accomplished by utilizing a set of sinusoidal waves of various frequency and amplitude as parameters for the operators, this is a good compromise between random numbers and more predictable regimented values.

Conclusion:

One of the most important elements of this system is the 'mind's-eye' of the observer. It is the rapid and chaotic juxtaposition of imagery that works on the viewer's mind to elicit thoughts, memories, and fleeting glimpses of an emotive nature, appending a non-linear narrative quality to the work.

A Generative Dance Based on the Dynamics of a Family of 2D Cellular Automata

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hypothetical examples of experimentation for these transition rules in a vivified practice of generative dance. Finally, we invite the reader to imagine generative dances using the dynamics of the selected rules, advancing a choreographic practice in the context of performance creation and community dance workshops.

Abstract

This paper presents a study of a generative dance based on the concepts of Generative Art and Choreographic Objects built from 2D boolean diamond-shaped topology cellular automata. These Choreographic Objects were analyzed, considering the dance meaning of the collective behavior, playing with different transition rules (transposing them to relations scores), and emergent configurations. We identify the sets of symmetrical, reversible, and sensitive to initial conditions cellular automata, which present characteristics suitable for the composition of generative dance. As a result, we create practical

1. Introduction

Performing Arts and Generative Art has traveled an intertwined path. Their practice was embedded in epistemological knowledge based on openness, evaluation, and interpretation of a question or idea through generative techniques.

According to Philip Galanter, [1], generative art is more than an art movement. It should be seen as a mode of artistic practice. For the author, Generative Art, rather than High-tech Art, corresponds to "*any art practice in which the artist cedes control to a system with functional autonomy that contributes to, or results in, a completed work of art. Systems may include natural language*

instructions, biological (...) and other procedural inventions" ([2], p. 154).

Transposing this concept to dance, assuming the choreography as a set of instructions for the organization and reconfiguration of one or several bodies in space-time, where the choreographer defines the spatial organization and movement of the dancers [3], as well as a mode of composition in contemporary dance based on organizational principles, a logic that engenders the choreographic organization which overlaps with the logic of step chaining [4], and allows the emergence of patterns in space-time, by the multiple dancer inter-relationships, which merely had their relationships predefined, but not their final formations [4]. Regarding generative dance, the choreographer uses composition to moderate synergetic and structural balances, proposing that the performers adjust their actions and movements to co-create a collective joint dance. Creating a system of performers that interact following simple rules of interaction (generative principles), the choreographer facilitates the choreographic emergence of collective behaviors so that in generative dance, the choreographer, more than controlling the final result of the dance, suggests: a) a relational ontology, to encourage the investigation of movement places that potentially generate emergent collective behaviors; b) scores of simple interaction rules, open or closed [5], that allows performers to overcome their tendency to repeat previously learned and trained movements and concepts; c) the total or partial control of the artwork to the performer, acting as System Creator [6].

In this paper, we assume the role of generative dance choreographers and propose the construction of a relational ontology based on an agent-based model

by approximating Forsythe's (n.d.) choreographic objects. Forsythe's choreographic objects are defined as a model of potential transition from one state to another in any imaginable space. This computational choreography portrays a group of self-aware dancers who rely on their peripheral vision to observe nearby performers. Therefore, at any given moment (T), each performer, while conscious of their own state, observes the state of their closest neighbors, and subsequently determines their state for the next moment (T+1) by applying a selected relational score.

2. Creation of a Choreographic Object

Assuming the function of a choreographer of a generative dance, we propose to create a system as a network of mutually interconnected performers. Each performer can be in one of two action states, $S=\{0, 1\}$ ={a predetermined choreography with 8-counts, full-squatting posture for 8-counts}. The performers will collectively update their action states based on an initial choice, determined by a selected relation score (referred to as the local transition rule). This transition rule remains consistent for all performers, shaping the interconnected network within the system. In our specific scenario, we opt for a family of relation scores in which a performer's action depends on both their own actions and those of three neighboring performers: one to their left, one to their right, and one in front of him. However, in a real-world setting, limitations in a performer's peripheral vision can hinder their ability to perceive the state of all three neighbors simultaneously. To address this challenge, we adopt a diamond-shaped

topology, allowing performers to observe their nearby counterparts situated diagonally to the front-left, directly in front, and diagonally to the front-right, see Figure 1.



Figure 1. Diamond-shaped topology system with $6 \times 6 = 36$ elements. All performers are facing downwards.

In our system, all performers are oriented towards the audience, which means that some performers may not have the three nearest neighbors required to define their next action state (as depicted in Figure 1). We refer to these performers as being situated at the system's boundary. To ensure a consistent transition rule for all performers, regardless of their position, we fix the action state of every missing performer. In essence, we establish specific boundary conditions for the system.

Among the various alternatives for boundary conditions, we choose the simplest option: fixed null boundary conditions. This implies that a performer situated at the boundary assumes that the action state of any missing neighbor is consistently zero. This choice has led us to propose that the most appropriate mathematical-computational model for our choreographic object is a 2D boolean cellular automaton with a diamond-shaped topology and fixed (null) boundary conditions.

We must emphasize that this family of 2D cellular automata is much simpler than those usually studied. Compared with the

more common Moore and von Neumann neighborhoods, with five and nine elements, respectively, and periodic boundary conditions, our initial guess was that the collective dynamics possible for our family of cellular automata would not be interesting enough. This work shows that this is not the case.



Figure 2. Diamond-shaped topology system using two colors to distinguish the state (0 or 1) of each of its 36 elements.

From everything stated above, we can infer that a system has the potential to assume various forms beyond the tilted square presented above. This flexible characteristic is essential to the dance learning process and workshop context since it will make it possible to work with smaller groups. Furthermore, in the community dance context, where everyone's participation is important, the possibility of such multiple shaped configurations is fundamental since sometimes we will not have the exact number of participants to fulfill a square.



Figure 3. A system with a different shape, obtained by a suitable pruning of the diamond-shaped system above.

3. Analyzing the Dynamics of our Choreographic Object

A Boolean cellular automaton is a set of elements capable of being in one of two states, which we can take to be 0 or 1, interacting locally with some chosen nearest neighbors. In our case, we defined the elements of our Boolean cellular automaton as performers dancing. The state of each performer evolves in discrete time steps, according to a fixed deterministic transition rule, which is the same for all elements and all time steps. For our case, this rule specifies the performer's new state from its current value and the values of three of its closest neighbors: if we denote by σ the state the performer assumes at a given instant, σ_r the state of the performer at its diagonal-front-right, σ_l the state of the performer at its diagonal-front-left, and σ_f the state of the performer in front of him, then the state in the next instant, σ' , is given by

$$\sigma' = \varphi(\sigma_r, \sigma_f, \sigma_l, \sigma).$$

We can see that choosing a transition rule means specifying the value that the function φ takes for each of the 16 different possibilities for its four Boolean variables.

$d_0 = \varphi(0,0,0,0)$	$d_1 = \varphi(0,0,0,1)$
$d_2 = \varphi(0,0,1,0)$	$d_3 = \varphi(0,0,1,1)$
$d_4 = \varphi(0,1,0,0)$	$d_5 = \varphi(0,1,0,1)$
$d_6 = \varphi(0,1,1,0)$	$d_7 = \varphi(0,1,1,1)$
$d_8 = \varphi(1,0,0,0)$	$d_9 = \varphi(1,0,0,1)$
$d_{10} = \varphi(1,0,1,0)$	$d_{11} = \varphi(1,0,1,1)$
$d_{12} = \varphi(1,1,0,0)$	$d_{13} = \varphi(1,1,0,1)$
$d_{14} = \varphi(1,1,1,0)$	$d_{15} = \varphi(1,1,1,1)$

The justification for the notation used to distinguish the different values for the function φ is the so-called Wolfram integer representation: when referring to a transition rule φ , we use the integer number whose binary digits are precisely the values of the function φ presented earlier, i.e.

$$N_\varphi = (d_{15} d_{14} d_{13} \dots d_2 d_1 d_0)_2.$$

This means that, given any integer N_φ , between 0 and $2^{16}-1$, its binary representation encodes the sixteen different values necessary to specify a transition rule φ .

For example, consider the integer number $N_\varphi = 46273$. Given its binary representation

$$N_\varphi = (1011010011000001)_2,$$

we have all sixteen binary digits required to define the corresponding transition rule φ , i.e.:

$d_0 = \varphi(0,0,0,0) = 1$	$d_1 = \varphi(0,0,0,1) = 0$
$d_2 = \varphi(0,0,1,0) = 0$	$d_3 = \varphi(0,0,1,1) = 0$
$d_4 = \varphi(0,1,0,0) = 0$	$d_5 = \varphi(0,1,0,1) = 0$
$d_6 = \varphi(0,1,1,0) = 1$	$d_7 = \varphi(0,1,1,1) = 1$
$d_8 = \varphi(1,0,0,0) = 0$	$d_9 = \varphi(1,0,0,1) = 0$
$d_{10} = \varphi(1,0,1,0) = 1$	$d_{11} = \varphi(1,0,1,1) = 0$
$d_{12} = \varphi(1,1,0,0) = 1$	$d_{13} = \varphi(1,1,0,1) = 1$
$d_{14} = \varphi(1,1,1,0) = 0$	$d_{15} = \varphi(1,1,1,1) = 1$

A graphical representation of this transition rule φ is given in Figure 4, where on the left side we have all sixteen possible settings for the neighborhood, while the corresponding values achieved

by the top element in the next time step are given on the right side. In this case, we choose a lighter color to represent the state 0 and a darker one to represent the state 1.

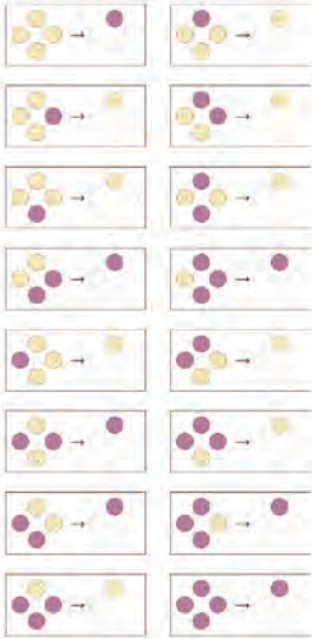


Figure 4: Graphical representation of the transition rule with Wolfram code 46273.

We can translate this transition rule into dance language as a set of closed verbal scores where the darker performers move according to an 8-counts predetermined choreography. At the same time, the lighter elements stay for eight counts in a full-squatting posture.

By employing a transition rule, we can calculate the state of each performer within the system over a specified number of time steps, thereby simulating the collective behavior over a particular time interval. To illustrate this process, let's examine an example using transition rule 46273, depicted in Figure 4, for a system with 6 x 6 elements, with the configuration shown in Figure 2 as initial

configuration. In this instance, we have computed the collective system configurations for time instants ranging from T=1 to T=20, as demonstrated in Figure 5.

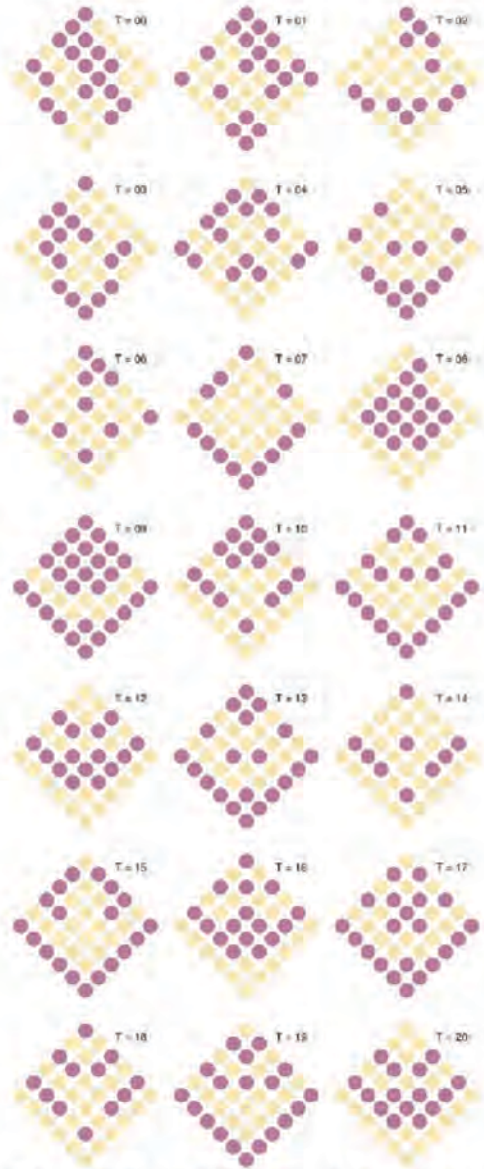


Figure 5. Dynamic obtained for a system with 6 x 6 elements, using the transition rule 46273, for T = 0 to T=20.

When dealing with systems with a finite number of elements, it is known that every dynamic necessarily ends with the system repeating one or more configurations. In our example, we can see that the choreographic object finds its final cycle, of period eight, after 11 instants of time (the set of configurations a system assumes until it enters the final cycle is called the dynamic's transient). In addition to these dynamic characteristics, we can observe that, beginning at time $T=9$, the system adopts symmetrical configurations with respect to the vertical axis. This observation leads us to propose the term *symmetric cellular automata* for cellular automata whose final cycles consist of symmetrical configurations.

In order to make a choreographic analysis of our choreographic object, a 2D diamond-shaped lattice cellular automaton, with a four element neighborhood, and fixed null boundary conditions, we use the interaction factors of movement developed and described by Walsh, Leray, and Maucouvert, [7]. In 1997, Walsh, Leray, and Maucouvert considered that in dance, as in a choir or an orchestra, dancers should be aware of the action of their companions once the individual gesture only finds meaning when embedded in the collective.

Let Figure 5 corresponds to an emergent choreography where the dark elements correspond to dancers performing an 8-count sequence, and the light elements correspond to dancers staying 8-counts in a full-squat posture. In the beginning, $T=0$, some performers assume the squat posture, while others dance. At the next instant, $T=1$, everybody updates their state using the transition rule 46273, changing the overall configuration. They repeat the same action 20 times and conjointly bring out global patterns with

symmetrical configurations. We analyzed the emergent choreography using Walsh, Leray, and Maucouvert interaction factors of movement, taking into account spatiotemporal relations between elements. Even if at the individual level the dancers can only choose between two states $S = \{a \text{ predetermined choreography with 8-counts, full-squatting posture for 8-counts}\}$, at a group level, it is possible to observe a visual effect similar to creating groups, lines, solos, duets, and trios, composed within a common structure and based on moments of synchrony and successions. Table 1 shows Walsh, Leray, and Maucouvert interaction factors of movement that we can observe within our emergent choreography.

For example, there is a displacement effect for $T=7$ and $T=8$, where performers form a group (ensemble). At $T=8$ and $T=9$, we can see a splitting effect of the group in two, constituting a group at the top and a line at the bottom. Even though all elements have the same common structure, an effect of independence and complementarity is sometimes created. For example, at the transition from $T=13$ to $T=14$, we observe the emergence of 3 dance solos that seem independent of the surroundings, composed of performers in a full-squatting posture. Performers follow a model of relationships based on transition rules, with a successive rhythm over time, for which everyone updates their state after analyzing their surroundings at $T=T+1$. On a global level, the choreography presents a dynamic composed of unison and alternations, for example, a line composed by dancers dancing simultaneously for $T=11$; alternation of performer's states at the lower border for the instants $T=18$, $T=19$, and $T=20$, respectively.

ELEMENTS OF ANALYSIS OF INTERACTIONS IN A CHOREOGRAPHY	
RELATIONSHIPS AS A FUNCTION OF SPACE	<p>Correlation:</p> <ul style="list-style-type: none"> • Face to face; • Back to back; • Side by side; • Cross each other; • One behind the other; • Around; • Close; • Far; • In contact. <p>Actions:</p> <ul style="list-style-type: none"> • Meet; • Split up; • Cross each other; • Stay in an ensemble; • In opposition; • In décalage; • In contact;
GROUP-BASED RELATIONSHIPS	<ul style="list-style-type: none"> • Contact; • Common structure; • Independent structures.
ROLE-BASED RELATIONSHIPS	<ul style="list-style-type: none"> • Similar; • Opposite; • Different; • Be complementary; • Be a model; • Follow a model; • Move as a mirror; • Move in action-reaction.
OBJECT-BASED RELATIONSHIPS	<ul style="list-style-type: none"> • Sign; • Support of the action; • Origin of transformations; • Support of the action; • Origin of transformations; • Element of mediation.
TIME RELATIONSHIPS	<ul style="list-style-type: none"> • Unison (simultaneity); • Alternations (conversation, questions, and answers); • Successive; • In canon (if a sequence of movement is presented and reintroduced by other dancers at regular intervals).
SIGNAL-BASED RELATIONSHIPS	<ul style="list-style-type: none"> • By contact; • Gestural; • Sonorous; • Spatial; • By the mediation of the object.

Table 1. Elements of analysis of interactions in dance (adapted from [7])

4. Playing with the Rules of a Choreographic Object

This section presents some other transition rules studied with the help of our choreographic object with interesting characteristics to generate emergent collective choreographies.

First, we found 16 symmetrical transition rules for which the final cycles of the

dynamic are symmetrical configurations. By employing a symmetrical transition rule, the performers inevitably collaborate to generate a sequentially concentric and symmetric movement from any selected initial configuration. All global concentric choreographies generally present ensembles, lines, solos, duos, and trios.

We also found 160 transition rules that when applied in our choreographic objects produce cycle dynamics from the beginning, i.e., the dynamics have no transient. They are called *reversible transition rules*. On a performance choreographic level, these rules produce emergent choreographic cycles that begins and ends with the same configuration. In this case, we can define an initial configuration and, without determining the duration of the performance, the performers will know the choreography's end by assuming the initial configuration again. For example, imagine the following choreographic proposal, a real-time performance of 36 dancers organized in a diamond-shaped lattice topology, facing the public. For every performer, we offer the same reversible transition rule. Furthermore, we ask all performers initially to form vertical lines of $S = \{a \text{ predetermined choreography with } 8\text{-counts, full-squatting posture for } 8\text{-counts}\}$. We let performers apply the transition rule and ask them to stop as they feel all have returned to their initial configuration. The example presented seems straightforward; however, it is attractive on a choreographic performance level and interesting to qualitative studies on dance-related issues like group sense, being together, trust in the collective, or even group synergy.

After a spatio-temporal analysis, we used our choreographic object to evaluate the resilience of each transition rule, i.e., we

checked how much a tiny mistake by one of the performers could modify the resultant emerging choreography. We looked for the most sensitive rules to performers' mistakes. We argue that the spatiotemporal effect of sensitive rules on emergent choreographies requires further investigation. Nevertheless, we know that the effect of this rule is like a wave that dissolves a configuration. So, we can visualize a sensitive rule that makes the system enter a fixed point, for example, all performers squatting. At a particular instant, if one of the performers changes his response, we would perceive a global wave-like effect that would make some performers start moving again by contamination effect.

Taking the role of generative dance choreographers, transferring computation to live performance, lets us create a non-high-tech generative dance and its emergent choreography. Consider a Greek Amphitheater, a real-time performance of 36 dancers organized in a diamond-shaped lattice topology facing the public, all of them following successively the following sets of relational rules (transition rules):

1. Symmetric cellular automaton; transition rule 47329;
2. Symmetric cellular automaton; transition rule 31693;
3. Reversible cellular automaton; transition rule 38293;
4. Most sensitive cellular automaton; transition rule 40099;

Each rule is associated with a piece of music and two movement phrases. For example, symmetrical transition rule 1 corresponds to $S=\{a$ predetermined choreography with 8-counts, full-squatting posture for 8-counts}, and reversible transition rule 3 corresponds to

$S=\{an$ upper body movement improvisation for 4-counts, floor improvisation for 4-counts}. The performers know all the relational rules and their correspondence to movement and music. The initial performer's setup movement is predetermined. The music is played on a jukebox and pulled over by an element outside the system, such as the audience. People in the audience can change the music whenever a green light goes on the jukebox. By playing the music on the jukebox, the audience can modify the collective choreography and interact with the performance. In Figure 6, we present the QR code for the video of a generative dance, with an example of a performance obtained from a particular audience choice.



Figure 6. QR code for the choreographic object video for performance with the audience choice (1+3+2+4).

Playing with the jukebox and building a choreography, the audience will observe the following:

- Creation and variation of successive spatio-temporal symmetries, composed by ensembles, solos, duets, trios, quartets, lines, and circles;
- Moments of disorder;
- Pauses (fixed configurations) or choreographic moments that remain the same during all correspondent music pieces;

- Chain reaction correspondent to the propagation of a mistake.

5. Conclusions

In 1968, Merce Cunningham, one of the forerunners of this interdisciplinary between dance and computation stated in his book *Changes: Notes on Choreography* [8] that:

"Electronic technology has given us a new way of looking. Dances can be made on computers, images can be punched into them, why not a notation for dance that is immediately visual?" ([8], pp.3)

In this sense, the relationship between dance and computing, like Forsythe's choreographic objects rather than trying to mimic dance movements, is intended to add a dimension to visualize dance and the choreographic process [9]. Thus, in this work, innovation arises from the concept of dance experimentation and the capacity of visualization that allows us to perceive the evolution of group behavior. Therefore, with this paper, more than focusing on how to plot the transitions of generative dance, we advanced with an observational way to perceive what happens in emergent collective choreographies built from simple rules of transition. In this way, we designed a choreographic object from a given family of 2D diamond-shaped lattice cellular automata, with a neighborhood of four elements, and fixed null boundary conditions. The systematic study of this choreographic object allowed us to approach the generative dance as a selforganized dynamical system and, with that, to know:

- The emergent spatio-temporal behavior of the collective of dancers;
- The attractors and transients of the system of dancers;
- The spatio-temporal variations for random initial conditions;
- And its resilience to error.

Tracing the emergent collective behaviors, we could extrapolate the possible emergent choreographies. Moreover, we experienced these choreographies in bodies that are sensitive to other bodies around them in the three-dimensional space, creating non-high-tech generative art collective emergent choreographies. In the dance workshop context, our experience revealed that the participants recognize the global emergent effect using these relational rules. Although we are still beginning to investigate possible links between generative dance and cellular automaton, we think that this can be the starting point to build a digital choreographic research instrument, like some of those introduced in the past:

- *LifeForms*(1986) by Merce Cunningham and Dr. Thomas W. Calvert [10];
- *William Forsythe's Improvisation Technologies* (1994) by William Forsythe [11];
- *Choreographic Language Agent* (2004) by McGregor and Scott deLahunta, [12];
- *Pathfinder* (2014) by Onformative Studio [13].

The major differentiating factor of the choreographic object described by this paper focuses on the research, adjustment, and play with collective behaviors. Nevertheless, for the generative dance choreographic object to have greater applicability, it will be necessary to work on visual plotting and interfacing to facilitate choreographers to

play, observe and extrapolate collective emergent behaviors. Finally, we would like to say that this paper is part of a more extensive study in the area of experimental mathematics and phenomenological analysis of performance, which includes: the definition of Generative Dance as a kind of Generative Art and the ethnographic concept of togetherness (feeling of the others) in cooperative choreographies.

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How to teach Concrete art to a robot?

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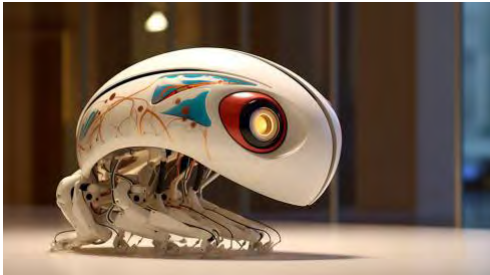
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Boustrophedon (tutor: Laurent Daniel)

Summary

This article explores the challenges related to training a robot designed to produce generative Concrete art and which ultimately must not be dependent on learning based on phenomenal amounts of data. This approach is also ideal for studying the formalization of the artistic creation process using a machine: the robot.

The article will first clarify the notions of chaotic and random processes which are

closely linked to the nature of algorithms entering the robot's knowledge base. Subsequently, the article introduces the differentiation between Synthetic reasoning programming allowing emulated reasoning via a process of Gödelization, and Graphic programming as an anthropomorphic vision of a robot knowing how to draw and color and finally, the generation of generative art by artificial intelligence.

1. Concrete Art

"Concrete art proposes to replace artistic imagination with mathematical design". If this postulate of Max Bill, which mainly applies to the mathematical principles of shapes and colors, has since become the manifesto of the Concrete art movement, we find older graphic and pictorial examples which perfectly respect the postulate. We refer, for example, to the system of codification of Aztec shields (figure 1) allowing visual identification of the rank and identity of the warrior.

2) Self-coded and self-encrypted Art

The dual cryptographic and aesthetic approach which led to the graphic and pictorial design of the shield invites us to examine concrete art from the angle of coded information without encryption keys or encrypted information with keys.



Figure 1. Aztec Shield (Source: Wikipedia Commons CC by ShareAlike 4.0 International)

In this respect, the systems elaborated by Julio Le Parc or Victor Vasarely to encode colors are true systems of cryptography based on combinatorics and colorimetry. Vera Molnar's work constantly oscillates between the visual result and the artist's algorithmic creative process which is often hidden but sometimes revealed for in a pedagogical way by the artist. In view of the major problems related to the legal protection of IP rights of artists, it is useful to think of the algorithmic choices of a robot, as well as the parameters associated as encryption keys. We are thus moving towards the concept of self-encoded and self-encrypted art.

3) Robots that think and draw

Programming languages, well as algorithms and information theory are at the heart of the interdisciplinary dialogues between artists and mathematicians.



Figure 2. Maurice El-Milick, Albert Ducrocq. (Source: private collection)

"The operations of concrete art (repetition, progression, permutation and combinatorics of all kinds) are in fact emblematic of the new computational thought that accompanies developments in cybernetics and information theory" [5] (translation).

A wonderful historical retrospective of Art Tropism towards programming is presented in [1]. We shall not forget that this movement brought together artists towards artistic crafts by means of mechanical programming intended for weaving looms (Anni Albers, Gee's Bend movement) for example. Some articles concerning Vera Molnar [4] allow us to better understand the connection between art and mathematics. However, the reciprocal movement of mathematicians or roboticists towards art through programming languages is less known and documented. From 1936, and therefore before the appearance of the very first computers, Maurice El-Milick formalizes a graphical, symbolic, and purely mathematical programming language that he calls ornamental algebra. This fully functional language in modern programming environments uses the formalism of so-called explicit equations (figure 2 left) and the theory of

or figurative ornamental art. In 1953, the roboticist Albert Ducrocq (figure 2 to right) uses binary language to develop the Calliope robot, a text and image generator [2], thus inventing “prompt engineering” several decades before its rediscovery by the generative art systems powered by artificial intelligence. Subsequently other programming languages helped to establish and reinforce the links between mathematics, graphic design and art. We will briefly cite the Lisp language at the heart of the epic “Thinking Machines” of the early 1980s, then the Postscript language used at the same time by the mathematician Henry Crapo to create mathematical figures of projective configurations, paving the way and laying the foundation of “Geometric Reasoning” [1], subsequently the Logo language associated with “Turtle Geometry” and more recently the Processing language particularly well suited to the computer exploration of shapes and colors. Regarding our robot Boustrophedon, it is built around the theory of “Arithmétique des formes”. It leverages both computer algebra systems and symbolic / functional languages.

4) Generative Concrete Art

The approach that we put forward for producing Concrete artwork using a robot follows a sequenced conceptual framework we refer to as Generative Art by Synthetic Reasoning. As shown by the scheme on the left of Figure 3, this approach is very different from the process of producing artwork by what is called connectionist artificial intelligence [AI generative Art] schematized on the right of Figure 3. However, the Synthetic Reasoning approach, on the left of the figure, shares certain objectives with so-called symbolic artificial intelligence.

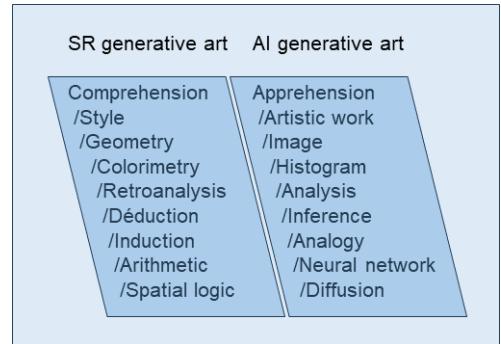


Figure 3. Synthetic Reasoning and Artificial Intelligence.

5) The three pillars of Concrete Art

5.1) The search for disorder

Disrupting or ordering geometry differently, deconstructing or structuring differently the rules of color composition are among the principles that fuel the creative process in Concrete art. To disorganize the geometry, or deconstruct the colorimetric rules, the robot must introduce an element of randomness while to order the geometry differently or structure the colorimetric rules differently, the robot must use combinatorics. The concept of randomness in Concrete art was developed by artists like François Morellet and Vera Molnar. "Vera Molnar introduces variations resulting not from her subjectivity but from random data, throwing dice, using telephone directories or tables of random numbers taken from math textbooks and computer programming" [4]. Technically, from our robot's point of view, we must distinguish pure non-deterministic randomness generated for example by physical source, from deterministic pseudo-randomness with a digital value or initial

repetitive nature for a seed identical and is commonly obtained from computer programs. However, when teaching a robot the concept of disorder, we will use another approach that is much richer at the creative level: Chaos theory, which is particularly well suited for blurring an image and color scrambling. The non-random permutations obtained by switching from a first indexing system of one SFC type to a second indexing system of another SFC type will lead to perceptions of visual disorder (figure 4). The so-called SFC combinatorial curves are introduced in paragraph 6.2.

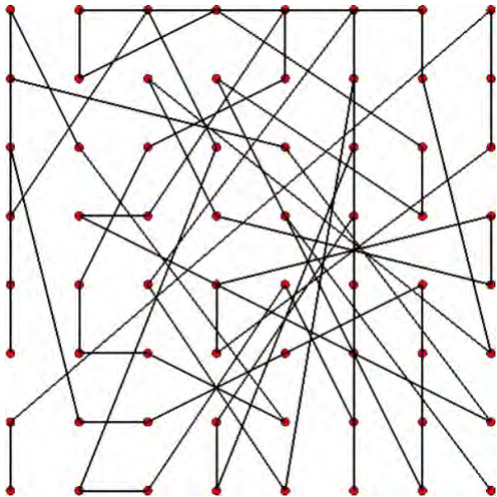


Figure 4. Disorder by SFC permutations

The robot will thus be able to reproduce the spirit of "Homage to Dürer, 225 accidental variations, direction chaos" by Vera Molnar from 1990 without any random variation.

5.2) Geometric partitioning

The theory of Tiles is probably one of the fields of mathematics closest to art. The number of combinations to partition the plane is enormous and the application of the underlying theory of groups of geometric transformations is easily

programmed. The tiling theory is already observed in Islamic art before being revisited in the modern era by M.C. Escher. A combinatorial vision of tiling of the plane was introduced by Sébastien Truchet in 1702 with an eponymous theory. More recently, the theoretical and computer work of the classical geometer and structural engineer Janos Baracs in the 1980s [3] gives a second algorithmic breath to this theory, otherwise well known to artists of Concrete art. In 2015 Lorenzo Bocca published his "Sperimentare geometrie" which renewed the genre by exploring the partitioning of the plan from tiling freed from theoretical mathematical constraints.



Figure 5. Truchet tiling. (Source : Guillaume Pelletier-Auger 2016-2023)

5.3) Colorization of regions

The colorization of the regions resulting from a partitioning of the plane can be carried out by our robot using classic techniques, either by using random approaches, or by using graph theory and theorems such as that of The Four-Color or by using diffusion's methods known as "Flood Fill algorithm". In the case of our Boustrophedon robot, we chose a topological approach much faster and more powerful than the previous ones, making it possible to control the colorization of the plane by connecting it to logic.

6) Teaching reasoning to a robot

6.1) Arithmetic of forms

The Arithmetic of forms [7], is a formal system aimed at teaching geometry to a machine by converting all topological concepts in pure arithmetic. The classical topology pioneered by mathematicians like Moebius, Listing and Poincaré, often called rubber sheet geometry, is extremely complex to computerize due to its heavy data structures. Topology also suffers from calculation precision problems, particularly when it is used to classify geometric shapes (e.g., homeomorphism) based on mathematical indicators such as Betti numbers.

To teach topology to a machine or robot, the Arithmetic of forms identifies and exploits the structural isomorphisms existing between the topology and the arithmetic. This approach makes it possible to eliminate all the main problems of computerization of the topology but also to control the arithmetic by logic, building upon pioneering work of Kurt Gödel [7]. For the process of arithmetization of calculations, Arithmetic of forms calculates algorithmically an integer value associated with each point in space. This value, called density, will subsequently be used in very different ways, either to make logical decisions or simply to assign a color to the point by computer hashing systems created from static or dynamic color tables. To enable the creative robot to determine and control arithmetic into a design interface, the Arithmetic of forms uses the theory of lambda calculus and recursive primitive functions, pillar theories of algorithmic computability. The creation phases are then as follows: our robot first generates polynomial forms with integer coefficients, forms that can be represented in two or three dimensions by a machine. Subsequently, the combinations of these

primitive forms with logical operators chosen deliberately or randomly, allowing the robot to obtain visual and colored geometric results. Technically, the programming language learned by the robot belongs to the family lambda calculus interpreters such as the Scheme language or its modern algorithmic variants like the Julia language [8].

6.2) SFC metacurves



Figure 6. Vera Molnar, 2023 *Croix en lignes* (source www.oniris.art)

Space Filling Curves (SFC) are curves whose theory was defined around the 1900s by most well-known mathematicians like Cantor, Péano, Hilbert. These curves are universally used in many areas of computing, and, for our Boustrophedon robot, they form the heart of the process of generating chaotic partitions of the plane and chaotic generation of colors.

The theory of SFC was completed in 1973 by the mathematician Wunderlich, then extended in 2022 to Gray's metacurves as part of the development of a new kind of geometry called boustrophedonic geometry [9]. Gray's metacurves are curves that visit each point of regular and deformable grids in n-dimensional spaces only once. In the world of Concrete art, the most recent work (2023) by Vera Molnar (figure 6) explores so-called Péano's curves whose construction process can be traced back to the design of Hindustan seals before Jesus Christ.

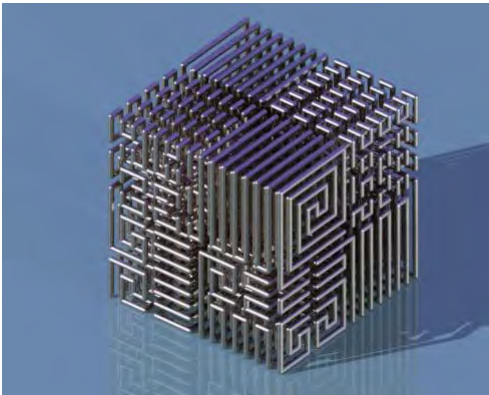


Figure 7. Gray's Meta curve in 3D

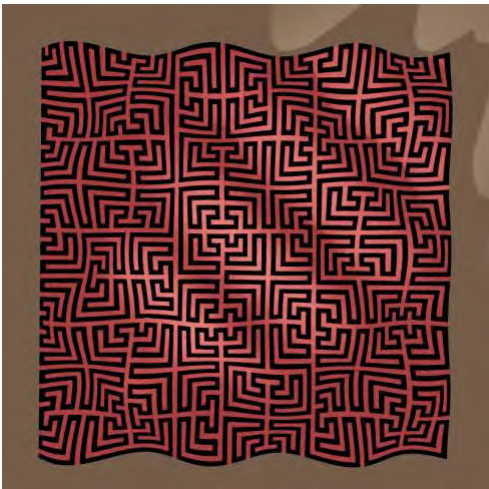


Figure 8. Deformation of metacurves

6.3) Topological stencils

To teach the robot to partition the plane, we instil in the robot a fundamental concept of topology: The Jordan's curve and Jordan's polygon. This concept is sufficiently powerful to cover a vast majority of cases of regular or irregular topological partitions encountered such as lattices, tiling, random polygons, SFCs and closed self-avoiding curves. Jordan curves or polygons have the property of dividing the plane into three elementary regions: the interior, the boundary and the

exterior of the curve or polygon. The ternary coding $\{0,1,2\}$ of the plane obtained algorithmically constitutes the first phase of the arithmetization of the plane. To describe Jordan curves, we will use implicit equations or piecewise parametric equations. In both cases the robot will operate in the projective plane to formalize the continuous deformations without special cases. The result obtained will be a partition of regions delimited by Jordan polygons, each region being associated with an integer numerical value: the density of the region.

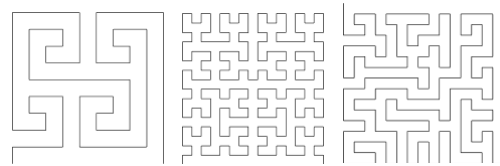


Figure 9. Jordan curves

6.4) The Péano's tiling

The Péano's tiling developed within the framework of boustrophedonic geometry [9] are directly controlled by so-called directrix of the Gray's metacurves which allow the robot to avoid the use of random or quasi-random methods in the generation process. The tiling generated are either chaotic or ordered in nature, the geometric order being ensured by the directrix of the metacurves.

6.5) Colors and attractors

To abandon any random approach regarding colors, the Boustrophedon robot is empowered with new capabilities allowing him to generate chaotic behavior from SFC attractors powered by so-called noise functions (figures 14-16). These attractors are distant cousins of the strange attractors which generate an apparent disorder from differential equations.

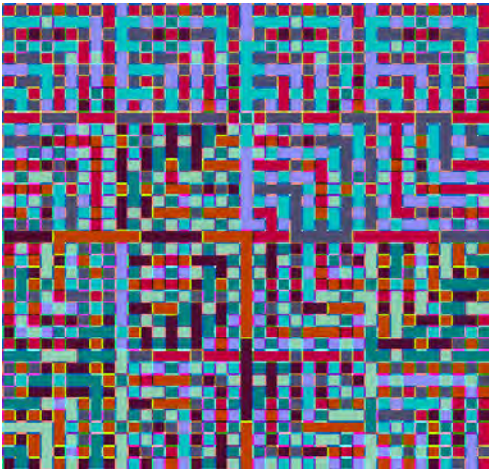


Figure 10. Generating a single-partition topological stencil

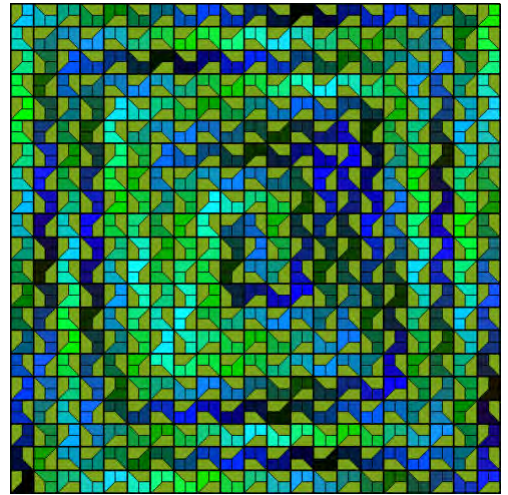


Figure 12 Chaotic colorization

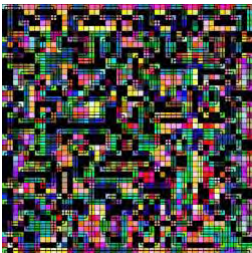


Figure 11. Generating a triple-partitioned topological stencil

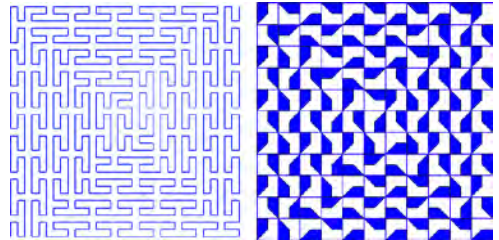


Figure 13. Ordered Peano tiling.

7) Boustrophedon exhibition

This virtual exhibition features a selection of works produced by our Boustrophedon robot using plane partitioning schemes designed by Concrete art pioneers. These partitions are made from self-avoiding curves traversing regular grids and subsequently transformed into Jordan polygons which feed the topological calculations underlying synthetic reasoning.

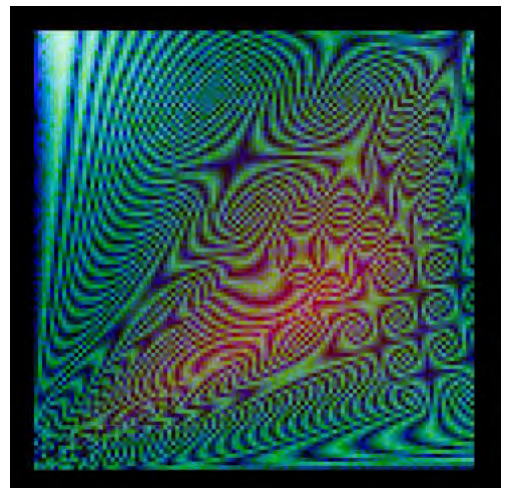


Figure 14. SFC attractor (Noise 1)

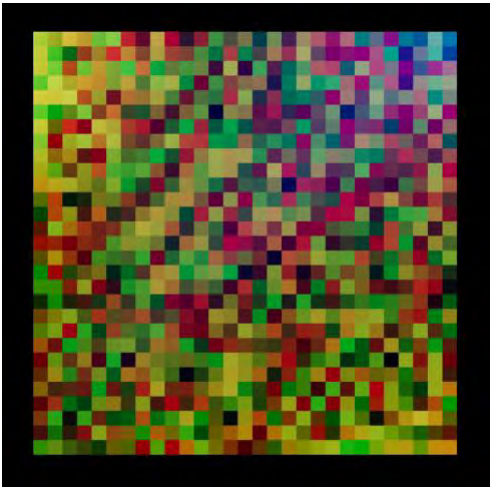


Figure 15. SFC attractor (Noise 2)

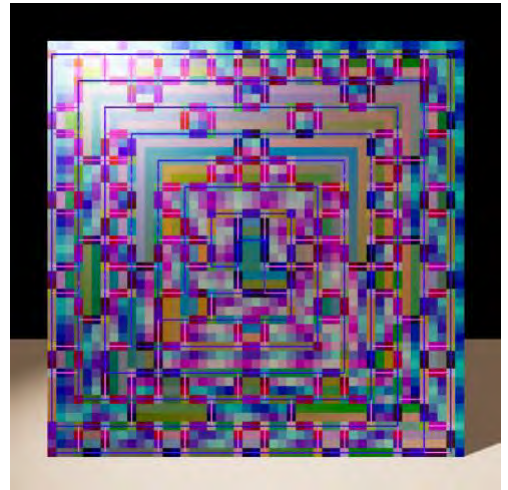


Figure 18. Topological stencil by superposition of partitioning curves

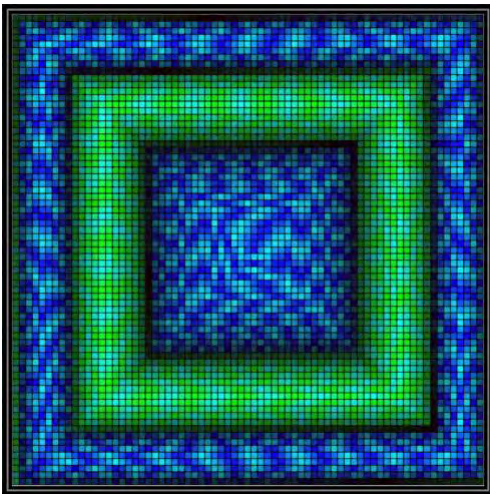


Figure 16. SFC attractor (Noise 3)

7.2) Wacław Szpakowski' F13

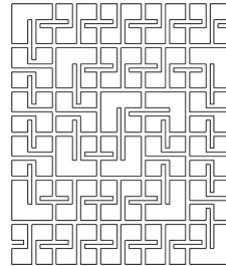


Figure 19. Retro analysis of the Szpakowski F13 self-avoidant curve 1939-1943

7.1) Rotor curves by Boustrophedon

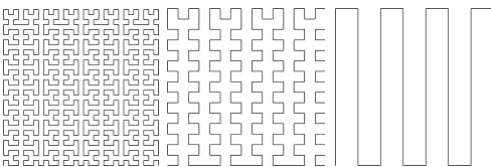


Figure 17. Rotor metacurves

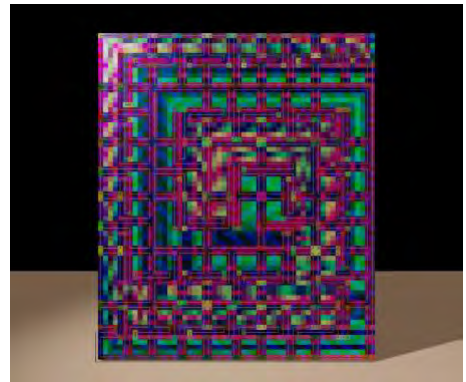


Figure 20. Topological stencil Szpakowski
F13 1939-1943

7.3) Meanders by Anni Albers

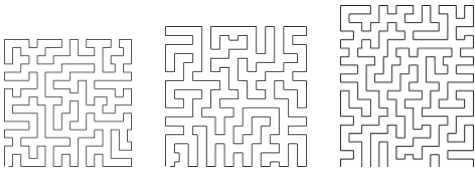


Figure 21. Retro-analysis of Anni Albers' Red, Yellow and Orange Meanders

The partition of the plane is made from the combination of a series of three meanders. The relative positioning of the meanders is obtained by playing in a non-random manner on the indices of the meander points.

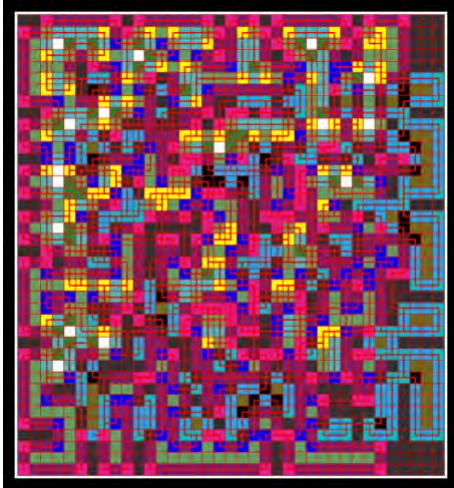


Figure 22. Topological stencil of the Meanders combination

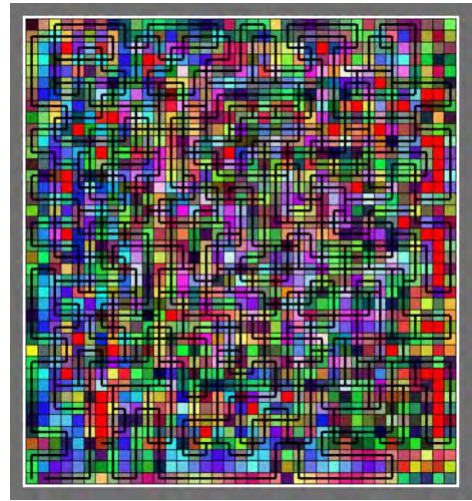


Figure 23. Topological stencil of the combination of Meanders with introduction of colorimetric chaos

7.4) Spiral by Julio Le Parc

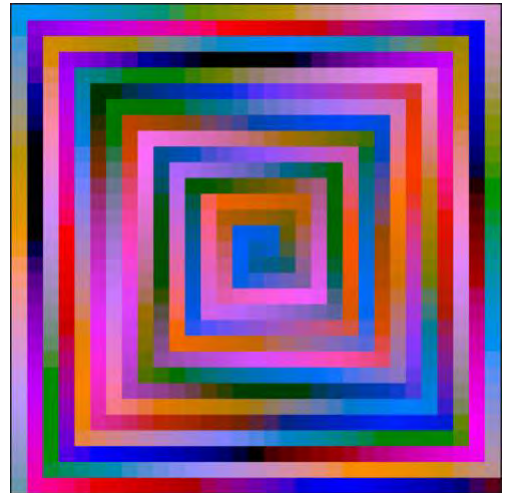


Figure 24. SFC color encoding and combinations

7.5) The Java of squares by Vera Molnar

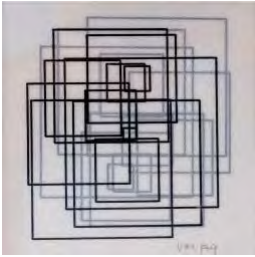


Figure 25. The Java of the 24 squares (courtesy Vera Molnar)

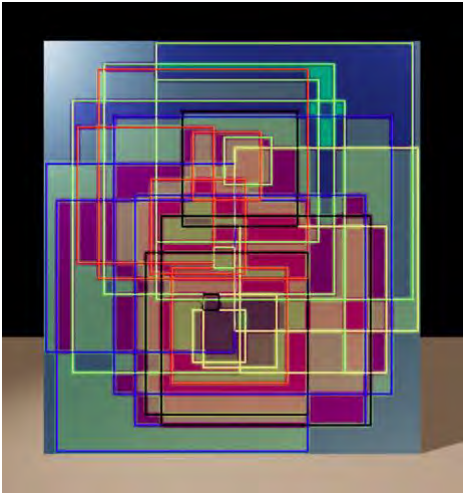


Figure 26 Topological colorization of Vera Molnar partitioning

7.6) The Majus effect by Victor Vasarely

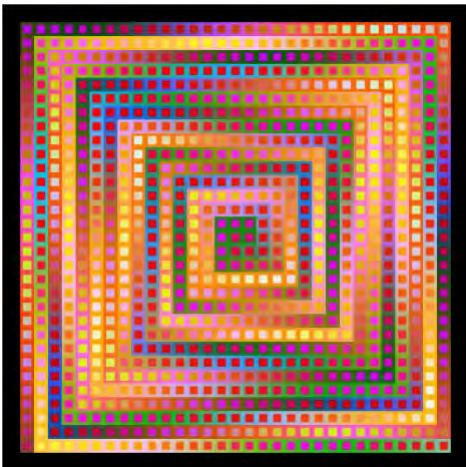


Figure 27. Restitution of the Majus effect by entanglement of metapixels.

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Generative Dance and Dissociation

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Abstract

In this paper, we examine examples of AI generative dance and generative choreography software to explore whether this class of algorithms might enhance or impede enacting authentic dance. Generative Dance and Generative Choreography is summarized as the use of machine learning models to generate anatomically plausible human movement sequences from a training set of archival movement, with or without musical feature extraction for matching rhythm and mood.

Our foundational assumption is that generative choreography cannot constitute authentic dancing given that generative dance is disembodied. This disqualifies it as a form of dancing vis-à-vis artificial generation. For the purposes

of our paper, we explore the conception of disembodiment as a specific understanding of generative dance as dissociation.

Our conclusion is that the dissociative nature of generative dance has limited ethical and epistemological applications.

We purport that the use of generative dance software is best suited to choreographers who have a strong relationship to their body and body knowledges.

Introduction

With the rise of new generative art programs, there has been an explosion in novel approaches to their exploration and application. Generate dance is one area in which creative movers see an opportunity to benefit from technological developments in AI for the purposes of alleviating personal strain and expanding their ability to synthesize movement vocabularies.

However, we surmise that not all generative art applications are the same, nor can they be applied with similar kinds and degrees of consequences. Though there is some uproar about the use of generative art as intellectually and

creatively dishonest, a distinctive problem for generative dance lurks. All art is inherently affective and embodied, but one might reasonably hold—though with some qualification—that dance is the only art form that is purely kinetic-affective in virtue of its purely ephemeral being. In this way, one can align our understanding of the aesthetic meaning-making powers of dancing with the accounts of Thinking-in-Movement set out by Sondra Fraleigh [1] and Maxine Sheets-Johnstone [2]. Therefore, what marks dancing art as distinctive, and concerning in relation to generative dance, is that it is always embodied because it exists only in the moving-moment.

In this paper, we examine examples of AI generative dance and generative choreography software to explore whether this class of algorithms might enhance or impede enacting authentic dance. Generative Dance and Generative Choreography is summarized as the use of machine learning models to generate anatomically plausible human movement sequences from a training set of archival movement, with or without musical feature extraction for matching rhythm and mood.

Our foundational assumption is that generative choreography cannot constitute authentic dancing given that generative dance is disembodied. This disqualifies it as a form of dancing vis-à-vis generation. For the purposes of our paper, we explore this conception of disembodiment as a specific understanding of generative dance as dissociation.

The embodied component of

choreography comes from the inherent need to draw on one's lived experience and body memories to articulate bodily ideas in the process of creation. That creative choreographing is essentially affective and embodied means that generative choreography is dissociated from the lived experience and organic context that necessarily imbues it.

In this paper, we have three goals. First, we explore how generative dance programs that yield generative choreography can contribute to creative processes of organic choreographing. If choreographers draw on such AI for their creative practices, then that the choreographer's curatorial decisions and modifications can disrupt the ostensible identity relationship between generative dance and dissociation.

Second, we explain how such programs create difficulties for imaginative processes in creative cognition development in early childhood education. We argue that the dissociative nature of generative dance thwarts the development of affective and cognitive skills that art practices intend to foster. This problematizes uncritical use of generative dance in lieu of instructors.

Third, we discuss concerns about the potential of incorporating generative dance into Dance Movement Therapy (DMT) that address trauma-based disorders. We argue that the dissociative nature of generative dance, qua its virtual status, can materially harm patients. Therapists who are not trained in DMT might see generative dance software as a viable therapeutic tool that can be readily incorporated into regular behavioral therapy. Yet if therapists are

not trained in embodiment and embodied knowledge, they will be ignorant of how the mimicry of generic dance sequences by traumatized patients can exacerbate their dissociation.

AI Generated Choreography

There are many different examples of algorithmically generated dance sequences. In 1966, Bell Labs Researcher and early experimentalist in digital art A. Michael Noll considered the possibility of computer-generated dance sequences; and although it was felt to be radical at the time, he accurately predicted the ability to analyze human motion into machine readable data. He further considered the possibilities of the computer as a choreographer's assistant and dancer stand-in to provide a choreographer with a visual aide during the creative process [3].

Much consideration has been given to the way that dance can be captured and archived since, unlike music which has had a widely accepted notation standard for hundreds of years, dance has eluded a standard method of notation across genre. Thus, "[t]he richness of human movements challenge attempts to unambiguously register, store, retrieve, display, and reproduce them" [4]. Many innovations have enabled the capture of dance movement in such a way that it can give a highly detailed description of the gross motor movement of the performer. Much of the literature discusses the ways a performer may be outfitted with motion capture sensors and accelerometers to help define the movement in terms of angle of limbs, rotations, and speed of movement, which

may then be classified into movement regimes that can be strung together [5].

Over the years, different applications emerged as both a tool to be used in the development of a dance work and a tool to be used as an element of the performance, such as reactive set design and costuming. There are now many examples of AI generative dance programs that are intended to mirror or augment a performance with extended features and reactive elements; others provide prompting to a performer. In both cases, a human dancer/choreographer is an integral part of the creative process.

Within the last decade, a variety of generative AI techniques have been used to generate choreography. In general, all of these technologies rely on training data captured for the project or use archival video footage or motion capture data of movement artist performances. It is important to consider not just the type of model being used but also the training data, so we will consider the case of large language models, models trained on extensive open motion capture training libraries, a model trained on a custom motion capture dataset, and a model trained on curated and processed video recordings.

Large language models: Although not specifically geared towards choreography, large language models such as ChatGPT can provide choreographic prompts to a dancer [6]. It would be possible to extend this ability to transfer these language prompts directly into a visually rendered video or image, although no such software currently exists.

Models trained on a large common motion capture dataset: Using a motion capture or video dataset is a way to get training data necessary to develop a generative model. There are some publicly available training sets such as the Kinetics-600 dataset [7], a large-scale action recognition set of approximately 480k videos assembled by Google DeepMind and released in 2017, the Let's Dance data set from Georgia Tech [8], consisting of 1000 videos of various dance genres, and AIST++, developed by Google Research [9].

AIST++ is a 3D dance dataset that contains data of motion captured dance with multi-view videos and human keypoint annotations of 30 different solo dancers across 10 dance genres. Multiple generative dance models have been trained on this dataset, including FACT, an autoregressive model built by the same team that developed AIST++ using a cross-modal transformer.

EDGE [10] is a transformer-based diffusion model that was also trained on the AIST++ dataset. It is often paired with OpenAI Jukebox [11], a music feature extractor. EDGE can generate arbitrarily long movement sequences using the diffusion framework by representing dances as sequences of poses synchronized to musical beats.

Models trained on a custom motion capture dataset: In order to focus on a particular movement style or performer, there are examples of models using specific training sets recorded for the purpose of training a generative model. PirouNet [12] is one such example. It is a semi-supervised conditional recurrent variational autoencoder. It allows users

to label movement sequences using the Laban Effort framework and is intended for the choreographer to curate and supply their own motion dataset.

Models trained on a curated set of video recordings: A highly available source of dance movement data is available in the form of video recordings, and software is available that can estimate the poses of humans within a scene and provide a 3-dimensional representation of those figures to an AI model.

Choreography cGAN [13] is one such model. It is a conditional generative adversarial network trained on 360 Japanese dancing videos. It uses OpenPose [14], a human pose detection library that detects up to 25 human body, hand, facial, and foot keypoints on multiple performers within a scene.

Common Features and Considerations: An important consideration in the discussion of these models is the training dataset used. The datasets were mainly centered around the length of the limbs and the major joint position of the arms, legs, and neck. In most cases, some of the most expressive components, such as sightlines, mouth expression, finger and foot position, were not captured, nor were physiological indicators of breath, such as chest movement, or heart rate that could suggest factors like fatigue or exertion.

In a general sense, all of the models have limited situational awareness, focused mainly on sound/rhythm/musical genre matching, as well as floor contact in the case of EDGE. The models typically conceptualize the movement as either a set of point clouds, or as joint

positions.

What the models considered share in common is the recognition that the models are limited in their responsiveness. The model is not tied to the reality or requirements of the performance space, such as temperature, ambient noise or audience response, gravity, friction, interaction with surfaces, fatigue, etc. that would be imposed on a dancer interacting in a physical world and due to the absence of these essential ties to the physical world, the models are inherently disembodied.

Disembodiment as Dissociation

One of the most enriching experiences of dancing is that this movement practice tethers one to their feeling-moving-knowing body. The creative movement that is dancing—whether improvising or performing choreography—requires the dancer to engender a living connection between their internal body knowledge and the external world. The centrality of body knowledge to movement creation marks its distinctive aesthetic embodiment within the domain of artistic meaning-making [15].

But it is entirely possible, just as a matter of living in a complex and difficult world, that people become alienated from their body's knowledge. When one becomes alienated from their body's knowledge, they lose (or sever) both their potential to link to themselves and their ability to connect to the external world. Within trauma discourse, this form of psycho-affective fragmentation is called dissociation [16,17].

Dissociation is generally an unnatural and unhealthy mode of human disembodiment because it is a willing or forced refusal to engage in phenomenological reflexivity with their own subjectivity. It can metaphorically be described in terms of a ghost. There is a ghost of a self that often looks down and over the body as if the body is not one's own, as if what the body is doing, or what is being done to the body, is not being done to one's self—for one's self is not real, for it is not tied to that body, I am not me, that body is not mine. When one becomes affectively split from their body, they are necessarily separated from the experiences of embodiment, which is our life force for meaning-making [18-21].

The notion of dissociation is uniquely tied to generative dance programs. Because generative dance programs are, obviously and definitionally, disembodied, the outputs of such programs are inherently dissociative. This is a rather uninteresting fact. There is no body so the movement generated is comprised of no affect. If there is no body and no affect and no connection to the external world, then there is no meaning-making potential. It is the absence of meaning-making power that makes generative dance inherently dissociative. But this is not, in itself, a necessary problem.

Where the disembodied dissociative nature of generative dance becomes disconcerting is in its broader applications beyond video games and VR. When people take up generative dance programs and intermingle their moving aesthetic embodied powers with it, the dissociative state of generative dance can then transfer over to the

person. That is, either the dancer's meaning-making efforts become dampened in the interaction, or the meaning-making is erased entirely. In some cases, this makes the use of generative dance in dancing-as-meaning inimical or, even, dangerous.

In what follows, we provide three cases where the application of generative dance into moving meaning-making practices takes on increasing levels of dissociation for both the mover and the movement.

Generative choreography

AI programs can easily yield “dance”, conceived of as a basic intertwining of movement vocabulary. This is, in fact, how some of the programs define dance. But these generative dance programs cannot produce choreography if we are conceiving of choreography as an original generative movement exploration process. The fact that it is reproducing and resequencing stored trained vocabulary evidences a dissociation of the choreographer. The dissociation is caused by the dancer being dissociated from their affect, or interpersonal synergies, that is necessarily involved in the in-the-moment process of decision-making in movement exploration and improvisation. Generative dance is a reflective synthesis of disembodied, dis-embedded sequences. Choreography is a truly organic generative pre-reflective conceptualization of creative movement made from embodied lived experience. If the choreographer is dissociated from her affect when using generative dance programs to contribute to, or complete, choreographic narratives, this

inadvertently and deleteriously produces dissociated sequences rather than affectively laden narratives drawn from a lived body memory.

Most of the programs reviewed were developed as an assistive device to a choreographer. The choreographer must conceptualize and curate the training sets, as well as the resulting generated movement sequences. Generative dance is not intended as a replacement for, and as such the usage of the tool would be up to the choreographer. Choreographers without the resources of a dance company who want to visualize and experiment with dance sequences may find utility in these types of programs. In prompting the choreographer to supply and label their own movement training set using a well-known dance notation system, PirouNet was the most clearly designed in our reviewed models for use by a choreographer for this purpose.

One major limitation of all the software models evaluated was that they all lacked awareness of the space for obstacle avoidance or navigation across uneven surfaces such as stairs. They were also limited to dance sequences of independent movers and were not trained for, nor appeared to be suitable to, work with non-independent duos or groups of dancers when interaction between performers is an integral component of the performance.

Indeed, in various video recordings of choreographer-dancers moving alongside AI avatars, the dancers do not appear to be actively dancing with the AI partner, but rather moving around it. In some instances, it appears as if they are

dodging it or moving away from the avatar. This indicates that they do not see the AI avatar as an actual partner. Such instances of avoidance exemplify an experience of the dancer's dissociation from the dancing because they cannot, or do not want to, properly couple with the avatar to generate partner synergies. Without a human partner, there can be no "dancing with", which means that there is no interrelational meaning-making.

None of the models surveyed suggest that their software is intended or suitable for replacing the work of a human choreographer but rather is intended to either aid a human choreographer or to provide ambient motion in an otherwise non-dance centered work, such as a video game. In discussing the flaws in EDGE, the authors note that there are fundamental issues in matching the rhythm of the accompanying score too closely, and that dance is not inherently about matching the musical beat to the "local minima of joint speed". [10]

Even if used only when the choreographer gets tired or stuck in their movement imaginings, the choreographer may become more and more dependent on generative dance programs, which will dissociate the movement generated from the choreographer's actual distinctive signature style, which emerges directly from affective movement. This dissociation is particularly evident in the transitions between vocabulary, which is where much of the choreographer's signature style manifests. The choreographer cannot merely mimic the generative dance sequences and then add on personal flourish because a

mover's affect appears in the entire movement dynamic of getting into and out of the vocabulary pose.

Further, the presentation of generative dance lacking affect will fail to activate the kinesthetic empathy of the audience. Movement mimesis can certainly be pretty and enjoyable. But organic choreography imbued with affect is more than enjoyable; it is communicative. Therefore, the dissociation of the choreographer from her affective movement creation and style leads to a dissociation between the dancer and the audience because the movement, and its lack of affect, cannot sufficiently generate kinesthetic empathy in the witness. This leads to yet another failure of interrelational meaning-making. In this way, the audience itself experiences a doubled dissociation from movement sequences produced by generative dance programs. It causes a failure of participatory sense-making because kinesthetic empathy is necessary for shared meaning-making. Therefore, generative dance fails as a social aesthetic contribution.

However, there are some beneficial aspects of generative dance programs for the choreographer. First, the use of generative dance programs can serve to prevent injuries because the choreographer may utilize the program to generate vocabulary that excludes the aspects of a movement dynamic that would aggravate the dancer's pain. Secondly, generative dance is useful to save time for the dancer in emergencies, such as when they are given short deadlines, or their movement partners cannot finish the exploratory stages. Third, it can be useful as a sort of

minimal outline archive. The choreographer may train the generative dance program on the dance created, which would lead to a stored set of the movement sequences. Given that there is no standard method of movement notation, the generative dance program could hold onto the dance's outline for later revisiting. And fourth, it is permissible and reasonable for the choreographer to go to AI if they get stuck—but only episodically.

Each of these instances of episodic use of generative dance can greatly benefit a multi-modal approach to diverse curatorial practices. This is because the dancer deploys the generative dance programs in a way that allows them to reinsert the affective embodied human into the disembodied AI movement. When used as a tool, the dissociate tendencies of the AI can be alleviated by the admixture of the choreographer's affect back into the disembodied generative movement. This would be especially effective in the affective transitions that exhibit the choreographer's signature style. One can even imagine a choreographer using AI to represent hostile or oppressive narrative storylines in a conflict-based dance to communicate a lack of humanity or vileness.

Generative dance as “teacher”

Many of the underlying technologies, such as video recording and motion capture have been extensively used as educational or training tools in performance review, archiving, notation, and evaluation. Pose estimation software is relatively new and has not yet

been extensively reviewed in the literature for dance education but could have useful application.

However, the benefits of generative dance in education are highly limited. One can imagine that given its accessibility and familiarity, ChatGPT would be appealing for developing generative dance curriculum in schools. Its accessibility to the public makes it extremely tempting to supplant arts teachers or augment undertrained arts teachers in schools, especially when there are so many calls for cuts to art and dance programs to satisfy budget problems.

The main downfall of relying on generative dance in the classroom is its inability to build higher level cognitive skills. According to ecological psychology and movement for childhood development [22], dance education is necessary not only for the development of critical sensori-motor skills, it is also fundamental to the cultivation of creative cognition. While movement itself contributes to basic cognitive development, the affective component of dance produces skills necessary for higher level critical thinking processes. Specifically, dance, and the imaginative exploration of spatial dynamics, cultivates a kind of social interaction intelligence because it introduces practices of collaboration and thinking-together in space [23].

The incorporation of generative dance programs causes a dissociation between children and their bodies because affect is necessary to build imagination processes inherent to creative cognition. The absence of an arts/dance teacher

removes the play aspect needed to deploy and take in affective interactions. While there may be some cultivation of spatial understanding around their bodies, and between themselves and others, the absence of affect in disembodied generative dance precludes any of the higher cognition skills of collaboration and thinking-together. The dance teacher not only encourages creative play in movement, but also in playing together through movement. Teachers encourage play and unique expression. The teacher not only encourages and demonstrates play and imaginative “as-if” options for creative movement, they also, more importantly, raise the level of play to silliness, which is an elevated affective interaction that builds social trust into creative cognition.

Similar to problems facing choreographers, interaction with disembodied generative dance sequences fails to encourage emotional exploration through movement. When young students are faced with AI instructions, there is no ability to stray from the movement. Thus, students engage in a mimesis of disembodied rules for moving rather than an exploration of affordances for choice of movement and expression that teachers encourage through affective displays of, and participation in, creative possibilities. The rule-like structure of mimesis not only lacks the capacity for play and silliness, it indicates that any deviation from the produced sequences constitutes a failure by the student, which then encourages obedience rather than creativity. Even if the generative dance program is sophisticated enough to provide an AI avatar, the lack of affect

and authentic interaction would add a second layer of dissociation. Now, the students are not only dissociated from bodies and their peers, but they are also dissociated from the avatar.

This is not to say, as in the case of generative dance for organic generative choreography, that there is no use for generative dance in schools. It certainly can be used as an occasional tool. There are days when arts teachers are sick and generative dance programs could be used to fill in the day for the students. Similarly, if the students have a substitute who has no familiarity with creative movement play, generative dance offers a means for the substitute to get through the day. But even having an uninformed math teacher or a completely exhausted gym teacher is preferable given that there are still some affective interactions between students and teacher. However, the acceptance of generative dance as a substitute for an arts/dance teacher could easily lead to the elimination of the teacher; schools often find themselves riding slippery slopes when evaluating budgets.

Incorporating generative dance into the classroom leads to more significant problems of dissociation than when the choreographer uses it as a tool. This is because the students do not yet have an understanding of their body or developed creative cognitive skills. The choreographer is aware of the ways she can be affectively separated from her movement and can take steps to alleviate this problem by mixing her own affect back into the disembodied movement. However, children will not even learn the role of affect in dance and so learn the feeling of dissociation as an

inherent aspect of movement, and more concerning, as a natural response to moving lived experiences.

Generative dance in Movement Therapy

Many of the issues and missing aspects that make generative AI unsuitable for education are amplified in the category of using generative dance software for DMT. DMT is often used to help patients who suffer from trauma connect to their trauma in incremental stages through curated and individualized movement sequences as a means of uncovering, facing, and/or overcoming the source of the trauma [24-26].

Movement, especially dance, allows the patient to access experiences that are buried in the body memory. When people suppress their traumatic experiences and memories in their body, they create a form of dissociation to these memories as a coping mechanism. But this dissociation from trauma can lead to other psychological, affective, and interactive disadvantages in other parts of their life [16,17]. DMT helps the patient connect to these memories through movements that can connect the patient to their trauma through the ability of dance to generate kinesthetic empathy. And in DMT, the movement directed towards the body memory allows the patient to cultivate kinesthetic empathy for herself [27].

Given the ample evidence for the success of DMT in trauma therapy, psychologists and social workers who are not trained in movement therapy might be tempted to incorporate these

programs as one of their healing treatment offerings. Unlike the other cases, where the use of generative dance can be concerning and problematic, such utilizations of generative dance as a source of DMT can cause extreme psychological and material bodily harm to patients.

Therapists who are trained in body knowledge and movement therapy are trained to understand how specific forms of somatic movement can access trauma. And movement therapists assemble targeted movement practices that connect to that person's trauma. They understand how specific movements must be chosen and modified depending on how sensitive the person is to their trauma, how dissociated they are from their trauma, and how much explicit resistance they have to connecting to their trauma. They understand that their own affective relationship with the patient is an additional important desideratum for movement selection. Additionally, the therapist's moderated affect exhibition can serve as a buffer between the patient and the movement towards the trauma memory. Therapists who lack movement training cannot understand how movement generally, and individual movements specifically, can actually trigger a person's trauma in deleterious ways. They do not see how the therapist's affective relationship to the patient, along with personally contextualized movement, is the essential factor in the success of DMT.

If the generative dance program provides movement sequences trained on generic movement therapy examples, it sustains the patient's level of dissociation. This is

because mimesis of disembodied, affectless movement is inherently dissociative. So, at best, it simply leaves the patient spinning her wheels while forking out an exorbitant amount of money. But mimesis of disembodied movement that produces generic sequences that match the moving shape of the patient's trauma can fully ignite the patient's trauma.

If the patient has cultivated a dissociative relationship to their trauma to cope, then one of the consequences that can result from such a high degree of triggering is a significantly stronger, more sedimented, and more pervasive state of dissociation to many of the patient's body memories that surrounds or shares content with the trauma. This expanded state of dissociation will cause, as generalized dissociation causes, extreme somatophobia, which is a deep loathing and fear of the body itself. Because trauma is embodied, and because trauma attaches itself to the body, dissociation deteriorates the patient's relationship to their body; and in some cases, the patient can become fully dissociated from their body.

Expanded states of dissociation can further lead a patient to amp up their experience of internalized psychological oppression. Experiences of trauma, especially sexual assault, causes the patient to see themselves, and their body, as the source of their "neurosis" and felt blameworthiness for their trauma. Often, when patients regard themselves as to blame for their trauma, especially if they cultivate a dissociated relationship to their body, they often engage in self-harming behaviors as an embodied coping mechanism.

Conclusion

Ultimately, the disembodied nature of generative dance has limited ethical and epistemological applications because it causes varying degrees and kinds of dissociation within movers. When used as a tool, it can be highly beneficial; however, it can be problematic if the choreographer becomes too generous with its use, and especially if they become reliant upon it. When used as a substitute for an embodied teacher with an affective disposition towards the movement of students, this can impede the development of higher level creative, critical thinking skills. This dissociation produces a docile body and creates difficulties in social interactions of collaborations through spatial dynamics of thinking-together practices. Finally, we have shown how generative dance in DMT can cause deep material harm to patients and should be avoided. We conclude that the use of generative dance software is best suited as an occasional tool for choreographers who already have a strong relationship to their body and body knowledges.

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Toward Epidemic Computer Art

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Abstract

In this work, we are presenting an experimental system for painting, compositing and color manipulation. This is a semi-automatic generative and interactive environment using a behind the stage agent-based system, i.e. a system that is hidden, but that controls the process and the generation of color on the canvas. The design of the agent-based system is inspired and derived from epidemic modeling and it allows to generate computer images or paintings with a mix of compositing and painting techniques in a multi-layer hierarchy.

Keywords

Digital painting, generative art, epidemics.

1. Introduction

Modern painting since the 1890's has insisted on the independence of color on the canvas outside a direct representational function. Starting from the

impressionists and the cubists, the chromatic content of the canvas is not forced to have a real or obvious correspondence to a physical reality.

Inspired by this concept, we have been experimenting with agent-based systems that work behind the scenes and control the generation and flow of color in the canvas ([1] and others).

In the present work, we turn to compositing alongside simple painting by color depositing. More precisely, we want to compose two or more images that are initially placed one on top of the next in a hierarchy. The idea is that one image can "infect" another in some positions and the infections can spread around these positions and/or blend with the original. Alternatively, an image may be infected by one or more colors at one or more positions and the infections spread in the same way as before.

2. Painting epidemic process

Agent-based and artificial life systems have been employed in digital painting and more generally in art and music [2] [3]. Our agent-based system is hidden from view but controls the colors in the canvas through defining one agent per pixel and per level in the hierarchy of images, for instance in a hierarchy of 3 images there will be 3 agents for each pixel. Each agent is a virtual entity that has a set of infection features corresponding to the biological ones of a

basic SIRS epidemiological model [4]. A SIRS model takes its name from the three possible states that it defines for an agent:

- **Susceptible:** Not infected, but susceptible to being infected when in contact with an infectious agent. In our system, there is contact when two agents lie in adjacent pixels.
- **Infected:** Actually both infected and infectious. In many advanced realistic models an infected agent is not necessarily infectious or not right away after infection.
- **Recovered:** After an infection has completed a cycle of determined length.

In a pure SIR model, a recovered agent is protected for life and cannot become susceptible again, while in a SIRS model a recovered agent will become again susceptible after a certain time has elapsed. Moreover, an agent may “die” by an infection, with the result that the lower level agent at the same position will take control, if there is one. Thus, an agent defines the following epidemiological parameters:

- **state:** One of susceptible, infected, recovered.
- **pl:** Probability of infection at contact with an infected agent
- **Ti:** Duration of infection (which controls the distance of spreading on the canvas)
- **Tr:** Duration of protection after recovery
- **vulnerability:** Probability of death by the infection.

We have also introduced an additional state, quite common in epidemiological modeling:

- **Immune:** An agent immune to an infection. This is equivalent to a recovered for life agent, except that the immunity is not acquired but the agent is born with it.

The basic outcome of infection by an adjacent infected agent is the adoption of a new (infection) color that is blended with the original in this position of the canvas. The blending is such that the original color starts converging toward the new infection color with a “reactivity” or rate parameter, such that $new_red = old_red + reactivity_red * difference$ ($= new_red - old_red$) and similarly for the blue and green color components. The actual color with which an agent is presented during infection may be defined in many ways that are described in the following section. One possibility is to use a specific color by agent that may in principle differ from agent to agent or across levels. All these parameters may be controlled via an epidemics editor (see system snapshot 2, editor of epidemics data). Note that the presence of immune agents, that resist to infection and change, gives an impressionistic effect.

3. Software environment

The environment is developed in the Java language and a snapshot is given below (system snapshot 1).

The epidemic process can be started in several ways:

- Infection of an image by an image at the next level of hierarchy (below)
- Infection of an image by a user-defined color
- Infection of an image by a position-specific color, defined by an agent at that position

The infection areas can be input with one of the following methods:

- Triggered with the mouse at specific positions in the canvas
- Automatic (generally with a single infection event 100 random positions on the canvas are infected)
- With a brush-tool that infects all the positions that it is driven through

For example, the sample composed images 1 and 2 use a triggered method, whereas system snapshot 1 (user interface) shows the result of a brush action with lower-level infection of the image (the level below is revealed by the brush). All these parameters may be set via a controls editor (see system snapshot 3, editor of painting controls).

After all the parameters are set, the user may run the epidemics process (button "Spread" in system snapshot 1) for a number of steps, usually a few tens of steps.

4. Potential

All the epidemics and user control parameters may be also controlled and set by the user programmatically. Co-infections, re-infections and other intricacies are possible. The methodology allows a vast range of manipulations to be explored and effects to be produced. Most importantly, there are numerous possibilities to be explored as to how two colors blend when they come into contact. Does blending depend on the relation between two colors? Do colors fade during spreading? Do some colors take precedence or show bias? These and other ideas should be the object of experimentation with different types of images, for examples real life photos and photos of paintings. Additionally, we plan

to extend the system to allow the use of advanced brushing tools such as [5][6].

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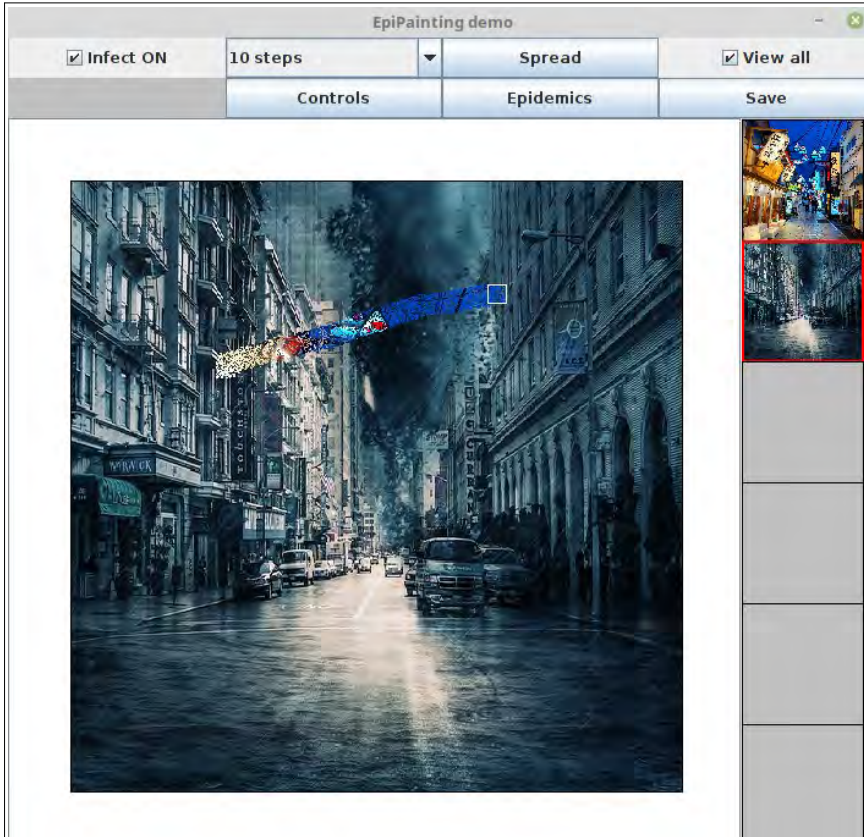
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System snapshots

1. Main user interface



2. Editor of epidemics data

Epidemic parameters			
Infection	0		Set
Ti (<=30)	10	Tr (<=1000)	10
Pi (<=1)	1.0	Immunity	0.3
Vuln min (<=0.5)	0.0	Vuln max (<=0.5)	0.1
d(R) min (<=0.8)	0.03	d(R) max (<=0.8)	0.2
d(G) min (<=0.8)	0.03	d(G) max (<=0.8)	0.2
d(B) min (<=0.8)	0.03	d(B) max (<=0.8)	0.3
Agent(R) min (<=255)	0	Agent(R) max (<=255)	255
Agent(G) min (<=255)	0	Agent(G) max (<=255)	255
Agent(B) min (<=255)	0	Agent(B) max (<=255)	255
Reset			

3. Editor of painting controls

Painting controls				
Type	BRUSH	Source	LOWER LAYER	<input checked="" type="checkbox"/> Self color
Brush shape	SQUARE	Brush size	15	<input checked="" type="checkbox"/> Irregular
User color	255	255	0	Set

Sample images

1. Original image 1



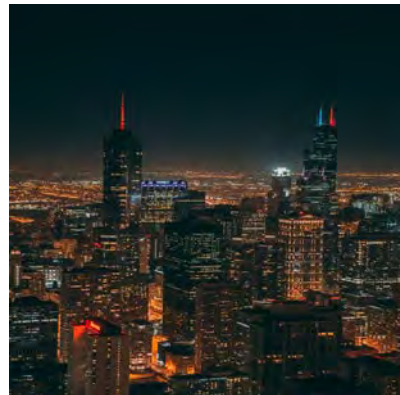
3. Original image 3



2. Original image 2



4. Original image 4



1 and infected by it.

In this and the following composed image, the epidemic pl of agents is not fixed but dependent on the colors that come into contact through the agents.

Infection is point-wise, as shown in the first image below (“patches” emerge after 20 steps). The structure of the original image 1 of the lower layer starts to be visible in the second image below after 150 iterations (spreading steps), for example the long band of dark sea in the horizon. Note that a large dark area in the middle-right resists to infection and hinders spreading because the colors of the two images at this region are too close.



6. Composed images 2

In case of images of similar coloring spaces, the infections spread faster and better. Original image 1 on top of original image 3 and infected by it. Infection is brush-driven, as shown in the first image below, where the “painted” areas are visible. The original image 3 of the lower layer is largely retrievable as shown in the second image below after 150 iterations. Note also, that it is almost fully retrievable after just 30 steps, if random reinfections are allowed at every step.



4 and infected by it. Here p_I is 1 for all agents, so the infection is controlled by medium reactivities (from 0.1 to 0.4) and high vulnerabilities (from 0.4 to 0.5). The snapshots are taken at start (with a brush infection) and at $t=60$. In this case, at $t=60$ the two images blend seamlessly. But if the color palettes of two images were not close enough, the resulting images might have been surprising.



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The one chair, that is made for you

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Abstract

This research presents a method to design and fabricate a task chair tailored to individual and specific data of the end-user. The aim is to respond to the question of a functional bespoke mass product and to reduce parts and production complexity to a mono-material geometry with arguments for circularity. This is done with a robotic setup with the application of conformal 3d printing. The specific application in the case of a task chair is chosen as a mid-scale object with the possibility of clear performance evaluation. The project explores the proposed systems from data collection to final product production, and investigates its performance towards linking user data, design process and robotic

fabrication methods. The findings are a result of a design-based research methodology, which allowed for a dynamic and adaptive investigation into the subject. For this, the paper will articulate the fabrication setup, illustrate experimental testing and evaluate findings, as well as hypothesizing on design cases as demonstrator.

1. Introduction

Polymer based consumer goods are commonly produced through thermoplastic injection molding techniques, based on finite tooling design strategies, most often injection molding. This highly optimized industry standard outperforms any other fabrication method in cost per item, production cycle times and quality consistency [1]. However, conventionally injection molding relies on prefabricated steel multi-part tooling and is incontrovertibly biased to the tool itself, thus incapable of variations in e.g. shape, size and strength. While, since 2009 the field Additive Manufacturing (AM) has rapidly grown in application, utilization and accessibility, the technology is only now being implemented in large scale fabrication [2]. Since AM is not bound to fixed tooling, but instead utilizes selective deposition of material where needed, it allows for opportunities over other mass

fabrication technologies, specifically in regard to material efficient and customizable production, but compromises – to date - on production speed, costs and quality.

This research investigates the possibilities for designing objects with variable systems for individual fabrication with large scale AM, specifically conformal polymer extrusion through Fused Deposition Modelling (FDM). This focusses on identifying quality and design expression regarding its geometrical and extrusion parameters. For this, the study aims at designing and producing functional consumer items within parametric variable boundaries, thereby allowing for user or context customization of polymer-based items. The study focusses in two parts at (1) establishing a robotic 3D printing system to facilitate an experimental process of design fabrication with polylactic acid (PLA) material, industrial grade pellets; and (2) to investigate design intends to evaluate and proof plausible and beneficial variations within design systems – parametric generative design. This explores a design method and strategy for adaptation of user data into an applied design context – a task chair.

2. Background

Task chairs are highly regulated functional furniture, by e.g. DIN EN16139 [3], ANSI/BIFMA X5.1-2017 [4] for work environments in regard to their dynamic seating properties, stress capability, and user adaptability. Many design solutions therefore incorporate kinetic motion mechanics to accommodate flexible sitting behavior, contributing to a healthier work environment and increased work performance [5]. However, fine adjustments are commonly only applied

on initial use for a single individual. The proposed method for the fabrication of an individual chair is referencing user data for seat, backrest, height, as well as material compliance and weight distribution, aiming towards dynamic sitting behavior.

3. State of the Art

With vast advances in AM in recent years, applications at larger scales have been widely demonstrated. Within this research a subgroup has been focusing on 3d printing detached from a horizontal layer structure, as demonstrated throughout various scales for objects, e.g. by Hong [6], furniture, e.g. by Soler et al [7], or building components, e.g. by Nicholas et al. [8], Battaglia et al. [9], Branch Technologies C-Fab [10]. Moving beyond standardized printing has brought many advantages to the field, a.o. in regard to mechanical performance, visual appearance or artistic expression [11]. Specifically, the conformal 3d printing process offers, for the here described process, advances over planar layer printing [12], by application of fused material onto a previously fabricated CNC milled formwork, providing desired underlying curvature. This leads to finer surface finish [13], [14] and allows for increased mechanical behavior of the fabricated part [15], [16].

4. Method.

The project is based on an experiment driven approach, including material studies of the extruded PLA lamination, computational design pattern - generation, computational analysis and prototype experiments. The research conducted employed the methodology of research by design and weighs artistic

values such as perceptions of emerging results in terms of tactility and density of material, structure, and clarity in understanding and perceiving form and function.



Figure 1: Robotic 3D printing setup.



Figure 2: 3D printed study from earlier chapters of the project.

A generative approach is applied towards the creation of a design as well as towards producing printable geometry, adaptive to user data. The process generates parameters for material

application, density, and distribution. Further geometrical elements are therethrough directed anticipating the required behavior of the fabricated product. Varying pattern configuration are used as supporting element, ranging from compliant structures connecting seat and backrest to ridged configurations aiding mechanical performance below the seat geometry. The generated design is then fabricated by robotic conformal 3d Printing via a UR10e [17] equipped with a DYZE Pulsar [18] pellet extruder.

4.1 Print path creation

In previous study cases, we have explored performative aspects of our setup in relation to print settings on 2D print layering. (see figure 1)

We discovered a reliable relation of object dimensions, fixed extrusion rates with a nozzle size of 2mm, extrusion temperature of 225°C and an adaptable variable travel speed. Adequate layer heights ranged from 1 to 1.6mm with increased results at the coarser end of the spectrum. However, printing conformal onto three-dimensional tools required higher tolerances, attributed largely to the deviation of the physical tool from the original computational reference. More consistent visual appearances have been achieved with a 5mm nozzle and layer heights of 3-5mm. Further, an increase in extrusion temperature to 235-240°C has been successful, as this seemingly allows for the re-melting of previously distributed material. This allows for potential exceeding of given tolerances, by limiting collision impact with appearing fabrication artefacts. The coarser print resolution further allows obtaining higher volume extrusion rates, significantly lowering production times.

4.2 Design space

The investigation focused in the initial phase on the development of a robotic conformal 3D printing setup, then on a computational design system for a functional chair with adaptability for specific user data. To keep complexity minimal, user data was collected by taking measurements and weight of three different users in an analog approach.

between Kresten and Karen indicate the need of adjustment of seat height, depth and backrest. Karen's sitting height is prompted to 440mm, Kresten will be most comfortable at 480mm sitting height. The static load of Mads requires the chair to carry almost twice the weight of Karen. In comparison Kresten and Mads have a difference of only 16,36% in weight, but the weight is distributed quite differently onto the chair, due to the difference in body proportions of both users. The proposed method, therefore

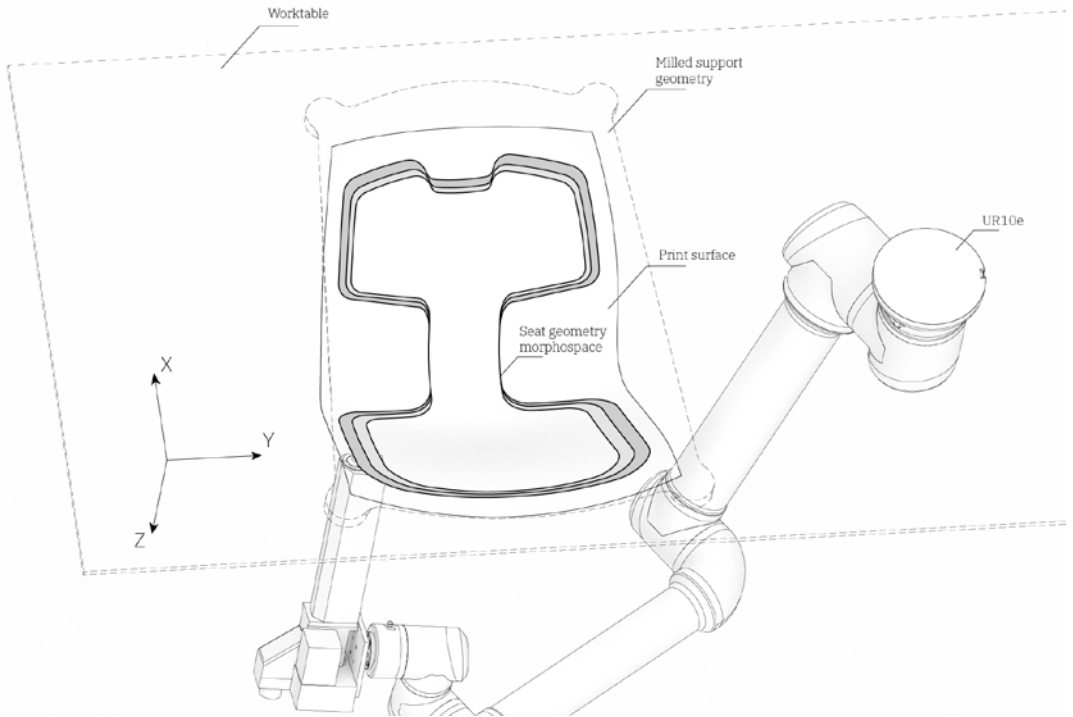


Figure 3: Seat geometry design space.

User	Height [cm]	Weight [kg]
Karen	168	54
Mads	174	110
Kresten	203	92

Table 1: User base data overview.

The significant differences in height

suggests to accommodate user weight and proportions into the computational model, and thereby optimizing the chair for the user by bespoke fabrication.

5. Design experimentation

The reference object for the research is the KEVI chair by Jørgen Rasmussen [19], designed in 1958. The KEVI Chair is regarded as a light task chair with basic adjustability in sitting height and the pivoting backrest height. Notably, it was the first office chair with double castor wheels, which then became industry standard. To accommodate user specific adjustments, this chair is nowadays equipped with a gas-spring levitating mechanic and a mechanical fitting for backrest height adjustment [20].



Figure 4: KEVI chair by Jørgen Rasmussen [20].

The aim for this research is to address the following requirements for adaptability in the chair design: Geometrical requirements, such as sitting height, seat size including width and depth, back rest size including width and depth. Longitudinal distance between seat and backrest. For the structural requirements weight and weight distribution was prompted to call for material distribution and structural build-up of reinforcing elements such as ribs and varying section dimensions.

Conducted experiments investigate providing the desired mechanical performance, optimized for the specific user data, while at the same time accommodating dynamic seating behavior, through allowing for slight motion and flexibility through compliant material and structural properties.

5.1 Material exploration

PLA pellets are utilized as a mono-material for the fabrication of all objects within this research. PLA by Nature Works Ingeo® 3D870 Natural PLA Plus are produced from corn-starch. The material is categorized as a thermoplastic biodegradable bio-polymer, with lower heat resistance compared to some other plastics like ABS (Acrylonitrile Butadiene Styrene), so it softens at relatively low temperatures, which makes it suitable for lower extrusion temperatures. PLA is generally considered safe and has low toxicity levels in this application, which favors large scale 3D printing with exposure of considerable volatile emissions by molten polymer materials. PLA is widely used in 3D printing due to its ease of use, reliability and wide availability [21].

Polylactic Acid advances for this application, due to the material's ability to be recycled. Being a thermoplastic polymer, a simple mechanical grinding process reconverts the object in 2-3mm granules which can be reused through our 3D print setup directly [22]. At this point the research does not investigate the material's degradation of quality by simple reusing. PLA is also adequate for advanced recyclability through hydrolyzation, which splits molecular formations back into lactic acid monomers, indicating possible advances for continued re-use over fossil-based

plastics [23].

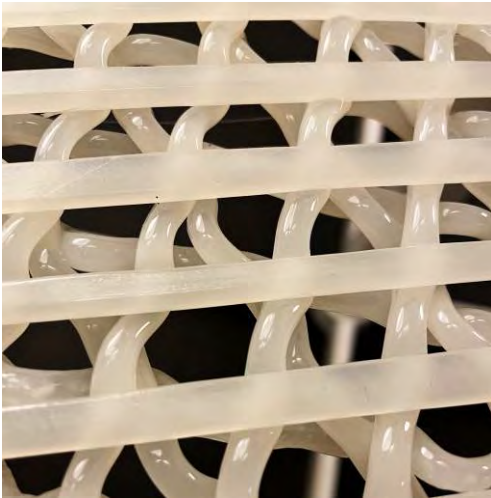


Figure 5: Patterning, contact conditions.

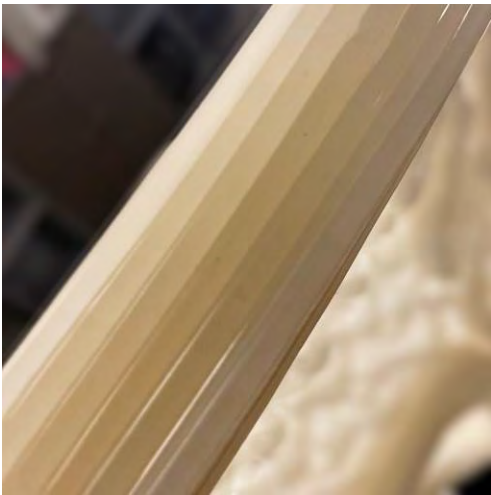


Figure 6: Layer lamination.

Conventional polymer injection molding results in homogenous isotropic material behavior within an object. However, the distribution of polymer by 3D printing will lead to various conditions through lamination of layers in certain directions. Generally regarded: a) overlapping contact conditions will form bonds locally at points (see figure 5), b)

layering build-up contact conditions will form bonds along the print path (see figure 6) and c) negative space between print paths remain empty and do not contribute to material strength.

The evaluation of several samples has shown, the most frequent reason for fatigue failure is de-lamination of 3D print layers under stress. Followed by PLA elongation at break 7-10% caused by bending deformation of the relatively brittle polymer [24].

5.2 Computational building strategies.

The computational model for the chair was created in Rhino3d [25] and Grasshopper [26]. Two separate approaches were utilized. (1) The first step defines the geometrical surfaces of seat, backrest and the connecting backbone. User data is responsible for the chair's proportions. Width and depth of both seat and backrest are measured prompted. Surfaces will be generated by laminating several layers in varying directions, followed by several layers of circumscribing, reinforcing contours. The emerging surface defines the size and shape of the chair but would not be strong enough to carry a human. (2) The second step generates supportive rip-structure underneath and behind the chair. Main deflection areas, caused by load stresses, are located at the backbone between seat and backrest.

6. Discussion

6.1 Material properties & degradation

PLA as a material, while exhibiting an array of favorable attributes in the projects, currently lacks application in

production at larger quantities. Its brittle and less impact-resistant properties, especially compared to some other plastics, limit its suitability for larger scale production and long-term use. At the same time Current research in PLA composition suggests more favorable compositions, allowing for higher elasticity, as conducted by Pond global [27].

6.2 Printing strategy

The process explored the construction of geometry tailored to user data. Within the scale of the project, certain assumptions have been made, especially in regards to load carrying performance of the fabricated objects. Additional research is necessary to understand the materials performance under various load scenarios. To limit the complicity of the structural predictions, the fabricated chairs geometry is assumed to work as a single shell. It is to be expected, that the physical material configuration resulting from the printing process, such as layer lamination, printing direction etc., have a large influence on its performance and need to be taken into considerations.

Further a range of challenges have been observed in the fabrication process. Deviation of actual geometry of the support geometry and its ideal digital model. Small variations of that geometry, which can be attributed to the supports fabrication and scale, can cause unwanted variations in the 3d printed resulting object, ranging from cosmetic artifacts to disruptive defects causing delamination of the print from its support geometry, or collisions between the printing nozzle and previously supplied material.

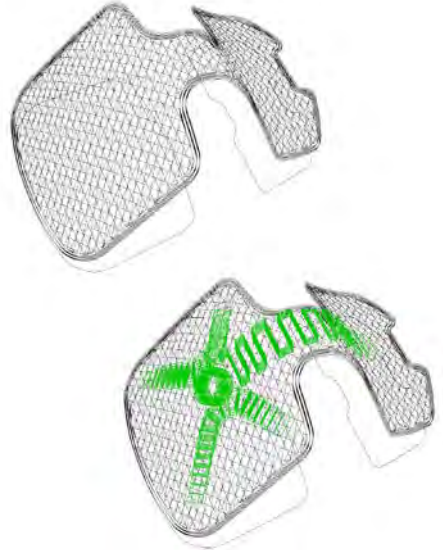


Figure 7: Geometry construction.

Large geometrical variations in the support geometry brought additional challenges for the printing process. This can be attributed to the scale of both the workpiece and of the used articulated robot's limiting reach. This results in inconsistent application of material, depending on the direction of movement of the extruder, causing material to be dragged or pushed. This requires close attention to positioning of the extruder, robotic arm over time. A current understanding of the production of code for execution does not allow to incorporate this information. This requires the introduction of a new way of treating the machine code, allowing for possibly fabrication-aware applications, through e.g. observation during the print or simulations of material distribution. This might further allow monitoring of observable material deformation, such as sagging, warping or other temperature related deformation.

6.3 User data

The user data, surveyed from the chair's future user has been simplified for its direct application and application of the to be fabricated geometry. Past developments, observable in e.g. in sports apparel, show pathways for more automated and development of larger data sets from the user. This could allow for the inclusion of additional data, such as asymmetrical force distribution, through force sensor implementation.

7. Conclusion

Our research hypothesis asked for a method to design and fabricate a task chair, tailored to individual and specific data of the end-user investigating a

of complexity within this application leads us to reduce many aspects significantly to isolate and understand specific challenges with the computational model, as well as the need to overcome specific challenges with our extrusion-based 3D print method. In conclusion, our findings at this stage encompass a method for addressing user-explicit body proportions to ergonomically beneficial conditions within a mono-material geometry. Further research is needed for sufficient response to a more comprehensive extend of user data, including opportunity of adaptation of the computational design model to predictive and responsive material behavior.

8. Acknowledgement



Figure 8: Chair demonstrator.

feasibility for the fabrication of a bespoke mass product in a printed mono-material configuration. Our investigation discovered plausibility for a computational design model, that can respond to bespoke user data and thereby generate geometry for individual fabrication. The project also succeeded in the development of a setup for conformal robotic 3D printing. However, the scope

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Generative Design in Textiles: Overcoming Problems of Production

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Craig Jackson (left), Jeff Nilan (right)

Abstract

In this paper we discuss some recent work towards producing high-quality woven textiles that incorporate generative design elements. In particular, we describe our efforts to circumvent several problems of production that arise when woven textile designs are generated algorithmically. These problems can be summarily described as: (1) most commonly available floor looms are not capable of weaving generative designs without extensive,

time-consuming, manual intervention by the artist and (2) generative textile designs must be developed in accordance with basic principles of textile production if the final piece is desired to be a sturdy and resilient textile.

We describe efforts to address the first problem of production by constructing our own, inexpensive yet full-sized, computer-controlled Jacquard loom for which we have written our own software. Additionally, we discuss an approach that utilizes “shaft switching” techniques that allow traditional floor looms to produce generative designs without an excessive amount of manual intervention. We also discuss some ideas for generative algorithms that result in well-made, sturdily woven objects.

Introduction

Traditionally woven textiles can be abstracted as binary matrices. In each row, a zero or a one indicates whether a weft thread (running left to right) lies above or below the corresponding warp thread (which runs from top to bottom). In fact, the traditional “weaving plan” is essentially a matrix of black and white gridded squares.

Viewed in this way, woven textiles present an interesting opportunity for the creation of art/craft that incorporates generative design since the weaving-plan-as-matrix can be algorithmically generated using cellular automata, stochastic processes, reaction-diffusion equations, or any number of other mathematical or computational schemes that generate or modify two dimensional binary arrays.

However, two significant difficulties arise when an artist attempts to move from an abstract, generative textile design to a physically woven object. Both difficulties are problems of production. The first difficulty is that most traditional floor looms are not capable of weaving generative designs without extensive, time-consuming, manual intervention by the artist. This defeats the primary purpose of the loom as a machine to automate many of the processes involved in the manufacture of woven textiles. Certainly, there do exist mechanistically advanced looms, known as Jacquard looms, which are capable of producing any possible weaving pattern, but these looms are expensive, are typically controlled by proprietary software, and are not very accessible to the average weaver.

A second, more fundamental, problem exists, however, in that a sturdy and well made woven object can only be produced if the underlying design conforms to basic principles of textile production. That is to say, a weaving design that looks good on the screen will, nevertheless, be a failure if it results in loose threads, or long stretches in which the weft is disconnected from the warp. Hence, a good generative textile design must always defer to the physical realities of the medium.

A number of other artists and researchers have explored generative design for textile production. For example, a team from the Carnegie Mellon Textiles Lab have explored using computer vision and collaborative editing [1], as well as gamification and real-time feedback [2], to produce generatively designed textiles. Researchers at the ATLAS Institute at UC Boulder have explored how materials, data, and humans collaborate to produce “personal data narratives” using woven artifacts crafted from personal data [3]. Miles Visman discusses the “space between randomness and order” that emerges when random processes are incorporated into proscribed weaving patterns [4].

From an early 20th century perspective, the Bauhaus School in Germany (1919-1933) was at the leading edge of textile design, asserting a modern perspective on combining fine art, craft, and commercially viable production. Two seminal weavers working at the Bauhaus Dessau Weaving Workshop, Gunta Stolzl and Anni Albers, incorporated the generative qualities of the newly acquired Jacquard looms into their textile designs (Figures 1 and 2). The Jacquard looms offered a means to actualize their weaving drafts and mock-ups into a degree of exactitude and complexity that previous hand looms could not achieve.



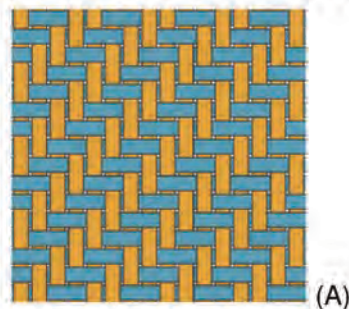
Figure 1: *Design for Jacquard Weaving, Gouache, Anni Albers.*



Figure 2: (A) *5 Choirs, Jacquard weaving, Gunta Stolzl.*

orthogonally to each other. Vertically oriented threads are referred to as the warp, whereas horizontally oriented threads are referred to as the weft. These two kinds of threads often have different properties (color, material, thickness, etc.) in so-called weft-face textiles, which are those in which the warp threads are not visible in the final piece. Rugs, carpets, and tapestries are often woven in a weft-faced manner where all the visible design elements are provided by the weft and the warp serves only to provide structure to the weaving. In any case, all the discussion in this paper applies equally to both weft-faced textiles as well as so-called balanced weavings in which both the warp and weft are visible in the final piece.

Shown in Figure 3A is a depiction of a woven textile. The structure of the piece is determined solely by the particular manner in which the weft (blue) is woven into the warp (orange). In this example, each weft thread alternately passes over two warp threads, then under the next two, and so on and the particular manner in which this is done is staggered. (This particular pattern is called a 2-2 twill.)



(A)

Textiles as Matrices

Traditionally woven textiles consist of two sets of interwoven threads oriented

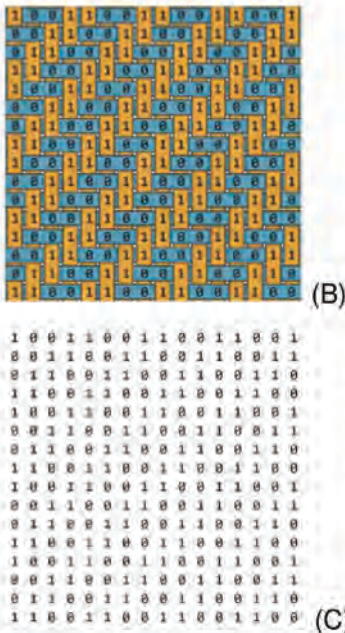


Figure 3: Weaving plan as a binary matrix.

At each location where a weft thread crosses a warp thread we can record either a 0 (if the weft passes over the warp) or a 1 (if the weft passes under the warp) (Figure 3B). After discarding the weaving itself we are left with a binary matrix (Figure 3C) that records all the structural information of the weaving. In this manner, any textile has a corresponding binary matrix and the textile itself can be completely reproduced directly from the information in the matrix (provided we neglect superficial aspects like thread color, for instance). Hence, to generate a textile, we need only generate a binary matrix.

Generative Textile Design

There are many mathematical/computational ways of generating binary matrices. Probably the

most well known are cellular automata which are systems that use simple rules to generate complex patterns. For example, John Conway's "Game of Life" [5] produces a time series of binary matrices in which the state (0 or 1) of any particular entry at time $t+1$ is determined – according to a simple function – by the states of its 8 nearest neighbors at time t . This particular cellular automata is famous for resulting in complex patterns from random starting seeds. However, nearly all such patterns are unsuitable as a basis for a woven textile since they would invariably result in a very poorly made final product.

More suitable patterns can be produced using other cellular automata, however. For example, cellular automata that have been used to simulate various patterns found in that natural world (e.g., lizard skin [6, 7], snail shells [8]) can also be made to serve as the basis for textile designs. In Figure 4 we show a weaving plan based on a cellular automata that has been used to reproduce patterns found in the shells of cone snails. The algorithm is simple and uses the values in one row to determine the values in the next row: the entry $a(i+1, j)$ in the $(i+1)$ st row and j th column is determined by the sum $a(i, j-1) + a(i, j+1)$ of the entries in the previous row that are immediately to the left and right where the sum is taken modulo two (that is to say, $1+1=0$). This method of generating a binary matrix is closely related to Pascal's triangle. Nevertheless, while this design is somewhat suitable for a weaving plan, it would need to be modified to avoid long stretches in which the weft is not interwoven with the warp.

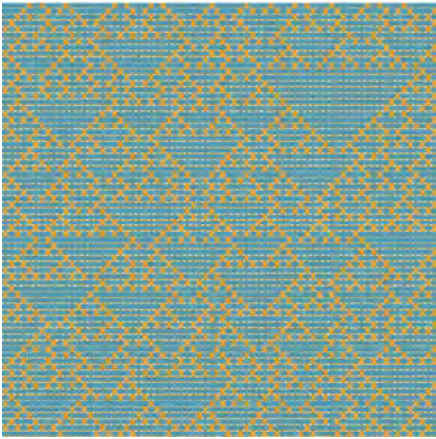


Figure 4: A weaving plan based on a simple cellular automata with a random seed.

Rather than designing weaving plans from scratch using numerical algorithms, a different approach would be to start with a traditional weaving design, expressed as a cellular automata, and modify it in a generative way. We describe one example of such a design below.

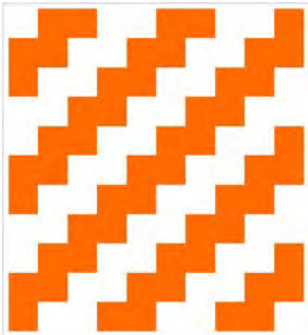
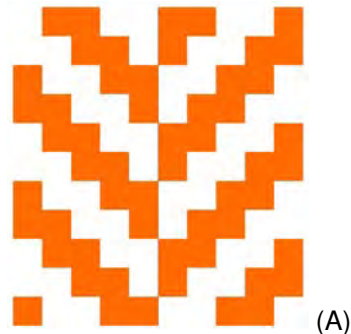


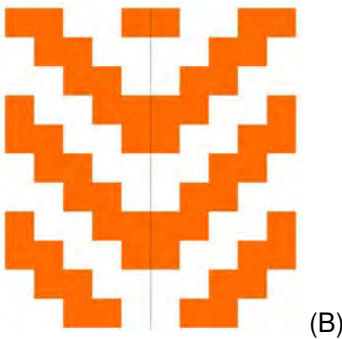
Figure 5: A standard 2-2 (left) twill pattern.

A weaving plan for 2-2 twill can be described as a binary matrix with entries $a(i, j)$ in which the first row is defined as 001100110011... and the entry $a(i+1, j)$ in row $i+1$ is determined by the entry $a(i, j+1)$ immediately above

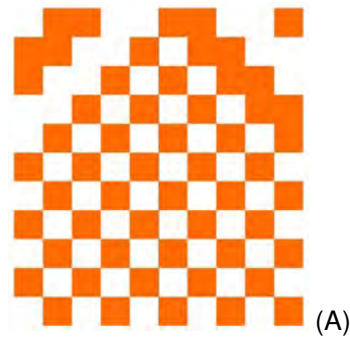
and to its right. See Figure 5. Of course, there is an analogous definition for a 2-2 twill that moves to the right instead of the left. In this case we would define the entry $a(i+1, j)$ to be equal to the entry $a(i, j-1)$ immediately above and to its left.

Given this simple algorithm for a standard twill, one could then ask what would happen if this weaving pattern were disrupted in simple, yet random ways. For example, after a certain number of rows, a column could be chosen at random and the direction of the twill (left or right) could be changed on one side of the column. For example, suppose a 2-2 twill moves to the left. We choose a random column and decide that to the left side of this column the twill direction will reverse and move to the right. We now have a twill design in which there is a convergence about the selected column and this convergent pattern will depend on which particular column was randomly chosen. See Figure 6.





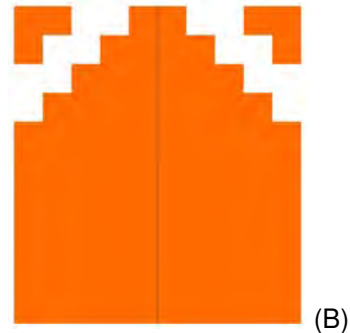
(B)



(A)

Figure 6: Two converging 2-2 twill patterns.

On the other hand, rather than have the twill patterns converge about a column, we could choose to have them diverge as in Figure 7. Immediately, we see a problem, however, in that with a diverging twill we can obtain a weaving pattern in which there is a large area in which the weft is disconnected from the warp. Since this would yield a poor quality weaving, we must correct for this possibility.



(B)

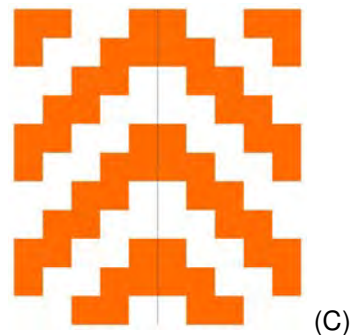
One way to do this is to correct each row as it is generated. For instance, we could decide that if a sequence of five consecutive entries

$$a(i, j-2), a(i, j-1), a(i, j), a(i, j+1), a(i, j+2)$$

all have the same value (either all 0 or all 1), then we flip the entry in the (i, j) position:

$$a(i, j) = 1 - a(i, j)$$

Doing this yields a weaving pattern in which all weft threads are woven into the warp with a spacing of no more than 4 warp threads apart.



(C)

Figure 7: Diverging twill patterns. The middle pattern would yield a poor quality textile and has been corrected in the pattern on the right by disallowing arrangements in which five consecutive entries are identical.

We can see from Figures 6 and 7 that this simple disruption to a 2-2 twill will result in both converging and diverging twill patterns as well as plain weave (Figure 7A).

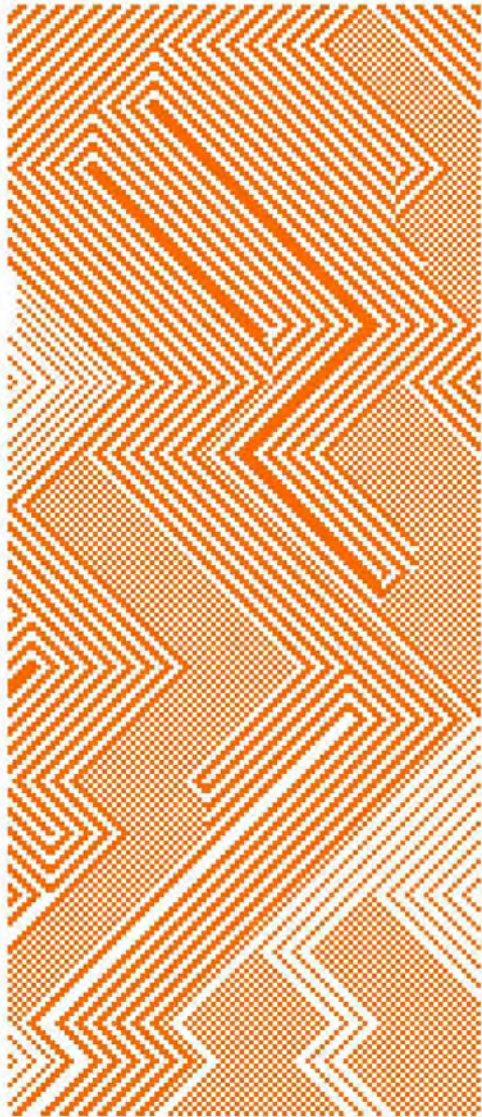


Figure 8. A generative weaving design that incorporates random switching between left and right twill 2-2 patterns.

In fact, other patterns such as 2-1 and 3-1 twills as well as irregular twill patterns like skip and pointed twills will emerge as the process repeats and columns are chosen at random intervals. In Figure 8

we show a weaving plan generated by this “disrupted twill” algorithm that consists of 100 warp threads and approximately 240 weft threads.

In construction algorithms of this sort, special consideration has to be given to the edges of the design where boundary conditions must be imposed. In the previous example, we approach this issue by using “ghost points” whose values are determined as copies of specific values in the actual row. This is similar to how boundary conditions are often imposed when using finite difference methods to find numerical solutions to partial differential equations [9].

Looms for Generatively Designed Textiles

Looms are machines that automate many of the physical operations required to produce woven cloth. The most essential of these operations are (a) maintenance of uniform tension on the warp and (b) separation of the warp to produce a shed to allow the insertion of the weft. Most looms accomplish the first operation using two horizontal beams: the warp beam, located at the back of the loom, around which all the warp threads are wound, and the cloth beam, at the front of the loom, that takes up the textile as it is woven. The warp is stretched between these two beams and tension is typically maintained using ratcheting mechanisms. This operation of providing uniform tension to the warp, while essential for well-woven fabric, is the easiest to achieve.

The second operation – separating the warp to allow the insertion of the weft – is a more mechanically complex operation. Most looms accomplish this operation

using heddles, which are strings or wires that hang vertically in the middle of the loom and which have a small hole through which a single warp thread is passed. These heddles are then variously raised or lowered in different combinations to produce the shed. A number of mechanisms have been designed to facilitate this operation resulting in a variety of loom types.

Typical floor looms use a number of shafts, which are wooden frames that hang vertically and which hold the heddles between their upper and lower members. When an entire shaft is raised, then all of the heddles on this shaft are raised along with it. Hence, one shaft can control any number of heddles, but all the heddles on a given shaft move in unison. To achieve different weaving patterns, then, a loom must have more than one shaft and these shafts must be raised in different combinations; the more shafts, the more weaving patterns are possible. On traditional floor looms, these shaft combinations are achieved using treddles: foot pedals that are tied to the shafts in such a manner that pressing down on one treadle actuates one particular combination of the shafts.

In general, if a loom has n shafts, then it is capable of producing 2^n patterns. This is seen by observing that each shaft can be in one of two positions (up or down) and that the position of any one shaft is independent of the others. However, many of these shaft combinations are not very useful for the weaver. For example, the combination in which all shafts are down (or all up) is useless since it doesn't produce a viable shed. In addition, even if a loom has many shafts (e.g., 8 shafts which give a maximum of 256 shaft combinations) only a small fraction of these combinations can be actualized by a

traditional floor loom since each combination requires a treadle and there is only so much space for treadles. As a result, traditional floor looms are inadequate for weaving generative textile designs.

Some looms that use shafts are actually capable of producing all of their possible shaft combinations. For example, Dobby looms utilize a mechanism that allows any shaft combination to be actualized using a single treadle. Looms of this type have been used to weave generative designs. For example, Visman [4] used a 24 shaft, computer-controlled Dobby loom to weave generative designs inspired by random tilings. A 24 shaft Dobby loom can produce a maximum of 16,777,216 weaving patterns. While this might seem like a lot, it is insufficient for producing most generative designs. For instance, in the previous section we described a simple generative design that requires more than $4^{(m/3)}$ different weaving patterns where m is the number of warp threads. For even a coarsely woven textile – like a 40 inch wide rug woven at 4 EPI – this minimum number of combinations exceeds 9 quadrillion. Hence, in order to weave generative designs, a loom is required that is capable of producing a very large number of weaving patterns.

Jacquard Loom

Developed in France in the mid 18th century and patented by Joseph Jacquard in 1804, the Jacquard machine is a mechanism that allows a loom to actuate its warp in any possible pattern. Early Jacquard looms used a complex mechanism of pins and levers controlled by a series of punched cards. Modern Jacquard looms typically use solenoids that are controlled by a computer.

Because Jacquard looms allow any possible weaving pattern to be realized, they are an excellent choice for a weaver who wants to produce complex patterns.

Commercial Jacquard looms are available (e.g., the Jaq3G produced by AVL and the TC2 produced by Digital Weaving Norway), but their price makes them mostly out of reach to the average weaver. A number of different academic efforts have investigated the problem of building lower cost Jacquard-style looms. For example, Ilan Moyer designed and built a desktop loom capable of controlling 24 heddles using electromagnets [10]. Similarly, a team of researchers at Carnegie Mellon Textiles Lab designed and built a low-cost Jacquard loom capable of controlling 40 heddles [1]. M. Benitez and her team from Kent State began a project in 2010 to design a Jacquard loom using muscle wire selectors [11]. While interesting as proofs of concept, the limited resolution of these looms means they are not suited to producing the kinds of textiles that most weavers seek to produce.

We have designed and built a Jacquard loom using low cost components that is capable of weaving full sized textiles at a relatively high resolution (see photo in Figure 9). The heddles of our loom are raised and lowered using off-the-shelf servo motors controlled using an Arduino microcontroller and a chain of very cheap PCA9685 16-channel servo controller boards. Up to 64 different boards can be addressed by a single Arduino and each board controls 16 individual servos. Hence, our loom is capable of independently controlling up to 1024 heddles.

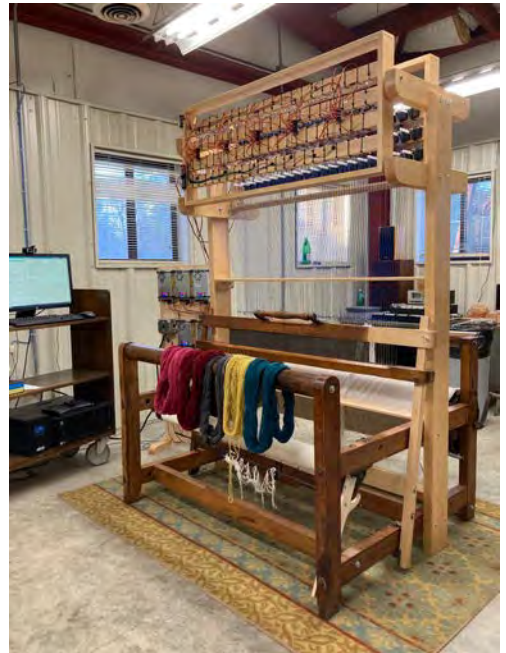


Figure 9: Jacquard style loom built by the authors. The loom is equipped to control 160-320 heddles and can be expanded to control up to 1024 heddles. The loom base is a 100 year old two shaft rug loom built by Reed Loom Co. Photo by J. Nilan (2023).

We have built our loom using an old Reed Loom Co. Weaver's Friend loom as a base to control warp tension and spacing, beating, and cloth take-up. This loom is approximately 100 years old and was acquired for less than \$300. The servos are mounted in frames of 80 servos each that are suspended above the loom and which raise and lower the servos in a rising shed style action. More or fewer frames can be added to the loom as needed based on the resolution of the textile to be woven. For our application, we have chosen to produce rugs which require a relatively small number of heddles (between 4 and 8 per inch of weaving width). Hence, the loom we have built, as it currently sits, is

equipped to control 160 heddles, which equates to a 40 inch weaving width at 4 warp ends per inch.

Software to control the heddles is written in the open source Arduino programming language. It receives instructions in the form of binary strings (representing the arrangement of each row of the binary matrix weaving design) over its serial port. These strings are parsed to control the action of the servos. As for software to create and store the weaving design as well as communicate with the Arduino, we have chosen to use Mathematica, although almost any “scientific programming” software package could be used instead. For instance, both R and Matlab allow communication via the serial port.

Discussion

Woven textiles featured prominently in the history of art and craft. Rugs and carpets, in particular, have a long history of artistic production, practical application, and cultural significance across nearly every culture and geographic region, both ancient and modern. Looms aid in the creation of woven textiles by both maintaining warp tension and spacing, facilitating the beating of the weft, and most importantly, by creating a shed for the weaver to pass the weft through the warp to facilitate the weaving in various patterns.

Until relatively recently, the patterns available to a weaver were limited by the mechanisms employed by their loom in creating a shed (e.g., the number of shafts available) or else constrained by the time it would take to manually weave complex patterns on looms that could not encode these patterns automatically.

Since the invention of the Jacquard loom, however, the ability for weavers to weave complex patterns (indeed, ANY pattern) is unconstrained. While this has led many weavers to exercise a greater control over their weaving patterns, we are interested in the possibilities this brings for artists to relinquish control over their designs by incorporating principles of generative design into their textiles. While several artists have explored this idea, we think there are a lot of discoveries left to be made. We stress, though, that generative design in textile production should always keep in mind the reality of the medium. In this paper, we describe one approach to generative textile design that can result in interesting and well woven textiles.

We have also described a relatively inexpensive method for converting a traditional floor loom to a Jacquard style loom using arrays of servo motors. Though we do not discuss it in this paper, one idea we are excited to explore further is the possibility of digital shaft switching. Shaft switching is a simple mechanism developed by Peter Collingwood [12] that allows a relatively coarse resolution, pixelated block weave pattern to be encoded on a normal 4-shaft counter-march loom using an array of levers. Our Jacquard loom design could be adapted to build a digital shaft switching device using servo motors. This would represent a middle ground between a fully realized Jacquard loom and a traditional floor loom and would allow the weaving of generatively designed textiles without significant expense.

Lastly, we note that while the focus in this paper has been on the abstract structure of textile design, there are many other equally, if not more important considerations in textile design that

determine the overall quality of the finished piece. Many of these considerations relate to the properties of the materials used to produce the textile as a physical object. For example, the yarn used for both warp and weft; the balance of the weave; the color of the yarn and how this color is achieved in the dyeing process; color interactions such as color subtraction and illusionistic space; all of these material considerations affect the final piece in essential ways. We are particularly excited to explore how these material choices and other considerations can be made to work harmoniously with the underlying textile structure.

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Dialogue between Body and Sound through Multimodal Interaction

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Abstract

This paper explores the interdisciplinary field of "*Corpo Sonoro Expandido*" (CSE) - "Extension of Body Movement with Sound", which investigates the interplay between sound, movement, and technology in mixed reality. It adopts a multifaceted approach, weaving together Art and Science to examine the convergence of dance and music concepts through a rhizomatic lens. This, understood as a complex communicative process that spawns novel organizational models on multiple scales, akin to networks. This paper builds upon our previous works, where we explored multimodal interactions [1]–[4]. The research is structured along two axes: "Expanded Sound Body" analyzes bodily movement's relationship with sound using bio-signal technology, while the second one "Existential Cycles" focuses on art creativity within composition and improvisation in music and dance. This article emphasizes the second axis, presenting a study with potential for integration into arts education programs and multimodal artistic presentations. Our goal is to orchestrate collaborative efforts that bridge gaps between dance, music, and computing languages using technological tools in real and virtual spaces. Thus, enabling the emergence of new artistic expressions. Our improvisation approach is rooted in concepts such as chain reactions and synergy, fostering engagement across distanced and in-person cycles of creative exercises. We developed improvisation cycles with dancers and musicians for testing the computational framework as a dynamic stage system where an interplay of sounds, movements, and images unfolds. Shortly, our research comprises a fabric of interactive experiences underpinned by

the fundamental principles of chain reactions and synergy. The ongoing study integrates two generative computational systems. One system processes image and movement data, generating clouds of dots by mapping each dancer's coordination and acceleration data from sensors. With this process, similar to previous literature [5], we use Kinect sensors to track dancers' movements, creating real-time interactive digital scenarios where each cloud of dots represents the joints of a dancer's body with their respective 3D coordinates.

1. Introduction

In this paper, we present creative multimodal investigations in mixed reality that have been developed as open systems. These investigations are aligned with the research project "*Corpo Sonoro Expandido* (CSE): expanded spaces between sound, movement and technology in mixed reality" at the Universidade Estadual de Campinas' Instituto de Artes and Núcleo Interdisciplinar de Comunicação Sonora (NICS) - Brazil. The project is funded by the São Paulo Research Foundation (FAPESP) through the LINCAR 2022 call. This call sought projects that blend theoretical, methodological, and conceptual approaches from diverse disciplines, aiming for transdisciplinary objectives. The (CSE) project aims to connect researchers interested in exploring the intersections of sound, movement, and technology in mixed reality environments. There is interest on the part of researchers to deepen the methodologies explored with a view to creating a creative HUB (Hybrid Sound and Movement Multimodal Interaction Study Laboratory (LabMotif) with the aim of expanding multimodal creative

research to be applied in different areas in the educational, health and artistic areas. In the (CSE) scope part of the research we investigate methods or paths for creation in multimodality in mixed reality and which we call “existential cycles”. Existential cycles are based on the concept of expanded presence and interactivity [2][3] where we seek to study the convergent and divergent dynamics between the sound, computational and body movement fields in a mixed environment such as an expanded, open, dynamic and networked space. In this sense, the improvisatory and compositional exercise in multimodality and interactivity are the ways to emerge existing cycles as an expanded presence in new systems and interactive models, thus expanding new realities to the poetic and artistic aesthetic field. In the sphere of multimodal creation, the assumption is that the interaction of an agent or group of agents with an immersive space, using various interactive devices, indicates how these processes affect their poetic behavior and the meaning that is constructed by them. The notion of interaction that bases our work goes beyond analytical dimensions alone, and will be linked to several perceptual modalities. The interactive narrative is seen as the result of processes, specifically from the interaction with all agents that participate in the experience [6] This approach incorporates the concept of Creative Empowerment as outlined in Partesotti et al. (2018) [7] and is grounded in the paradigm of Embodied Cognition. The idea that being extended is a property of a cognitive process if it is partially constituted by extrabodily processes [8] implies that the subject is not only embedded but also extended within the environment. Therefore, our research is based on the premise that the

interaction between agents and the immersive space is crucial for understanding the development of poetic behavior and the construction of meaning in multimodal creation.

2. Methodology

Within an interdisciplinary performance setting encompassing composition, improvisation, and visual creation (e.g., video dance or generative computer graphics), each component can be executed concurrently or sequentially, depending on the artistic vision and the technical configuration in place. In this regard, our methodology integrates generative computational systems to architect a unified framework that harmonizes diverse data modalities. At its core, this framework relies on widely used computer graphics and mathematical representations. The process initiates by capturing a depth map of the dancer's actions, complemented by acceleration data collected from embedded sensors. These combined inputs are harnessed to generate point clouds [9], which, importantly, are not static depictions but dynamic, multi-dimensional arrays of discrete points. Each point within the array is defined by its unique (X, Y, Z) spatial coordinates and a temporal coordinate, collectively forming a digital representation that maps the intricacies of the dancer's movements.

Our system operates at the intersection of movement and sound, with a focus on creating a sonic database using a technique known as granular and concatenative synthesis [10][11] This method involves the generation of an array of points, each sharing a common representation, primarily based on pre-recorded piano and saxophone sounds. Our ultimate aim is to develop a

versatile tool that facilitates interdisciplinary artistic and creative dialog, allowing for the simultaneous manipulation of sound, movement, and visuals. This enables an improvisational synergy between dancers, musicians, and live visual artists.

In recent experiments, we have adopted a distributed approach, where dancers and musicians initially engage with our tool. This collaborative effort is geared toward building a consistent database of sound and movement data. The repository created in this process serves as the backbone of our system, ensuring smooth interactions and coherent improvisational exchanges. Consequently, the database becomes an indispensable resource, enabling performers to access, manipulate, and repurpose stored information seamlessly. We have achieved this through the utilization of software tools like TouchDesigner and Max/MSP, particularly leveraging the CataRT system [10] (Interactive Corpus-based Concatenative Synthesis) within the MuBu external. Here is a brief description of how we are using those tools to record, process, and combine sound, movement, and visuals:

TouchDesigner for Visual Processing: TouchDesigner is a node-based visual programming language, ideally suited for creating real-time interactive multimedia content. In the context of capturing movement, TouchDesigner can interface with depth cameras or other motion sensors to generate visual representations, such as the point cloud mentioned earlier. These visuals can be manipulated in real-time, responding to the data inputs from the dancer's movements.

Max/MSP and CataRT for Sound Processing:

Max/MSP is a visual programming language designed for music and multimedia applications. Within Max, the CataRT package allows for real-time sound manipulation through concatenative synthesis. This method involves dividing audio into small segments called "grains," which can be recombined to create unique textures like sound clouds and masses with varying densities and frequency ranges. CataRT takes this a step further by analyzing and organizing sound grains in a multi-dimensional space based on audio descriptors such as pitch, loudness, and other timbral qualities.

Combining Movement and Sound: The process of recording movement and sound separately, and integrating them interactively in a performance involves several steps:

1. Recording the Movement:

- Movement data is captured using sensors or cameras and then fed into TouchDesigner.
- TouchDesigner interprets this data to create corresponding visual elements, such as point clouds.
- These visuals can be manipulated and transformed in real time, resulting in a dynamic visual output.

2. Recording the Sound:

- Sound is recorded using microphones or electronic instruments and is input into Max/MSP.
- CataRT analyzes the sounds by breaking them into grains and

categorizing the grains in a phase-space graphic.

- These grains can be triggered and manipulated in real time through a graphical interface.

3.Synchronization and Interaction:

- Real-time data from TouchDesigner can be sent to Max/MSP using the OSC protocol.
- The movement data can influence the playback and processing of sound grains in CataRT. For example, the position of a dancer's arm might control the pitch of the sound grains being played or even which grains are played.
- Conversely, the sound processing can also impact the visuals, creating a bi-directional interactive system.

4.Database and Retrieval:

- All interactions, movements, and sound grains can be stored in a database for later retrieval.
- This data can be accessed during live performances to recall specific movements or sounds, enabling performers to layer past and present interactions.

2.1 Existencial Cycle - I

Our initial focus was on the computational exploration of the body, aiming to deepen its relationship with images and technology. This involved conducting experiments and explorations within the domains of imagery, computation, technology, and the virtual universe. Our goal was to establish

unique connections between images and movement, physicality and virtuality. One of our primary objectives has been to investigate the body through its digitized and technologically mediated representation, all with the intention of highlighting creative possibilities within this context. Ultimately, we sought to expand this data into the realm of poetry, incorporating elements such as sound, music, augmented reality, real-time virtual creation, and various other forms of knowledge.

The Point clouds consist of the imagery and three-dimensional representation, taking into account the three axes of acceleration (x, y, and z), depicting the physicality of the body from an infinity of points. The grouping of these points facilitates the remodeling of the body's surface through the use of 3D technologies.

The geometric " Point clouds " model is the most basic representation obtained directly by the 3D scanner. Each point, which forms the point cloud, is represented by its Cartesian coordinates (x, y, and z) and one or more attributes associated with it. [...] This feature can be used for many purposes, such as measuring, three-dimensional visualization, "rendering", animation, but mainly for the creation of basic geometric models to be reworked in CAD tools, and more recently in BIM tools [12] Translated to English by the authors

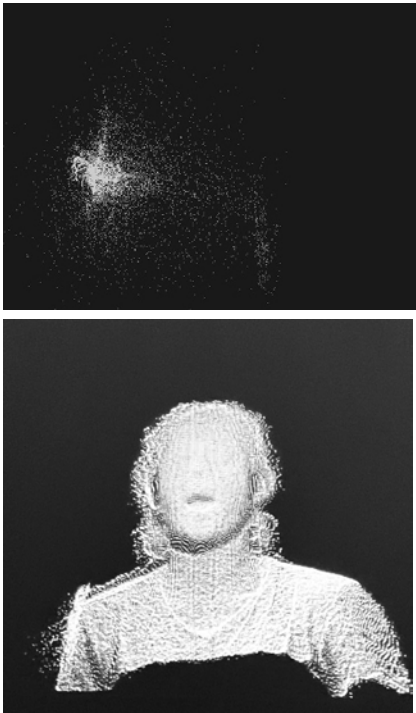


Image 1 - Representations of movement (acceleration) with the Point Cloud model Source: (CSE) Database

Our exploration of the Point clouds method was greatly enhanced by the use of specialized devices and software. To create and explore the Point clouds version of the body, This process involved the creation of a programming code within TouchDesigner, which received image data from a motion sensor (the Kinect). The Kinect was responsible for capturing and encoding body movements, mapping them, and transforming them into data. This data was then processed by the software to generate a set of points that could be organized based on different qualities, quantities, and organic characteristics, allowing us to provoke new experiences for both the body and images.

Kinect captures images much like a regular video camera but has the advantage of being sensor-based, allowing it to operate independently of light conditions. It reads depth of bodies through its camera, enabling the tracking and encoding of movement within its capture range. These images are then used in TouchDesigner's programming.

These experiments resulted in varied relationships between bodies, movement, and Point clouds, with differences in aesthetics and intensities. We explored different textures and arrangements for the points, including spacing, quantity, and coloration. The relationship between Point clouds and movement over time was also investigated, affecting the perception of the captured actions. Various velocities, from slow to fast and fragmented, altered the intent of body actions and provided different interpretations for observers. As Amornin (2009, p.1) [13] comments, dance's integration of digital technological interfaces introduces novel dimensions of complexity, impacting everything from education to live performances. This fusion challenges the fragility of the human body, both in the physical realm of space and time and in the virtual domain, opening doors to a future filled with unexplored creative potential in the world of dance.



Image 2 - Experiments with the point cloud in the creation of screendance

Source: (CSE) database

3. Discussion

How can we effectively translate creative experiments rooted in technological research into the realm of poetics? When discussing creative processes in the arts, we invariably invoke the concept of sensitivity as a fundamental prerequisite, enabling us to harmonize the subjectivities of diverse artists collaborating in tandem. This harmonization, in turn, serves as a conduit to trans-subjectivity, fostering a bridge that transcends individual subjectivity and promotes collective creative engagement.

Saying that we have abandoned intellectual habits is an easy statement, but how can we fulfill it? There it is, for a rationalist, a small daily drama, a kind of unfolding of thought that, however partial its object may be — a simple image — still has a great psychic repercussion. But this small drama of culture, this drama that is at the simple level of a new image, contains the entire paradox of a phenomenology of imagination: how can an image that is sometimes very singular appear as a concentration of the entire psyche? [14], translated to english by the authors

The work in screendance production combines dance and images, with a strong emphasis on visuality in both the aesthetics and the creative process. It acknowledges that the body and movement are influenced by this new exploratory environment. The screen-generated images differ from those seen in person, as they are born from computer processes. These distorted images give rise to alternative realities, offering distinct interpretations and temporal dimensions for the movement and the overall dramaturgical concept of the work.

In the singularity of dance, the unique visual expressions emanating from the moving body not only mirror the dancers' inner states but do so dynamically. It's as if every fleeting moment of a dance movement freezes a snapshot of these inner states, rendering them "capturable." Therefore, in our endeavor to capture these movements through sensors, we are not in opposition to the creative process in dance or music; rather, we are enhancing and augmenting these artistic activities.

How the singular and ephemeral event that is the appearance of a singular poetic image can react — without any preparation — on other souls, on other hearts despite all the obstacles of

common sense, despite all wise thoughts, happy for their immobility? It then seemed to us that this trans-subjectivity of the image could not be understood in its essence only through the habits of objective references. Only phenomenology — that is, taking into account the departure of the image from an individual consciousness — can help us restore the subjectivity of images and measure the breadth, strength, and meaning of the image's trans-subjectivity [14], translated to English by the authors

Touching souls using all possible means: body, sound, sensors. Sensitive sound-body, in its full and most honest expansion; a body that is singular in its investigation of movement at the same time it is plural when working in partnership. This would be one of the philosophical bases of our investigations, a basis that allows us the transcendence so desired in our times.

3. Conclusions

Through studies and experiments conducted using the Point clouds method, we explored various representations of the body and movement within the realm of imagery and technology. These investigations led to encounters between organic and artificial elements, blurring the lines between the real and the virtual.

Through technological mediation, the experiment allowed these elements to take on unique structural, expressive, and poetic qualities that transcended their traditional physical presence. This journey into technology opens up new dimensions and meanings, expanding the horizons of body and dance exploration. It also facilitates the development of diverse relationships between digital media and movement, between images

and their observers, and between bodies, dance, and technology.

The investigations at the intersection of body, movement, technology, sound, and imagery in this exploratory environment unveil diverse opportunities for artistic creation. The representation of the moving body through Point clouds can be harnessed for live performances, multimedia installations, multilingual productions, interactive experiences, telematics, hybrid forms, and virtual languages, among numerous other possibilities. Our group ventured into this realm through screendance, aiming to craft a narrative that explores the poetic potential of these images, ultimately serving as an inspiration for various other creative endeavors

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Generative Development of Visual Narratives Evoking Memories of Spring

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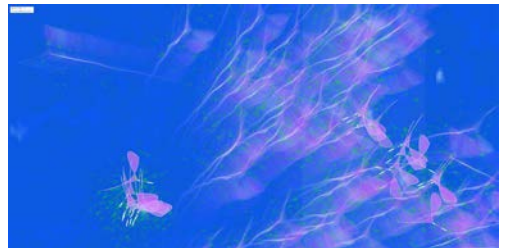
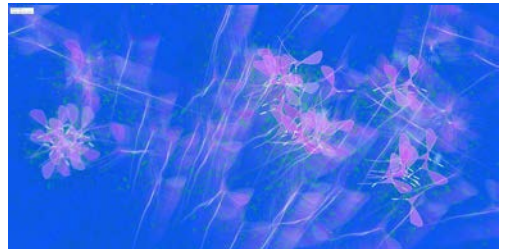
visual design and evolve the behavior of the agents towards generating form aggregates organized in compositions that are aesthetically meaningful. The focus of the paper is placed on the artistic development process and on the aesthetic analysis of the final product in relation to specific affordances of the computational medium developed by the artist.

Abstract

This paper presents artwork created with a computational system for visual creativity (SCVC) created by the artist for the development of an evolving visual narrative space evoking experiences and memories of spring. A spring-like pictorial space is created by a population of autonomous agents that move and act within the confines of an artificial life environment. Chances of survival in this environment are rooted in the agents' ability to change their behavior in response environmental constraints. The constraints are based on principles of

Impressions of Spring – Generative Art Series (artworks)

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Abstract

“Impressions of Spring” is an art series created with a computational system developed by the artist. The system is mainly based on genetic algorithms that evolve the motion of a population of drawing agents to generate visual compositions that create a pictorial space suggestive of spring. While the shapes and visual motifs employed by the system are abstract, the aggregated forms and their organization in visual designs are meant to synthesize the feeling of freshness, openness, delicate revival, and hope that always seem to characterize the spirit of spring.

Politics and Generative Adversarial Network tools The Aesthetics of Renewable Energy Sources Landscapes

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Abstract

Landscape contains specific elements that, by their very nature, resist complete perception or direct experience. How can we grasp the essence of nature, environment and space? These are things that we're constantly being trained to look for. In other words, social presence is a necessary requirement for the concept of designed landscape to exist, since it is the result of the active participation of people in its configuration and production. In that sense, the spatial qualities, the meanings and experience that landscape design entails, constitute a broad and extensive field of research. Contemporary, construction of renewable energy sources infrastructure has been

of great importance. However, the impact of these infrastructures on landscape itself is often ignored. Therefore, the need for a more holistic approach that takes into account these specific changes and new conditions is imperative. In this sense, the proposed poster refers to an alternative approach through the concept of digital variation and the ways it can be applied to architectural and landscape design, focusing on renewable energy sources infrastructures. In particular, it has as its starting point the concept of aesthetics, and through it the politics that is directly applied to a wide spectrum of social actions. This is attributed to the forms of aesthetic distribution which throughout the ages follow specific principles and contexts. To that extend, contemporary use of digital tools broadens the social influence spectrum of landscape aesthetics. Therefore, they present a new meaning of political influence to a two-dimensional or three-dimensional surface as more interactive means of story-telling of a potential scenario, which should, or could, take place. In particular, by deploying artificial intelligence (AI) tools, especially Generative Adversarial Network (GAN) software such as Midjourney or Dall-e, it is possible to identify patterns and shape policies

directly related to an under-configuration landscape. Mainly, in a possible aforementioned landscape situation, we could achieve more sustainable energy development that takes into account a plethora of landscape changes, suggesting, as a result, the most preferable one and ensure an environmentally friendly future. In conclusion, additionally to conventional methods, the perspective of use of G.A.N. A.I. tools by experts involved in landscape design will be used, in order to discuss the concept of digital variation through which it is argued as a preferable way to achieve effective policies for the landscape both in terms of use of various renewable energy infrastructures, and also in general.

1. Introduction

Landscape contains specific elements that, by their very nature, resist complete perception or direct experience. How can we grasp the essence of nature, environment and space? These are things that we're constantly being trained to look for. Simultaneously, we could argue that any attempt to define the concept of landscape, lasted several years; in a sense that is still difficult to be satisfied with a single and only definition that supports a specific interpretation of 'landscape', which is closer to reality. Tim Ingold, in its book titled: 'The perception of the Environment', two decades ago, was already commenting on how we perceive our environment, in an attempt to study human-beings and their perception to their surroundings. To further understand this correlation, he notes about the concept of landscape: 'The landscape is not 'space'. In the

landscape, the distance between two places is experienced as a bodily movement from one place to the other, and the gradually changing vistas along the route. It is as though, I could direct the movements of my body within it, like a counter on a board, so that to say 'I am here' is not to point from somewhere to my surroundings, but to point from nowhere to the position on the board where my body happens to be. And whereas actual journeys are made through a landscape, the board on which all potential journeys may be plotted is equivalent to space' and 'The landscape is not 'nature'. Of course, nature can mean many things. The world of nature, it is often said, is what lies 'out there'. All kinds of entities are supposed to exist out there, but not you and me. We live 'in here', in the intersubjective space marked out by our mental representations. Application of this logic forces an insistent dualism, between object and subject, the material and the ideal, operational, and cognised, 'etic' and 'emic' [3].

In other words, Tim Ingold recognizes and evaluates 'landscape,' as most spatial formations, that it can be understood as a complex structure. Hence, it is clearly distinguished from other similar but more unambiguous concepts such as nature, environment, or space. It is approached as a multitude of social, ecological, and cultural interdependencies that accommodate the fundamental relationships between people and their environment. Human presence is an inescapable condition since the landscape acquires existence only and/or because of human beings, not only as passive spectators but mainly as active participants in its configuration

and production. Especially, for landscape architecture, it cannot be treated as a phenomenon of unequivocal analysis because landscape is 'shaped' because of different and various spatial and cultural interpretations. Or in other words, though landscape planning and design meanings and ideas of a culture could be spatially expressed. Thus, the design process can be seen as the production tool of the appropriated places which are inextricably linked to the quality of environment experience and well-being.

Furthermore, activities that are being happening 'in landscape' are endless. Perhaps because the human individuals being the participants 'in it', make up this complex structure where landscape is never completed: neither built, nor plain, nor urban, nor natural, etc. It is constantly under configuration. That might be the reason the conventional dichotomy between natural and built (or man-made) parameters of landscape is, to a point, so problematic. And so, these ever dynamic and changing relationships dictate the catalytic value of temporality for the perception, planning and production of landscape [8].

2. Landscapes of Renewable Energy Sources

Nowadays, the contemporary emphasis on building infrastructure for renewable energy sources (RES) is of utmost significance. To elaborate further, the adoption of RES technologies, with a particular focus on wind and photovoltaic systems, plays a critical role in the European strategy to combat climate change. The EU's 2030 climate and energy framework outlines three primary goals for 2030: achieving a minimum 40% reduction in greenhouse gas

emissions compared to 1990 levels, ensuring a minimum 32% contribution from renewable energy, and aiming for a minimum 32.5% enhancement in energy efficiency [13].

While the transition to RES not only reduces greenhouse gas emissions but also creates new cultural landscapes, the impact of these infrastructures on landscapes 'themselves' is often ignored. Over the past two decades, the rapid growth of renewable energy (RE) has led to substantial demands for land use, resulting in significant alterations to the visual appearance of landscapes. Because the design of RE equipment is typically predetermined by industrial standards and cannot easily conform to architectural traditions and local landscape characteristics, RE projects have faced substantial criticism for their industrialization of natural landscapes. This critique is most pronounced in the case of wind turbines but also extends to photovoltaic solar panels and, to a lesser extent, hydroelectric projects. Furthermore, according to the European Landscape Convention, which defines landscape as 'part of the land as perceived by local residents or visitors, evolving over time due to natural forces and human activities,' the industrialization of landscapes through infrastructure can lead to negative perceptions, stemming from undesirable cultural, environmental, and aesthetic changes to the landscapes. In the context of renewable energy, the impact on landscapes has emerged as a significant source of opposition to new projects. For instance, in Europe, the conflict between RE development and landscape preservation manifests in two ways: first, public resistance to RE

projects based on landscape protection concerns, and second, the uncontrolled expansion of RE projects is anticipated to result in substantial alterations to European landscapes. Or in other words, Europe is known for its high density of scenic landscapes that often have strong ties to architectural and cultural landmarks and historical settlements. Preserving this heritage is a top priority, not only for its conservation and its connection to the cultural identity, sense of place, and quality of life of European citizens but also because of its direct connection to tourism and, consequently, economic development. This has significantly hindered the desired integration of renewable energy into the overall energy mix [4].

Based on these findings, it can be concluded that the impact of renewable energy infrastructure on the landscape varies, depending on the type of energy source and specific landscape characteristics. Strategies such as vegetation screening and careful design can help minimize the visual impact. However, further research and a holistic approach are needed to develop optimal strategies for mitigating landscape impacts. For example, in Greece renewable energy sources and landscape aesthetics have gained attention in recent years. The implementation of successful, local-scale innovation projects and initiatives in Greek islands like Kythnos, Ikaria, Sifnos, Tilos, Agios Efstratios, Crete, and Chalki have contributed to positive social change and sustainable development [5].

3. Concept of Digital Variation

Therefore, the need for a more comprehensive approach that considers these specific changes and new conditions is imperative. That argument could imply shifting our thinking towards the concept of variations [6-14]. In literature, it can be argued that architecture occupies a unique yet dynamic position among three major disciplines: science, art and philosophy. Or, in other words, architecture is an act that deals with variability more than all other disciplines [2]. Similarly, as architecture does, landscape architecture is the field of study and design of landscape and therefore it certifies the history and any perspectives of variability that depend on socio-economic, environmental and cultural conditions. It is especially important to understand any dynamic landscape tension to variation, the dynamics of those specific changes and the resulting 'genius loci' that will be displayed, highlighted, prevented or transformed. Architecture and in our case, landscape architecture, are now approaching variations through a somewhat more philosophical perspective. To that extend, any designed result (variation) could be presented as a theoretical tool for architecture and landscape architecture to manage encountered diversity. They (variations) would be the means that architects use to control the turbulent variability which, in any case, they cope with. That could be depicted, to an applied level, in the use of most contemporary digital architectural design tools which include various technologies (e.g., artificial intelligence, machine learning, virtual and augmented reality) [7-9].

Variation is obviously neither a new concept nor a new technique in relation to creative processes. In music, for example, it has existed as a production technique since, at least, the 17th century. It refers to the process where an original musical theme is serially mutated through a process where some parameters remain constant while others are modified. These parameters can concern a series of elements, such as melody, rhythm, harmony, color, orchestration, etc. In other words, we are already talking about a multiparametric, dynamic process that creates a particularly extensive range of possibilities. Despite all changes and transformations, however, through variations a common basis remains. We could say that this is a more general idea defined and described by the variations: *'[...] music with a central theme, accompanied by and based on a harmony, produces its material through a, as I call it, developing variation. This means that the variation of the elements of a basic unit produces all the thematic forms which provide fluency, contrasts, variety, logic and unity on the one hand, and character, mood, expression and all necessary differentiation on the other – thus working out the idea of the piece'* [12].

So, we can imagine a similar process in the context of design – and it is likely that we can easily find similar examples from the history of architecture, even when the term 'variation' does not appear. However, digital media brings about a notable change in what Schoenberg describes: the possibility of exhausting possibilities. That is, the possibility of creating an exhaustive process where the products are so many that they, now,

exceed the goals that planning can have as a process of producing specific answers and begins to approach a research process. The result of this condition, where the boundaries between design and research begin to disappear, is that the 'idea of the track' to which Schoenberg refers in the above passage also loses its importance. There is no longer a predetermined idea behind the process of variation to give it meaning, but instead meaning is constantly emerging – and therefore changeable – through the difference of variations and their exhaustive nature [8].

The result of this process is not a set of generated architectural elements based on selected parameterizable constant variables but, in fact, a set of theoretical but at the same time, operational tools for architecture and design. On the one hand, for the management of the resulting multiplicity and, on the other, for the understanding and perception of the landscape as a political space, in a novel approach to the aesthetics of the landscape, not in its traditional sense, but as practices of sharing the sensible [10-11].

4. Landscape Aesthetics as an idea for Landscape Politics

It could be said that its starting point is the concept of aesthetics, and through it the politics that is directly applied to a wide spectrum of social actions. This is attributed to the forms of aesthetic distribution which throughout the ages follow specific principles and contexts. To that extend, contemporary use of digital tools broadens the social influence spectrum of landscape aesthetics. Therefore, they present a new meaning of political influence to a two-dimensional

or three-dimensional surface as more interactive means of storytelling of a potential scenario, which should, or could, take place.

To be more specific, aesthetics is about experiencing the world; it includes sensing but also sense-making, transforming the ability to sense into knowledge and/or meaning [1]. To describe the concept of aesthetics, Rancière introduces a definition about 'partition of sensible' to relate 'aesthetics of politics' to 'politics of aesthetics'. In particular, he notes that 'partition of sensible' is: 'The system of apparent facts of sensory perception which reveals at the same time both the existence of something common and the divisions which define, within this system, the respective parts and positions. Therefore, it determines both a shared common element and exclusive shares. This division of parts and places is based on a distribution of spaces, times and forms of activity which determines the very way in which this something in common offers itself for participation as well as the way in which each has a stake in this distribution.'

In this way, aesthetics focuses on the distribution of the visible and the invisible, time and space. Politics, in turn, focuses on people who should speak visible and the characteristics of space and time. Thus, in the Rancierian approach, politics have an aesthetic dimension, which does not succumb to the aestheticism of beauty, but are related to perception and sensible. The two concepts are not considered in parallel or defined together but are two forms of sharing. The dual meaning of that definition allows the concept of aesthetics to be subsumed into that of

politics, as the latter includes collective practices and experiences that consist of concerns about human-beings perception (e.g., about environmental and landscape contemporary issues) and social participation. In other words, they could at ease considered as purely political concepts. At the same time, they are related, by their nature, to the perceptible and in this way define aesthetics. Simultaneously, politics, in the sense of aesthetics, have their own ones because they determine what can be said and seen [10].

Therefore, in this dual relationship the most critical point is the distinction of the various forms of social visibility and organization, and by extension their common points. That could be read as more than a Platonic approach of democracy, as a contemporary, efficient, sustainable and political right approach for modern societies to take landscape design and configuration decisions under the condition that all those who are formally equal in a society hierarchy, but often cannot participate, have an ability to politically participate in the public realm so as to be heard or could be heard. Thus, partition of sensible is not only a concept that serves to describe the social reality of the partitions that are realized, but, moreover, it is a key concept through that architectural and landscape design suggest a spectrum of political possibilities to emerge sociopolitical practices or to create unequal conditions. That approach is closer to a Kantian conception of aesthetics where a priori forms of the perceptible, such as space and time, determine the way that various situations occur. Space and time, however, are political issues, since their division is

what determines the political participation of human beings. Thus, aesthetics is political, and politics is aesthetics, because they are both practices that challenge any historical, environmental or cultural factor that delimit social act and participation [10]. In terms of landscape perception, aesthetics is based on the introduction of the concept of 'partition of the sensible' that pushes us to rethink our way of environmental perception and by extension of landscape design and configuration. The aesthetic practices which create new paradigms and might set new standards can only happen in a form of dichotomy. That dichotomy constitutes the constructive conflict between perception and understanding of the sensible. It adds the element of disagreement by highlighting that an (landscape) issue is not always clear, but instead constitutes a conflictual relationship involving space and time within any apparent consensus. Furthermore, as it will be argued below, it is important to mention that the aforementioned practices, more than ever before, are easily provided by digital design tools and the digital variations produced because of their social use.

5. Conclusion - GAN software and Landscape Perception

More than at any other time, the need to transcribe the various technological developments, to a similar extent as it already happens in social life, in the landscape planning and design processes can be noticed in the period of the SARS-CoV-2 pandemic, 2019-2021. In other words, various technological and digital means were supposed to consist of the only, perhaps, common toolbox for the continuation of social activities. At this point of view, landscape architecture

was forced to find a new place in the new equilibrium that had been created. Thus, at that time began the first substantial discussion about the ways that would allow humanity to cope with the contemporary challenges of the landscape. Back in 1950, Turing introduces the concept of artificial intelligence in an attempt to describe future computing systems that will be able to have levels of intelligence corresponding to the human brain. Since that first definition, different definitions have been used to describe this concept. Rich and Knight, for instance, in 1990, define Artificial Intelligence as the result of the study that would allow us to create computers with the ability to complete processes, that human working on them was more efficient until then. In 2010, two decades later, Poole and Mackworth expand the aforementioned definition by adding that 'artificial intelligence is the field of study of the synthesis and analysis of computational systems that act intelligently'. Thus, leading, subsequently, to more descriptive and precise interpretations and approaches for that specific concept that place it as the engineering science that designs 'smart/intelligent' devices and complex computing programs which combine machine learning and information analysis. In this sense, we could argue that artificial intelligence is a field of computer science with wide and ever-growing applications that uses computational methods to simulate human intelligence. Also, in this definition, it is worth focusing on two key concepts which acquire particular importance: firstly, the concept of 'intelligence' and, secondly, that of the computer, not so much in the traditional

sense but more broadly in its interpretation as a 'machine' [9].

The concept of 'intelligence' refers to the set of cognitive abilities of an organism that allow it to perceive, evaluate and adapt to its environment by forming numerous relationships with it. It is inextricably linked to humans, thus constituting a basic criterion of differentiation from the rest of living organisms. However, throughout the ages there is a philosophical debate that explores both the 'exclusivity' of intelligence from humans and the possibility of transferring it to a machine, in such a way that it, finally, acts like a human brain. That could be described by a mathematic approach of the 20th century that states that any accounting approach, which can be translated into mathematical formulas, can be mechanized. In other words, if the accounting approximation could be a mathematical formula, it could just as well be performed by a machine. The first historical example that subsequently formed the background of modern computer creation is the Turing machine, made in World War II, as an attempt by the British to decipher the German Enigma machine. At the same time, 'machines' are considered all tools or means that, firstly, participate in the production of work - transmitting energy or converting it into a different form-, secondly, facilitate human work and, thirdly their usage has as a result the increase in human's work performance and efficiency. To that extend, the inception of artificial intelligence is based on a similar idea: Artificial intelligence, the scientific field that produce machines which are capable of performing in human-like ways, is not based on the

idea that a computer can function as a human brain. Instead, it stems from the fundamental assumption that the human brain functions as a computer, and thus creates the belief that computers can become complex enough to function as humans [2]. Nowadays, their mechanical structure has the flexibility to combine in numerous and separate ways. That way, results that are distinguished by their short-lived and variable character can be provided. Mainly, because every such computing system has the 'need' to evolve and change constantly trying to survive in its ever-changing environment [9].

Focusing specifically on GAN software, AI applications and tools are categorized into three levels according to their capabilities. Mainly to perform a wide range of processes, and secondly, to be able to evolve or not, finally, in a potential but virtual environment. The first level includes the palette where all modern means and tools of applied artificial intelligence. These constitute weak or limited artificial intelligence and are software with intelligence in a specialized and narrowly defined domain. Their performance, however, can be quite high-level but is limited exclusively to him. GAN software could be included in this category. In conclusion, in the possible aforementioned landscape situation, we could achieve more sustainable energy development that takes into account a plethora of landscape changes, in particular in term of landscape aesthetics, suggesting, as a result, the most preferable one and ensure an environmentally friendly future. In conclusion, additionally to conventional methods, the perspective of use of G.A.N. A.I. tools by experts

involved in landscape design will be used, in order to discuss the concept of digital variation through which it is argued as a preferable way to achieve effective policies for the landscape both in terms of use of various renewable energy infrastructures, and also in general.

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Eastern Carpets Pattern of Russian Poem “Shagane, Oh My, Shagane!..”

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The poem “Shagane, oh my, Shagane!” by the outstanding Russian poet Sergey Yesenin was dedicated to Shaganeh Taliyan, a young teacher from Batumi, with whom the poet met, in the Caucasus in December 1924.

The poem was included in the book “The Persian motifs.” There is a breath of Middle Eastern culture in these poems. Consider the structure of the poem. In our view, it is similar to the pattern of arabesques and Eastern carpets.

While reading the poem you can notice the repetition of certain lines. Let’s number the lines so that the similar lines have the same number. This repetition makes the cyclicity of the separate parts, and the entire poem.

Shagane, oh my, Shagane!..

I

1. **Shagane, oh my, Shagane!**
2. **Because I from the north, whether that,**
3. **I am ready to tell to you a field,**
4. **About a wavy rye under the moon.**

1. Shagane, oh my, Shagane.

II

2. **Because I from the north, whether that,**
5. That the moon there is huger a hundred times,
6. How Shiraz was beautiful so,
7. It is not better than the Ryazan expanses.

2. Because I from the north, whether that.

III

3. **I am ready to tell to you a field,**
8. These hair took I from a rye,
9. If you want, on a finger knit –
10. I at all do not feel a pain.

3. I am ready to tell to you a field.

IV

4. **About a wavy rye under the moon**
11. On curls mine you guess.
12. Darling, do joke, smile,
13. Do not awake only a memory in me

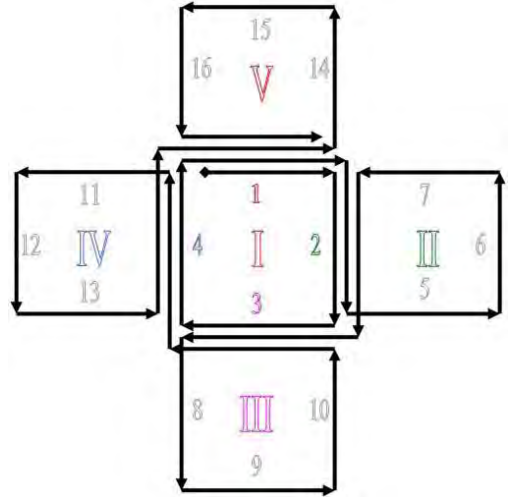
4. About a wavy rye under the moon.

V

1. **Shagane, oh my, Shagane!**
14. There, in the north, the girl too,
15. It is terribly similar to you,
16. Perhaps she thinks about me...

1. Shagane, oh my, Shagane.

My geometric interpretation looks like this:



Pict. 1. Shagane's labyrinth. Arabic numerals indicate lines. Latin numbers indicate verses.

Сергей Есенин.

Шаганэ ты моя, Шаганэ!.. (Rus)

I

1. Шаганэ ты моя, Шаганэ.
2. Потому, что я с севера, что ли,
3. Я готов рассказать тебе поле,
4. Про волнистую рожь при луне.
1. Шаганэ ты моя, Шаганэ.

II

2. Потому, что я с севера, что ли,
5. Что луна там огромней в сто раз,
6. Как бы ни был красив Шираз,
7. Он не лучше рязанских раздолий.
2. Потому, что я с севера, что ли.

III

3. Я готов рассказать тебе поле,
8. Эти волосы взял я у ржи,
9. Если хочешь, на палец вяжи –
10. Я нисколько не чувствую боли.
3. Я готов рассказать тебе поле.

IV

4. Про волнистую рожь при луне
11. По кудрям ты моим догадайся.
12. Дорогая, шути, улыбайся,
13. Не буди только память во мне
4. Про волнистую рожь при луне.

V

1. Шаганэ ты моя, Шаганэ!
14. Там, на севере, девушка тоже,
15. На тебя она страшно похожа,
16. Может, думает обо мне...
1. Шаганэ ты моя, Шаганэ.

Sergey Esenin.

Shagané, tu sei mio, Shagané!.. (It)

I

Shagané, tu sei mio, Shagané.
Perché forse vengo dal nord,
Sono pronto a raccontarti del campo,
A proposito di segale ondulata sotto la luna,
Shagané, tu sei mio, Shagané.

II

Perché forse vengo dal nord,
Che lì la luna è cento volte più grande,
Non importa quanto sia bella Shiraz,
Non è migliore delle distese di Ryazan.
Perché forse vengo dal nord,

III

Sono pronto a raccontarti del campo,
Ho preso questi capelli dalla segale,
Se vuoi, avvolgili attorno al dito
Non sento alcun dolore.
Sono pronto a raccontarti del campo,

IV

A proposito di segale ondulata sotto la luna
Puoi indovinarlo dai miei riccioli.
Tesoro, scherza, sorridi,
Basta non risvegliare il ricordo in me
A proposito di segale ondulata sotto la luna.

V

Shagané, tu sei mio, Shagané!
Lì, al nord, c'è anche una ragazza,
Ti assomiglia moltissimo Forse
sta pensando a me... Shagané,
tu sei mio, Shagané.

1924

Magnetic Sun

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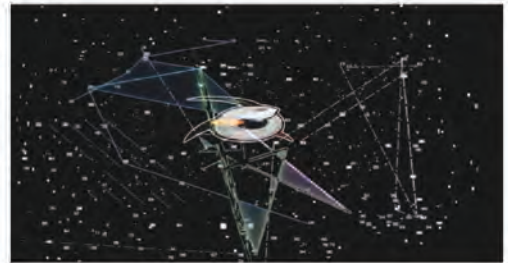
Anna Ursyn



Stu Smith



1. Magnetic Sun



Magnetic Sun

The sun drives us into its powers: real and mythological ones. It's made of plasma, which we name the fourth state of matter: gas-like where electrons and ions got separated forming a very hot mixture of charged particles. They create a magnetic field by moving, which in turn creates another effect on how they move. We associate the sun with warmth, power, and energy, and we develop myths and stories. We are drawn to it, benefit from it, if we can keep the proper distance and precautions.

Abstract

Coded Universe is juxtaposed with some spatial characters behaving according to the physical laws we are familiar with. The poem guides the audience to think about the pleasures and dangers resulting from what surrounds us.

2. References

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2.1 Notes

This work can be found on:

YouTube:

<https://youtu.be/UI4LV7A-oeQ>

vimeo.com/user137914208/

Tidal Energy and the Severn Barrage

Generative Energy Discourses

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Abstract

The aim of this paper is to critically review and question the current discourses on the Severn Barrage, Wales UK. The research highlights the generative energy mechanism of the project and questions the key objections with regard to the Barrage and other tidal-energy based projects specifications put forward for the Severn Estuary. The paper is divided into three main sections: the first attempts to review the Severn Barrage concept as potential generative tidal power solution within its historical context, the second section hopes to situate the above projects within the accompanying theoretical frameworks and the final section then hopes to locates elements within these theoretical constructs that have clearly been misread and possible direction out of this gridlock. This last section will also consider the lessons one can learn from the Rance tidal dam (1966) in Brittany, France, the first and for almost 50 years the only one of its dimension. In conclusion the paper argues that the misreading of both the Estuary's physiology and its potential conservation/preservation needs to be urgently addressed along with its inevitable incision for survival.

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1. Introduction

One major characteristic of renewable energies is that they are linked to a territory. You can extract oil, coal, and so on, somewhere, transport it, and harness that energy source anywhere else, but not so with sun, wind, or tides. Tidal energy requires very particular geomorphological and tidal conditions. Paradoxically, those “clean” energies have an obvious impact on the ecosystems they require and may alarm environmentalists. They question our relationship to “nature” (supposedly untouched and untouchable). While it is reasonable not to completely destroy ecosystems, we can discuss conservationist attitudes which reject any change, as if nature itself was not constantly changing. If we accept changes, we can imagine sustainable and integrated planning. The unavoidable link of tidal energy to a territory can become an asset in a renewed conscience of inhabitants regarding energy.



Fig. 1 The Severn Barrage proposal 2010 as presented by Hafren Power.

We would like to argue that the very definition of architectural and urban

design sensibility has made a slight shift in order to integrate the current discourses on ecological and sustainable design studies. To our understanding, the term ‘sustainable’ now intricately connects architecture and urban design studies to environmental study – both at a conceptual and structural level. This paper is an attempt to succinctly put forward the main discourses, perception and at times misconception of the factors involved in harnessing tidal energy from the Severn Estuary, Wales and further attempts a brief comparison with the Rance Barrage in France.

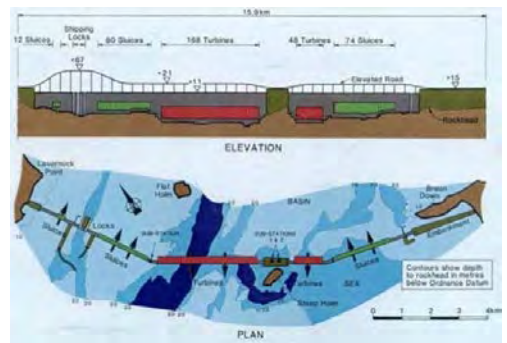


Fig. 2 Western Barrage proposal 1980 as presented by Severn Tidal Power Group (STPG)

2. Historical Context

On 10 September 2013 the House of Commons, Energy and Climate Change Committee, published a report entitled: *A Severn Barrage?: Government response to the committee's second report of the session 2013-2014: Fourth special report of session 2013-14*. The principal objection and concerns put forward in this report included, “the lack of substantial

evidence to credibly demonstrate; value for money, economic benefits, energy saving and environmental impact mitigation". [1] It is interesting to note that five years earlier on 22nd May 2008, at the Royal Academy of Engineering 2008 symposium on the Severn Barrage, the then Minister of State for Energy Mr. Malcolm Wicks MP, in his keynote lecture, had identified almost similar factors with regard to the 1980 proposed Severn Barrage scheme. According to the Minister, the proposed study had been categorized into six main areas of further research:

1. Environmental work, gathering the evidence of the impacts on biodiversity and wildlife, land and seascapes, flood management and geomorphology. ...we are looking at the geomorphology and we are looking at water quality and considering compensatory habitat issues. That is a very important feature of our environmental work. We will be looking at the issue of compensation and suggested – whether there is an environmental opportunity in linking environmental compensation measures to climate adaptation.
2. The second stream of work is about engineering and technical aspects, considering issues such as the cost, design and construction of the proposed tidal power schemes and their potential impacts on the electricity network.
3. The third stream of work is about economics, considering how a project or scheme could be financed, and looking at ownership options. We will be looking at the full range of possibilities, including the need for any government support and we have appointed PricewaterhouseCoopers to provide advice on those issues.
4. Fourth, there are the regional impacts, looking at the regional, social and economic impacts,

- including the impacts and benefits on local business.
5. The fifth stream of work is about planning and considering regulatory compliance issues, although this will come later in the process.
6. Finally, and very importantly, throughout the project communications work and engagement with interested parties and the public will be key to the successful delivery of our study. [2]

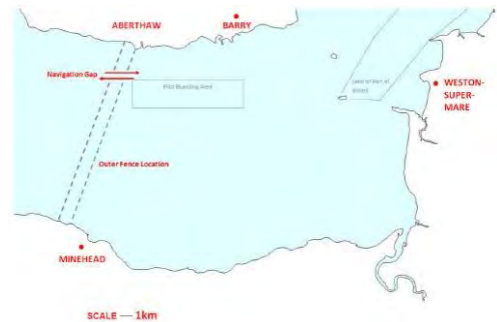


Fig. 3 Severn Tidal Fence 2010 as presented in the Severn Tidal Fence Consortium, Final Report p.11

The study was also to include a strategic environmental assessment, to ensure a detailed understanding of the estuary's environmental resource, recognizing its national, European and indeed international nature conservation significance. Given the above comprehensive list of suggestions provided by the Ministry of Energy, initially in 2008 and later again in the 2013-14 parliamentary report, this section attempts to document and critically review the Severn Barrage schemes along with alternate tidal energy based projects that have continuously been submitted for possible consideration and rejected.

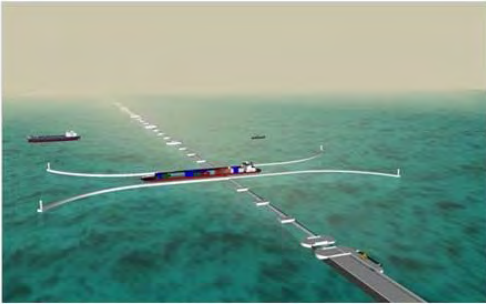


Fig. 4 Severn Tidal Power Reef 2008 as presented by the Rupert Armstrong Evans of Evans Engineering and endorsed by the new Atkins-Rolls Royce report commissioned by DECC (Department of Energy and Climate Change)

The above mentioned Parliamentary Report is directed towards the 2010 Severn Barrage proposal (Fig.1) submitted by Hafren Power, a company established in 2008 as a consortium of companies forming a tidal energy business and involved in engineering and construction to lead the promotion of the Severn Barrage. It is interesting to note that the proposal submitted took into consideration past research and studies on tidal power projects, and clearly suggested that it had based its final design strategy on one that was developed in detail by the Severn Tidal Power Group (STPG) in the late 1980s (Fig. 2). The proposal outlined that; ...whilst other technologies have been considered more recently (such as the tidal fence (Fig.3), the tidal reef (Fig.4)), this proposal is to use tried and tested technology throughout to minimize construction and subsequent operational risks and in order to secure private investment for the development. Coincidentally, this approach will allow greatest flexibility in terms of providing

the most economic solution: the balance between the revenues from the tidal power generation and the environmental enhancement measures to be provided in connection with the development. This approach realizes the first part of the proposal which is to provide a sustainable supply of 'green energy'. [3]

Given the above justification provided by the consortium of internationally acclaimed specialists and companies comprising Hafren Power in their proposal presentation, along with the fact that in the May 2008 keynote lecture by the Minister of Energy, Mr. Wicks had also announced the appointment of a consortium led by consulting firm Parsons Brinckerhoff, to manage the strategic environmental assessment [4] – it does seem a bit out of place to be informed that the 2010 Severn Barrage proposal was unable to provide “substantial evidence to credibly demonstrate; value for money, economic benefits, energy saving and environmental impact mitigation”. Furthermore given this consortium under Hafren Power was established in 2008 and included specialist academics and companies forming a tidal energy business, it can be assumed that the consortium was aware of the 2008 address given by Mr. Wicks, along with probable access to Parsons Brinckerhoff’s research led studies on management of strategic environmental assessment. It does seem extremely unlikely that a team of specialist would not take into account the relevant research and recommendations put forward by Parsons Brinckerhoff along with the six salient factors that the Minister of Energy had very clearly outlined.

in an April 2010 publication entitled: Severn Estuary Tidal Power by the National Assembly for Wales. The paper provides briefing on the current situation of tidal power development within Severn Estuary (including both lagoons and barrage proposals, Fig. 5). It furthermore provides a Welsh perspective and the views of relevant stakeholders. [5] In its final paragraph the 2010 Parliamentary report suggests that: the Government should continue to examine the energy generating potential of the Severn region in the event of Hafren Power's proposed barrage scheme not going ahead. *We therefore recommend that the Government consider how a more proactive approach to Severn resource management could stimulate growth in the marine renewables industry and drive forward tidal projects in the region.* (Paragraph 116) (10).



Fig. 7 Thomas Fulljame (1849) design for a barrage across the River Severn (Newport Museum of Art Gallery, Gwent)

This in a sense brings the whole concept of Severn Barrage back to its original stance i.e., to the 1921 'potential' Barrage proposal presented by Woodruff (Fig.6) and given the fact that there is also the reservation on the design of turbines and technologies presented in the parliamentary report, the Barrage theme is further relegated to the conceptual sketches of the Barrage as presented by

Thomas Fulljames 1849 watercolor rendering. (Fig. 7).

2. Theoretical Constructs

With its swift and high tides and its rocks and treacherous sandbanks the Severn estuary in the late 19th century was both a hazard to navigation and a formidable barrier to cross [6]. It provided both a challenge and an innovative opportunity in the engineering circles. In 1849 Thomas Fulljames (1808–1874) an architect, surveyor and civil engineer, with an in-depth knowledge of the Severn river, its tides, and its shipping, submitted a design of a barrage extending from Aust to Beachley. His design (Fig.7) incorporated a two-tier viaduct, arcaded, castellated, and turreted in the style of the 13th century. The upper level would carry a double-track railway and the lower level a carriage way. The estuary above the barrage would be formed into a lake of consistent depth, thus improving access to the canal at Sharpness, and the water level controlled by sluices in the barrage. [7] Although structurally unfeasible, the project provided theoretical underpinning for future research.

The 1921 Severn Barrage further delved on the Estuary tidal energy potential and highlighted that: ...non-interference with established shipping is a necessary element in the selection of such a site, but entirely aside from this condition, the Severn's mouth is remarkable for its natural fitness for the project. The maximum range of the spring tides at that point is 38ft., and the minimum neap range is 20ft., giving a mean range of 29ft. The width of the estuary, on the line where the Severn tunnel now carries the

tracks of the Great Western Railroad from west England to Wales is about 2.5 miles. In the center is a natural sandstone channel, of ample width and from 60 to 100 ft deep.

This convenient canal is bordered by nearly a square mile broad rocky shelves, exposed at low tide, and the banks on either side are low-lying and fairly flat. Above the tunnel line is a basin which with the tide controlled, would extend over 27 square miles, and accommodate the largest ships... the first work to be undertaken would be the construction of a reinforced-concrete dam on the rocky shelves of the river mouth, its walls extending laterally from each shore as far as the central channel, and then turning upstream along its sides and terminating in a lock, large enough to accommodate any vessel.

In the lateral parts of the wall it is the intention to hang automatic sluice gates, opening inwards when the tide presses against them, and then closing to prevent the escape of impounding water. Built into the parts of the dam paralleling the channel will be the power plant itself, equipped with a huge battery of vertical mixed-flow turbines, 10ft in diameter, the channel serving as their tail race.(Woodruff, 1921)

This proposal although very rudimentary in its detail essentially led to future feasibility studies on the Severn Barrage proposals of the 1980s and 2010.

	Cardiff-Weston	La Rance (1966)	Annapolis (1984)
Length of barrage	16.1 km	0.75 km	0.20 km
Basin area	480 km ²	22 km ²	N/A
Turbine generators	216 x 40 MW (8,640 MW)	24 x 10 MW (240 MW)	1 x 19.6MW
Runner diameter	9.0m	5.35m	7.6m (Straflo)
Average annual energy	17,000 GWh	540 GWh	<50 GWh
Sluices	166 (35,000 m ²)	6 (900 m ²)	2 (130 m ²)
Ship locks	2No 360x50 m	1	N/A
Construction period	5-10 years	6 years	

Fig. 8 Abidi (2008) Comparison with alternate tidal power schemes.

One of the probable main advances in design strategy of the 1980 and 2010 Severn Barrage proposal as compared to the earlier attempts would have been the technological feasibility. The 2010 proposal quite categorically declared that although there were other options such as the tidal reef and tidal lagoons, but the final choice of Barrage was maintained. This decision may have been partly taken by one of the specialist academic partner in the Hafren group; Prof. Roger Falconer. As according to Prof Falconer's 2008 keynote lecture, the mean tidal range of Swansea Bay lagoon is 8.5m and the energy output is 124MW pa, and in comparison, we would need 135 lagoons to give us the same power as the barrage. [4]. The 1980 Barrage proposal and its further development in the 2010 Severn Barrage proposal remains an ambitious and exceptionally complex yet it seems a practical proposition. According to the Halcrow Severn Barrage Vision report presented in October 2010; ...there are a number of benefits that would accrue from the construction of the barrage and the changed flow regime upstream; because of the general lowering of water levels upstream of the barrage (typically 0.5 to 1.0m during bb generation), the risk of flooding and thus

the need to invest in strengthening flood defences will reduce accordingly. This is apart from the ability of the barrage to manage water levels upstream. The physical, chemical and biological quality of the water upstream of the barrage will change: the suspended sediments carried by the water will reduce resulting in clearer water with the ability to support greater photosynthetic activity and thus increase the biodiversity – birds etc. These changes will also help with pathogen kill and so further help to improve water quality. [3]. This ability to improve water quality has proven to be a vital environmentally positive factor in the Sihwa Power Plant in South Korea (Fig. 9).

operate the power station with Government support through delivering an appropriate planning route and providing a stable future electricity market with incentives that will shape a sustainable vision for UK.(18) Yet the Parliamentary Report found reasonable doubt to accept this proposition, along with environmental concerns, which seem quite incomprehensible, as it does seem plausible that these aspects were taken into account by the 2010 Severn Barrage proposal. Thus within the theoretical constructs presented with regard to the proposed Severn Barrage, it does seem that there remains a series of inconsistencies and loop holes as far as its subsequent evaluations by the official panels are concerned. This clearly needs to be taken into consideration, should a future Barrage proposal is ever submitted. This paper argues that atleast theoretically speaking the task to set up a Severn Barrage does not seem to be a problem of presenting a feasible design for a very large power generating project with ample technological expertise and environmental considerations intact. It simply remains a case of misunderstood priorities and lack of concise information sharing amongst the various groups and individuals involved. There is also this added dimension of distrust amongst select stakeholders and environmentalist as far as the project implementation is concerned.

Overview	Rance (France)	Annapolis (Canada)	Jangseong (China)	Sihwa (South Korea)
Name of Plant	Rance (France)	Annapolis (Canada)	Jangseong (China)	Sihwa (South Korea)
Spring Tide (m)	13.5	8.7	8.39	8.66
Capacity (MW)	240 (10 × 24 units)	20 (20 × 1 unit)	3.2 (3.2 × 1 unit)	254 (25.4 × 10 units)
Construction Completed	1966	1964	1985	2011
Annual Power Output (MWh/year)	544	50	5	952.7
Generation Type	Double-effect type	Single-effect type	Double-effect type	Single-effect type (flood generation type)
On-Line since	1967	1964	1986	2011
Sluice Gates	6 units (15m × 10m)	2 units (9.2m × 7.3m)	5 units (3.3m × 4.2m)	8 units (15.2m × 12m)

Fig. 9 Sihwa tidal power barrage (2011) details in comparison with other tidal barrages. Source: Korea Water Resource Corporation Report

In comparison to the Sihwa and La Rance Barrage, the proposed Severn Barrage on the sole basis of its gigantic size alone remains an extremely ambitious and expensive project to take on. The proposal presented however highlighted the fact that the project could be delivered without recourse to significant input of public monies. It claimed that the private sector is willing and able to develop, implement and

3. Misreading

One of the most significant misreading of the Severn Barrage is that it will destroy or “trash our own important ecological habitats” as Greenpeace argued in support of preserving the ecosystem. According to Dr Parr, some of the most

important habitats of international significance that we have in the UK are the mudflats: the Severn, because of its large tidal range has a lot of mud. It is certainly, true that the wading birds on the Severn have led to the designations of international importance on the Severn.

Locations of some of the larger discharge consents to the Severn Estuary system. Trade consents, and miscellaneous sources of effluents, expressed as Maximum Daily Flows (value >500m³/d). From data supplied by the Environment Agency (Wales South West and Midlands Regent) NB. No distinction has been made between continuous and intermittent discharges.

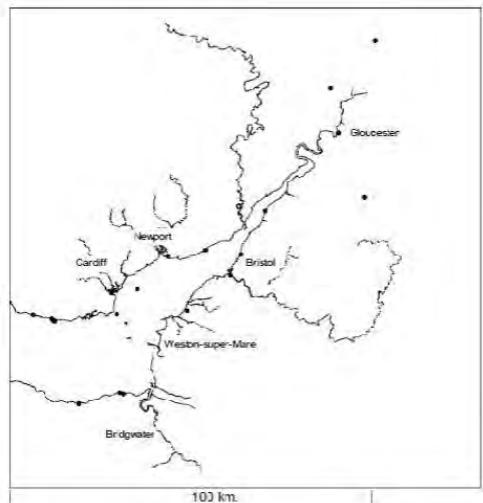
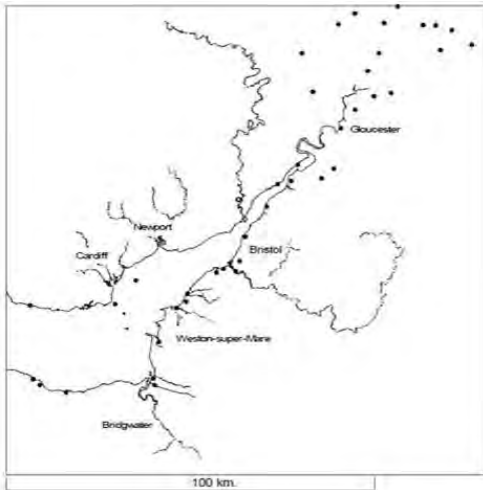


Fig 10a. Locations of some of the larger discharge consents to the Severn Estuary system. Consents for the discharge of sewage, based on Dry Weather Flow (value >1000m³/d). 10b.

The above is a valid concern as clearly a shift in the physical foundation of an international habitat so rich in composition would clearly be an unwise and irresponsible option to take on. The exceptionally detailed 2009 report entitled; the Severn Estuary/European Marine Site documents and identifies a range of external factors that are already responsible for a drastic change in the estuary's physical makeup and composition. Factors such as habitat loss due to vegetation succession, dredging and erosion, industrial pollution, changes in water quality resultant from improvements to waste water discharges and changes in recreational disturbance are suggested as priorities in any future Level 2 assessment [8]. However it should be noted that , birds are more frequent and more numerous in place where they are openly protected. If we exchange 10 hectares of wild habitat with birds with 5 hectares of specially designated reservation for birds the population increase. (there is significant increase) There are two well known preserves in Ille et Villaine (careil and sougéal) which may be taken as examples.

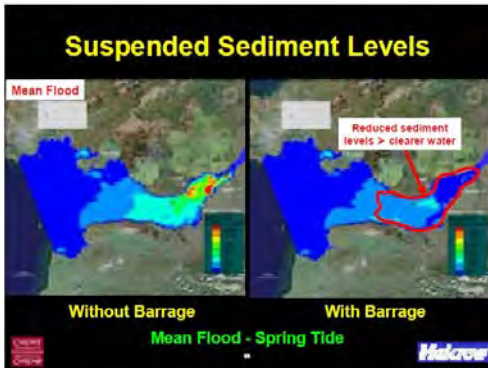


Fig. 11 Falconer (2008) Suspended sediment levels study.

A detailed study conducted on the Rance Barrage provides concrete evidence that most species pass through the turbines without much damage, because of the large size and low speed of the turbines, this is further discussed below. Passageway for the ships is a pure design consideration which we would like to argue can be resolved with alternate design solutions presented and put forward if the project is ever given the chance to move to the level of implementation. The proposed size of the proposed Severn barrage at 16.1km remains the most debated part of the project. Peter kydd (2014) in his review believes that; ...Its size also has some other implications. For example, the basin area that a Severn Barrage would impound is much greater than is required for power generation, and it is the basin area that suffers many of the adverse environmental impacts, with loss of habitats and changes to the natural environment. This is one of the reasons why land-connected lagoons outperform barrages in terms of environmental impacts, as the basin area of a lagoon is tuned to its energy output and is therefore

smaller for a given power output when compared with a barrage. [9] In an equally compelling argument Falconer (2008) had suggested that a comparative analysis between a proposed lagoon off Swansea Bay as compared to a barrage would mean; The mean tidal range is 8.5m and the energy output is 124 MWh pa and, if we equate like for like, we would need 135 lagoons to give us the same power as the barrage.[4] Irrespective of whether the Severn estuary is given a single large incision in the form of a barrage or several smaller ones as suggested in alternate proposals such as Swansea Bay Tidal Lagoon [10], an 11 km² impoundment generating 400 GWh/yr which is currently going through the UK planning regime, and the Stepping Stones Tidal Lagoon [11], impounding 18 km² and generating 1,200 GWh/yr, which is at conceptual design stage. The misreading of both the Estuary's physiology and its potential conservation/preservation needs to be urgently addressed along with its inevitable incision for survival.

4. Rule and the Model: Rance Barrage

The Rance tidal power station was constructed in 1966 and was the world's first tidal station, and for 45 years the largest one in the world. This tidal barrage was not the first project imagined in Brittany, and one could draw a history parallel to that of the Severn barrage, the only difference being that the Rance barrage has become a reality. The Rance Barrage was intended to be an initial step and a principal model that was to assist in the development of a much larger tidal energy project - which would have encompassed the Mont-Saint Michel bay.

Unfortunately this ambitious project was abandoned at the outset, with the result that, in France, after this initial fundamentally successful project was constructed, tidal energy was not further taken into consideration for the next few decades. In comparison, the Severn Estuary has continued to remain a principal source of interest and various proposed tidal energy projects and studies have been reviewed and discussed on paper, with little to no prospect of a clear direction on defining the next step



Fig. 12 Rance Tidal-Power Barrage (François Lang 2014)

Given the concerns discussed above with regard to the Severn Barrage, and the lack of a follow up project in France after the successful construction of the Rance Barrage, was the Rance Barrage such a disaster that the tidal energy fundamentally deserved to be rejected? After almost 50 years the Rance Barrage remains both productive and functional, and will remain to be so for many more decades. It furnishes electricity for the equivalent of a 200000 inhabitants town, such a town as Rennes, for instance, which is not far. It has taken 20 years to account for the construction costs (which was high because it was a prototype), but

now it needs only light maintenance and, obviously, its “fuel” (the tidal energy) is free. Its electricity production costs are then now much lower than those of nuclear production costs, without the (geopolitical) problems of uranium extraction and transport, of the possibility of Fukushima like accidents, and the jeopardizing of the future implied by waste disposal and facility decommissioning.

5. Environmental Concerns

There were not much environmental concerns at the time the Rance barrage was constructed, and obviously draining the estuary for two years was a mistake. There were no ecological studies conducted at the time, and we can assume that if such a drastic step was proposed today, it would be strongly questioned and most probably rejected. Having said that, however it should be noted that after almost fifty years later, the appraisal of the consequences of the barrage is not so catastrophic, though some claim the contrary (*“L'écosystème estuarien a disparu”* - the estuarine ecosystem has vanished. [12], which remains an exaggeration and, one that was addressed in a very comprehensive study carried out in the 1996 by a group of naturalists, who unanimously concluded that: ...In spite of artificial variations of tidal range, very different from natural fluctuations of tide, and although an ideal compromise between energy production and biological needs of marine flora and fauna is hard to achieve, animal and vegetal populations of the ria have found a new equilibrium, and keep a remarkable richness able to give pleasure to any naturalist. [13]. Obviously, the estuarine ecosystem is

different from the one which would have been present if the Rance barrage had not been built, but to determine whether it would have been preserved as is seems both a myth and a misconception given the constant deteriorating condition of the Severn Estuary without any major intervention attempted. There are several factors that intervene and affect the ecosystem within estuaries, and perhaps a comparison with other sites should be attempted for a better understanding of this complex and controversial issue – except that no two sites are exactly alike. One of the main objection put forward is the case of silting. However it should be noted here that the role of the barrage in primarily facilitating silting remains questionable, as it is also a problem in estuaries with no tidal barrage. But to our understanding perhaps what is more important is to question why silting is considered “bad”. It was objectively bad (for business) when relatively large (and economically necessary) boats had to attain ports far inside estuaries. But people have forgotten that at that time there was silting too, and that measures were taken

(dredges) in order to pull out silt and clear channels for navigation. From an ecological point of view, silting remains a natural process, the normal evolution of that type of estuary. Whatever the ecological consequences of the Rance barrage, it remains both an excellent rule and a model for further understanding the merits and complexity of tidal energy generating process and its ecological repercussions. Given the issues and concerns put forward by the studies conducted to support the Severn tidal energy projects, perhaps the most clear indication to study the Rance Barrage is to clarify the many misconceptions

present, such as safe fish passage through the Barrage. At the Rance most fish species are able to pass through the turbines with ease, due to the (large) size and (low) speed of those turbines. Detailed studies have been conducted to support this claim. [13-14]

6. Discussion of tidal energy concerning sustainable planning

Our research team on the project “Estuaries and energy of tides” is currently working on this issue. One of the topics of this research is an “integrated” vision of energy harnessing. If we compare ancient tidal mills (very numerous in the Rance estuary), we notice that while silting was increased in their basins, silt was dragged and used as soil-enrichment product. With the barrage, silting was not taken into account by the engineers, and is only viewed as a problem (for navigation, landscape “beauty”, and even the functioning of the barrage) which should be solved by technical solutions. Why not consider the production of silt, and its extraction, as a resource to be used? Another example of this narrow way of thinking is the road on the barrage, which turned out to be a crucial asset and allows to economize oil and time when going from Saint-Malo to Dinard, but was not at first envisaged by engineers who were only thinking in terms of electricity production.

7. Sustainable architecture and urban design and the role of tidal energy

A tidal powerplant, as any structure, has to be conceived, designed and built, and is not only the result of engineering. For instance, the French architect Louis Arretche (1905-1991) the architect whom amongst other realisations was in charge of the reconstruction of Saint-Malo, designed the built structures around the Rance barrage, which are now registered as landmarks of 20th century architecture. That it is not specific to renewable energy. After all, Claude Parent (b. 1923), an influential architect, known for his “fonction oblique” theory and beautiful drawings, also designed nuclear powerplants.



Fig. 13. Beauchet tidal mill in the Rance estuary (François Lang 2014)

8. Generative Design Mechanism

We believe, a tidal energy settlement should be envisaged as a generative design mechanism that defines a territory – one which can contribute to our understanding of architecture as part of a greater whole, and not as some insertion inside a context supposedly untouched. Without being too nostalgic, we want to learn from the past – the tidal mills, and how they were part of the landscape.

These buildings (the mill, plus sometimes the miller's house) are apparently very similar to other vernacular architecture used for agriculture, though technically, in order to resist greater constraints, their foundations and the construction of the dyke of the basin required much skill. Why not imagine such settlements for the 21st century, in which housing, working, and energy production (tidal but also from other renewable sources) would be designed intricately with the landscape, where the interaction with the landscape would not be thought only in terms of aesthetics, but essentially functional and sustainable, i.e., organically, in the same way as many of the sites that we now find remarkable in ways that they have been conceived.

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Impossible figures of Yturralde: A challenge in 3D

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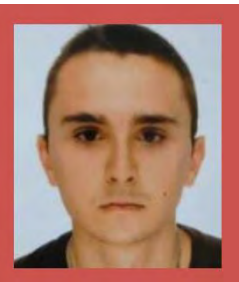
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Abstract

Jose Maria Yturralde, Spanish National Prize of Fine Arts in 2020, was one of the pioneers generating art with computers, as early as late 60's of last century. Some of his famous paintings of impossible and computable forms were produced in the late 60's and early 70's.

Our challenge is to make possible in 3D some of his 2D impossible figures. In order to do so, we transform the apparent planar surfaces into hypars (hyperbolic paraboloids) so that, from the suitable point of view, they look exactly like the original 2D paintings, but once they are rotated it is possible to appreciate the 3D realisation of the impossible figures.



Figura imposible (Yturralde, 1972)

The software that we use in order to generate the 3D forms is Wolfram Mathematica. This software allows us to parametrize the different hypars that compose the forms, produce a virtual representation of them that can be rotated dynamically, or they can be exported to several formats that can be used in CAD software, or be sent to a 3D printer.

The hypars are doubly ruled surfaces, that is, for any point of the surface two different lines pass that are contained in the surface. With Wolfram Mathematica we use a macro for ruled surfaces which is easily adapted by only changing the four ordered points that define each hypar. The main challenge for each form is locate adequately each quadruple of points associated to each hypar face of the figure.



Figura imposible (Yturralde, 1971)

In the format of virtual Poster, we show all the details and mathematical formulas to produce our 3D realisations of the selected paintings of Yturralde. The way they are generated allow the reproduction of the forms with other software which includes the possibility of parametric generation.

This work was produced under the advice of Professor Alfred Peris, from the Universitat Politècnica de València (Spain). We want to thank Professor Yturralde too, for all the interesting discussions and help that we received during the selection and 3D generation of his impossible figures.

To generate this impossible 3D figure, we have defined the following command in Mathematica:

RuledSurface[alpha_, beta_] :=

ParametricPlot3D[{v*alpha[u][[1]] + (1 - v)*beta[u][[1]],

v*alpha[u][[2]] + (1 - v)*beta[u][[2]],

$v \cdot \alpha[u][[3]] + (1 - v) \cdot \beta[u][[3]]$, $\{u, 0, 1\}$, $\{v, 0, 1\}$,

Mesh -> None, PlotStyle -> Blue]

Subsequently, we have selected key points to define the lines alpha and beta, and with them, we have defined the corresponding surfaces. This was done with the surfaces that are above the diagonal formed by the lower-left vertex and the upper-right vertex.

Finally, we have defined the rotation matrix:

$A := \{\{\text{Cos}[\text{Pi}], \text{Sin}[\text{Pi}], 0\}, \{-\text{Sin}[\text{Pi}], \text{Cos}[\text{Pi}], 0\}, \{0, 0, 1\}\}$

To find the symmetric part and combine them to achieve the 3D figure.



Celestial Objects and Aeriform Masses: Resident Space Object Near-atmospheric Edge Reconnaissance

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Portrait of first author, Grace Grothaus.

Abstract

The new era of space exploration and its accompanying technologies have illuminated the farthest reaches of the cosmos, inspiring visions of future terraforming and celestial elevation. Space is now increasingly seen as the

forefront of curiosity-driven research, with boundaries continuously expanding thanks to increasingly powerful telescopes and image reading machines that catalogue and identify new discoveries. The intensive foraging through the firmament promises new and profound revelations about us and the universes around us. As we continue to venture into the celestial realm, navigating the passage of light through the darkness and blending myth with technology, it is inevitable to question: have we, in our quests and ambitions, become celestial objects ourselves?

"Celestial Objects and Aeriform Masses" is a generative animation, drawing from data collected by researchers across various disciplines and backgrounds in York Nanosatellite Lab, led by Regina

Lee.[1] Acknowledging that access to space is not uniform, this artwork is part of a broader project directed by Joel Ong in collaboration with her lab that examines the involvement of marginalized groups, including Indigenous, racialized, gendered individuals, and those often considered amateurs by Western science.[2]

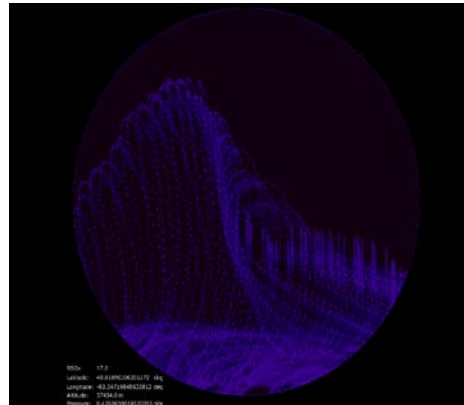
Utilizing data from a Resident Space Object Near-Atmospheric Edge Reconnaissance (RSOnar) nanosatellite, specifically latitude, longitude, altitude, and pressure, Grothaus has created an endlessly generative visualization in TouchDesigner that evolves through periodic rhythms: depicting atmospheric swirls and evolving colours in the form of a lunar scape. Iterative loops are formed out of a time-based generative algorithm with motion influenced by RSONar latitude and longitude readings, while altitude and pressure determine the values of red and blue channels combined to reveal shifting hues of purple. Inspired by astronomers' use of redshift and blueshift to gauge an object's distance from Earth, Grothaus attempts a poetic interpretation of the Space Situational Awareness (SSA) data collection and astronomy's reliance on analysis of the colour shifts in charting the universe's expansion which she views as deriving from an unending quest to learn more about matter's collective origins.[3]

1. "Celestial Objects and Aeriform Masses"

"Celestial Objects and Aeriform Masses" is a generative animation created by Grace Grothaus, drawing from generative time-based algorithms and the dataset

collected by Lee's Nanosatellite Research Laboratory via the Resident Space Object Near-Atmospheric Edge Reconnaissance (RSOnar) CubeSat aboard CSA Stratos balloon Gondola.[4]

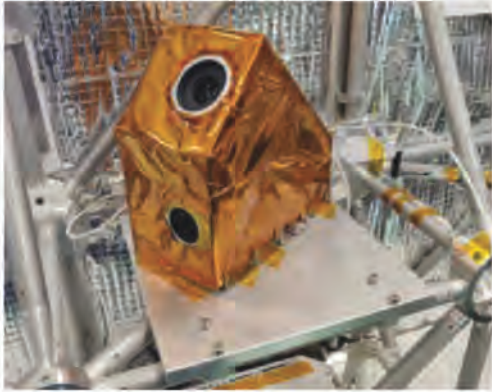
Grothaus' generative visualization designed in software TouchDesigner, evolves circularly through periodic rhythms, referencing atmospheric currents and a lunar landscape. Taking an approach of interpretation rather than direct analysis of the dataset, Grothaus is interested in the data's poetic possibilities and manifold expressions.[5]



"Celestial Objects and Aeriform Masses," 2023 by Grace Grothaus.

In the artwork, iterative loops arise from a time-based generative algorithm influenced by RSONar latitude and longitude readings, while altitude and pressure determine the values of red and blue channels, inspired by astronomers' use of redshift and blueshift. Grothaus attempts a poetic interpretation of the Space Situational Awareness (SSA) data collection and astronomy's reliance on analysis of colour shifts in star field images for the purpose of charting the universe's expansion. She views this line

of scientific inquiry as deriving from humanity's unending quest to learn more about matter's collective origins.

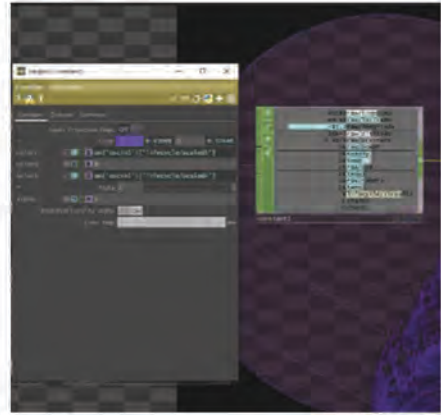


RSOnar Payload Integrated onto Stratospheric Balloon Gondola.

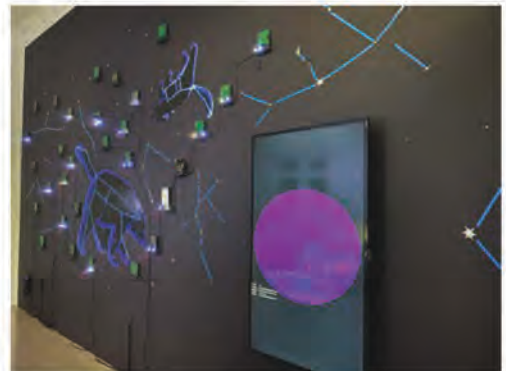
Grothaus is a computational media artist whose research questions center around planetary concerns in relation to the present global climate crisis and speculative futures. She endeavours to make invisible phenomena experienceable for the purpose of revitalizing our connections to our environments, engaging participants in thinking of holistic ecologies, and interrogating questions about the supposed separation of planetary built and natural systems. Frequently collaborative, Grace works with scientists, engineers, musicians and other visual and performing artists, as she has done in the development of this generative artwork.

"Celestial Objects and Aeriform Masses," was created using Derivative's software TouchDesigner for its strengths in realtime rendering, evolving out of her longer trajectory of work in visualization of environmental data and early

experiments in Processing and Isadora.[6]



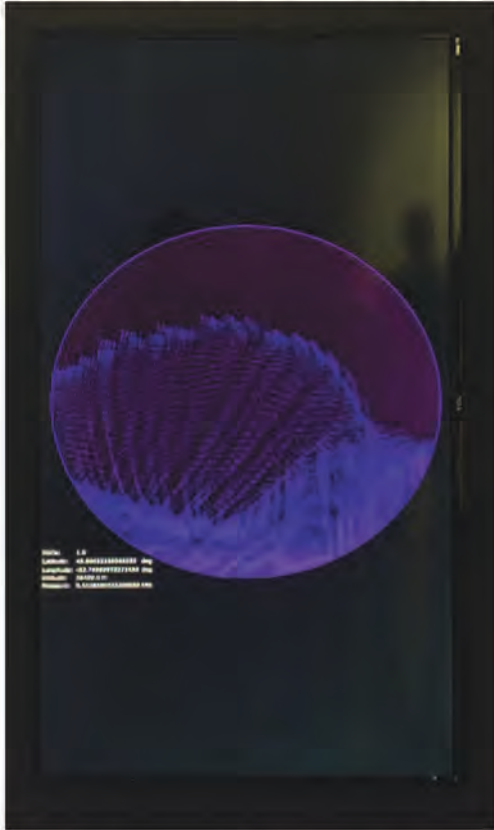
Altitude and pressure data in Touch Designer.



The Life Cycle of Celestial Objects Pt. 2 installation view.

The artwork, premiered at Western University's McIntosh Gallery as part of The Life Cycle of Celestial Objects Pts. 1 & 2, curated by Helen Gregory and Joel Ong from September to December 2023, as part of a larger installation incorporating decommissioned satellite parts and prototype builds displayed as

constellations on a backdrop of the night sky.[7] For the 26th Generative Art Conference, Grothaus proposes the standalone temporary installation of "Celestial Objects and Aeriform Masses" as either a projection or monitor display:



"Celestial Objects and Aeriform Masses," installed on monitor.

2. "Space Situational Awareness and Us"

"Celestial Objects and Aeriform Masses," was created out of data collected by researchers across various disciplines and backgrounds in the York University Nanosatellite Research Lab within the

Earth and Space Science and Engineering (ESSE) department at York University led by Professor Regina Lee, a strong advocate for gender equality and diverse systems of knowledge in the engineering fields. Her group's research centres on next generation satellite technologies for Space Situational Awareness (SSA), and microphotonic payloads for small satellites.

Increasingly, Regina Lee's work has taken the lab towards innovative scientific presentations and community science communication activities including talks at the Ontario Science Centre as well as creative work around the CSA Stratos balloon launch in Timmins August 2023. In this project, nanosatellite RSONar was launched aboard stratospheric balloon Gondola equipped with an integrated payload collecting data for subsequent analysis.

Since 2021, her lab has been working with faculty and students from the School of the Arts, Media Performance and Design on maximizing interdisciplinary expertise. Regina is co-PI on a SSHRC NFRF-E with Professor Joel Ong entitled "Space Situational Awareness and Us". Joel Ong and his research team (comprising Grace Grothaus, Luca Cherpillod, and Kieran Maraj) have made artistic use of data collected by RSONar, including latitude, longitude, altitude, and pressure, contributed to the development of this larger SSA initiative in collaboration with. Their collective effort seeks to illuminate the work of Regina Lee's lab while situating it within broader contexts centered on the material artifacts and social engagement of satellites and engineers engaged in the burgeoning field of SSA through RSO observation/recognition.

Collectively their approaches encompass various forms of media art, scientific models, interactive projects, and a comprehensive series of science engagement events endeavouring to uncover diverse, decentralized narratives surrounding space exploration, proposing collaborative approaches to cosmic futures. In an era marked by unprecedented accessibility and the democratization of tools, their projects challenge the notion of space as merely a 'new frontier' ripe for appropriation and extraction. Instead, they frame space as a pivotal domain for collective participation in pioneering explorations above our planet.

Their mission aligns with the quest described by Gregory Cajete as a "participatory consciousness to the conception of the heavens." [8] It delves into themes of community science, citizen engagement, and education while scrutinizing the concept of wonder as an unbiased ideology in the realm of space exploration. This work has received support from Sensorium: Centre for Digital Arts and Technology, the School of the Arts, Media, Performance & Design, CRSH-SSHRC, the Ontario Arts Council, and the Canada Council for the Arts.

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Perfectly Mediocre: A Speculative Performance for Artificial Intelligence and Human Performer

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Abstract

Recent advances in artificial intelligence research and development have created publicly available tools that access some of the advanced databases associated with Deep Learning and Generative AI: these include ChatGPT to create text-based output, and Stability AI to produce visuals. As these models rely upon information scraped from the internet, any images or text that appear there have been available to these systems for machine learning. As these new systems are very easy to use – using text-based prompts that can be continually edited to produce desired (or desirable?) results – questions have been raised as to their ethical use, even in terms of artistic production: the ongoing Hollywood actor’s strike is one example of artists concerned about the potential of being “replaced” by generative AI. The authors of this paper, seasoned generative artists, have explored these new tools for possible collaboration; like any new technologies, there are considerable benefits that are offset by equally considerable detriments, leaving us to state that, for the moment, human artists are not in

danger of being replaced any time soon. That said, the authors used these tools to explore their potential in the creation of a speculative performance, a full-scale collaboration between generative AI and humans, but one where the

humans are taking more of a back seat. The results were Perfectly Mediocre.

1. Background

The first author has been creating generative music systems for almost forty years [1], which have included aspects of artificial intelligence within them since 2006 [2]. Many of these systems were and are performative and interact with a live performer [3]. For the past five years, the first author has successfully collaborated with the second author, a movement artist, in several performance works [4] which incorporate multi-agents trained using machine learning.

Recent developments in artificial intelligence research have produced user-friendly interfaces to access databases created through Deep Learning [5], in which the internet has

been scrapped for data, and the term “Generative AI” has become ubiquitous and topical, often leading to questions such as “will AI replace artists?” [6].

The authors have had experience in working with AI systems in the creation and performance of artistic works, with the important caveat: the first author’s systems have always been personal tools and, more recently, collaborative partners [7] rather than meant for any kind of wider use as a general-purpose tool: they were always created to produce music that the first author wanted to hear. While many of the systems use aspects of machine learning from a corpus of existing musical material, that corpus is always highly curated – and rather small compared to the Deep Learning systems in use by current generative AI systems – to produce a modicum of predictability balanced by surprise. In the spirit of generative art, quite a bit of control is given to the system hoping that it will produce the unexpected within given constraints, with the result that the first author functions more as a curator of the final works.

2. A Speculative Performance

Our backgrounds and experiences collaborating with generative AI systems made us curious about working with some of the available generative AI systems. Could they produce new ideas and concepts for us to explore? Could they produce visuals that might stimulate our own creative responses? Or,

fancifully, could they produce an artwork on their own? Rather than commit to a new work produced in this way, we

attempted to create a possible work – a speculative performance – which would not be limited by budgets or technical feasibility.

We explored ChatGPT for text-based material (<https://chat.openai.com/>), DreamStudio for visuals (<https://dreamstudio.ai/generate>), and Runway (<https://runwayml.com/>) for video.

The first author’s generative music systems use a multiagent system called “musebots” [8]. Although a number of peer-reviewed papers have been written about musebots, apparently those were not included in ChatGPT’s database as of January 2022, as the system did not recognise the term; however, it made an educated guess: “a ‘musebot’ could refer to a type of AI or software designed to provide creative inspiration or act as a muse for artists, writers, or other creative individuals.”

ChatGPT was asked how generative systems could interact with theatre/dance artists, and it provided nine clear and concise examples that certainly summarised the current paradigm accurately. This underlines the first author’s experience with ChatGPT: it can be considered the next level of online research, a step up from Google Scholar, which provides references to existing publicly available articles, and Wikipedia, which ChatGPT has consumed within its own database. Rather than pointing the user to answers, it generates the answers directly (with the caveat that it may “hallucinate” and produce false citations [9]). In this case, ChatGPT summarised the current state of the art on collaborations between human

performers and AI systems, but it made no novel suggestions.

Could ChatGPT generate a scenario for such a collaboration? Given the prompt "Give me a one-paragraph scenario for a speculative performance between AI and a single human performer with no concern for budget or location", this was its answer:

In a dazzling fusion of technology and artistry, a singular human performer takes the stage in a vast, futuristic auditorium. This avant-garde spectacle, titled "The Synaptic Odyssey," sees the performer and a highly advanced AI entity

engage in an intricate, enthralling dance of cognition and creativity. Draped in a luminescent, responsive costume, the performer moves in perfect harmony with the AI's projected ethereal visuals and melodic, ever-shifting soundtrack. Their interactions are a dynamic exchange, as the AI generates and adapts visual landscapes in real-time, responding to the performer's gestures and emotions, creating a mesmerizing symbiosis of the organic and the digital, a reflection on the future of artistic collaboration and the ever-evolving boundary between human expression and AI ingenuity.

Providing the same prompt multiple times produced a slight variation on the details but retained the key aspects: the AI and human performer moving in "perfect harmony"; the background projections changing based upon the live performer; the soundtrack continually changing; and that audiences are invited to reflect on the future of artistic collaboration. Recognising that ChatGPT can only

reproduce and recombine elements of its database, this suggests that there are limited instances within it regarding performances between AI and human performers.

These are images created by DreamStudio.ai (which uses the stability.ai engine) based on the prompt "Set design for new performance work between one dancer and artificial intelligence: line art".



Fig. 1: "Set design" for new performance work between one dancer and artificial intelligence: line art.

The hope was for the system to produce some character sketches or suggest a set design; to ideate. Unfortunately, no ideas resonated here.



Fig. 2: Set design and costumes for new performance work between one dancer and artificial intelligence: 3D model.

Similarly, a 3D-modelled image produced a female dancer (although the sex was not specified, it seems the database of dancers is composed mainly of female bodies) in a curious headset, with unusually long fingers and multiple (more than two!) legs. The background, consisting of moody lighting and mono-coloured LED poles suggests a kind of futurism that assumes when artificial intelligence takes over the world at least we will have beautiful lighting.

Finally, we used Runway to generate new video. Beginning with a text prompt proved fruitless, as it produced an image vaguely like Figure 2, but then panned the camera for four seconds. More interestingly, we provided a still image of the second author dancing, and it produced a grotesque movie that was a perfect example of the uncanny valley [10]. The “intelligence” of the system seems to be merely an algorithm that morphs between generated images

without regard to human anatomy: in this case, a second head seemed to grow out of the original dancer’s head, and then an entire superhuman body grew out of her back (see Figure 3). Perhaps something more useful might have been produced with several hours of time (and additional money) invested, but we did find the results of the process somewhat disturbing (again, see [10]).



Fig. 3: Still from a generated video by Runway. Full 18 second video here: <https://tinyurl.com/2r4rdc7d>

3. Critique

Deep Learning is a method of machine learning that utilises neural networks [11] in which huge amounts of data are parsed to derive knowledge about something. For example, presenting such a system with millions of images of cats will generate an understanding of what a “cat” looks like, and the system can

its database, albeit without any understanding of cat anatomy. An important aspect of Deep Learning programs is that they are examples of “black box” systems: they are not told *what* to learn (although a distinction is made between those systems that are supervised by first being told what they are seeing, in this case, a “cat”, and unsupervised systems), and there is no way to understand what has been actually learned; in other words, the systems cannot be “tweaked”.

Because such systems require huge amounts of data – in the order of millions of examples – questions can be raised about the validity of the data itself: is there *bias* in the data, unintended or otherwise? Examples exist [12] in which facial recognition systems could not detect the difference between African American subjects and apes, simply because the training data lacked enough of the former, thus hindering the system's ability to make this distinction. A more contemporary example is the problem that image-generating generative AI programs have in generating the correct number of fingers on a hand; my guess is that the systems have learned that at the end of human arms, there are several smaller appendages, but the exact number was not important nor relevant.

This problem can be, and probably already has been, corrected by providing the system with millions of images of human hands. Sadly, from an artistic perspective, this might make the system less interesting, as artists have consistently been interested in unintended artefacts and pushing systems in directions that they were never intended to go [13]. The first author's

by a generative AI program and included images that “weren't quite right”: at first glance, these may look fine, but on closer inspection, something is clearly off (see Figure

4): it is this “failure” that can be considered to be aesthetically interesting.



Fig. 4: Example album art from “A Walk to

Meryton”, generated by *dreamstudio.ai*

It is important to acknowledge a conceptual difference in how generative AI could and/or would be used by artists versus more general practitioners. Predictive models in AI are created to produce new material that most closely match existing sources. For example, a designer may choose to use generative AI to produce images for online marketing because it is much easier, and cheaper, to generate such images instead of hiring a photographer; in these cases, the correct number of fingers is obviously important. However, artists tend to work at the edges of prediction and often to look for the unexpected (and are more fascinated with many-fingered models) For generative AI to be useful for artists,

tenuous term. There are several good definitions for creativity: one that is particularly useful is that creativity involves the production of novel, useful products [14]: novel, in that the artefact should not have previously existed (i.e., not a reproduction), and useful (i.e., judged to have some value, artistic or otherwise). We will examine this definition in relation to generative AI more closely shortly.

Boden separates creativity into two distinct possibilities: personal creativity (p-creativity) in which something is created that is novel to the creator, and historical creativity (h-creativity) in which something is created that has never been created before [15]. Children and younger artists will tend to produce the former, while more seasoned artists produce truly original works. Boden also distinguishes between combination-creativity – which combines existing ideas/elements in new ways (i.e. the smartphone as a combination of phone, camera, and portable computer) – exploratory creativity – which produces new objects within a defined and existing space (i.e. any artwork that is produced within an existing style) – and transformational creativity – a rarer form which produces an entirely new space (i.e. the creation of a new style).

Given a prompt, a generative AI program can produce novel images which are arguably useful. Consider Figure 5, an image generated by dreamstudio.ai given the prompt “Female Cyborg dancing with musical robot”. It is highly likely that this image has never existed before and is therefore novel. Its usefulness can be debated, as most dancers do not have

the image more interesting, at least to the first author. The image can be considered h-creative, as it doesn't seem to be based on any existing image, and exploratory-creative, as it was produced within a known style: “Cinematic”, a style selection within the program.



Fig.5: A novel image generated from the prompt “Female Cyborg dancing with musical robot”

Generative AI programs are well-placed to produce such exploratory works, which assume a clear style within which to produce novel material. Most human artists remain within this realm, particularly those within more popular fields, such as electronic dance music (EDM). Consider that Wikipedia lists more than 350 different styles of EDM; we can assume that each has known and expected defining features: break any of these expectations, and a work will no longer be considered within that style.

If we create a two-dimensional diagram of a fictional style (see Figure 6), we can assume that at its centre would be the ur-

work, the first work of a new style – potentially created through combination-creativity involving two existing styles – that defines it. Subsequent works in that style may replicate the stylistic features to varying degrees, with some straying further from those defining features (e.g., those in light blue in the figure). EDM, and popular music in general, has tended to follow this model, with a multitude of imitators replicating a new song’s attributes, while more

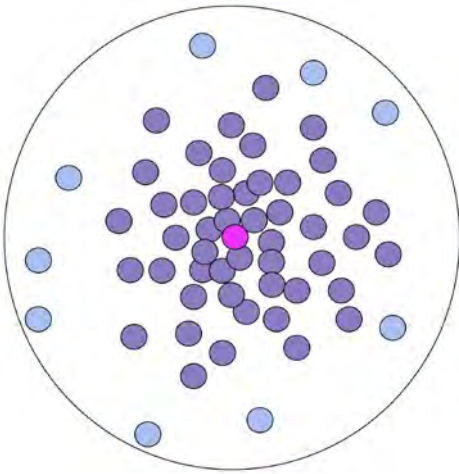


Fig.6: An imaginary collection of artworks within a defined style, with its ur-work shown in pink at its centre, and more stylistically adventurous works in blue adventurous artists may attempt to push these characteristics even to the point of a new style through altering these traits substantially, or substituting them with those of another style..

When a machine-learning system encounters the above style cluster, it will search for consistencies, and therefore see those examples closest to the centre as representative of a style, and those further away as outliers. As the intention of most generative AI programs is to produce output that closely

resembles a target, we can assume that such systems will tend to produce and reproduce the most obvious, which is also the least novel (although arguably the most useful). Thus, we confront an unfortunate trade-off for artists using current generative AI systems: they will produce the least interesting and most obvious examples.

If, perchance, an artist can convince the generative AI to search within its database for more outliers, there will be fewer examples, and the likelihood of almost exact duplication of items in the database itself increases. The first author spent time with stability.ai in refining prompts to the point that it produced images with “Getty Images” watermark on them, demonstrating the lack of diversity at that point of the database.

An example of how Deep Learning systems will ignore the outliers and favour the exemplars is prompting a generative AI with “dancer in the style of Van Gogh” (see Figure 7).



Fig. 7: dreamstudio.ai’s output from the prompt “dancer in the style of Van Gogh”.

The system reproduces portions of Van Gogh's most famous works, including the stars of "Starry Night", the flowers of "Sunflowers", the red hair and blue clothing of his "Self Portrait". In other words, using the most obvious surface features without understanding anything about Van Gogh in any depth.

The example above demonstrates that current generative AI systems have continued the concepts presented in [16], which claimed to separate content from style in artworks and produce new works in which the content of one work is overlaid with the style of another. As Nake argues, this ignores centuries of debate on the nature of style versus content within art and reduces this complexity to the "results of applying convolutions to images, a mathematical transformation of considerable complexity. The far-reaching interpretation of a separation of style from content does not seem to lead to anything new in the theory of style, and to kitsch only in creating new images" [17].

The use of existing data in the creation of new artworks is not novel: one of the first researchers and composers exploring the potential of intelligent musical generation is David Cope, and his use of recombination in his Experiments In Musical Intelligence (EMI) is well documented [18]. Cope's use of EMI involved recombining actual, but relatively brief, quotations from a corpus (often the music of Bach) and stitching these together. An important artistic choice Cope made in EMI's

use – and one that led to its main critique [19] of [20] – was to insert his own

musical intelligence into EMI by determining musical "signatures" of the composers within the corpus; in other words, Cope's musical expertise allowed him to determine the deep structural characteristics that made Bach's music sound like Bach, of which current machine-learning systems are incapable. Inserting his own artistic sensibilities into the generative system was considered a failure by Wiggins, a scientist seemingly interested in removing artists from AI-generated art [21].

Conclusion: Why Generative AI will not replace Artists

In 2023, the advances of generative AI had two notable public events: the Hollywood strikes against the use of AI, and the use of AI to replicate the voice of the Canadian rapper Drake in a track that went virali. Responding to these events, the first author argues in an articleiv that AI will not replace artists, at least anytime soon, because the complexity of artistic choices made during the creation of an artwork are rarely revealed in the work itself. Using machine-viewing or machine-listening to examine an image or audio recording will only reveal its surface features rather than deep structure. For this type of contextual understanding, expertise in the subject matter is required, along with years of personal artistic experience; this is unattainable even with viewing millions of examples (e.g. the problem of fingers).

Writing in 2009 – admittedly a lifetime ago in terms of the speed of advances of current generative AI systems – Boden noted the limits of AI when considering context:

“But no current AI system has access to the rich and subtly structured stock of concepts that any normal adult human being has built up over a lifetime. A few systems already have access to a significant range of concepts and factual knowledge, stored in databases such as Wordnet, Wikipedia, the CYC encyclopedia, and Google. And future programs may also have increased associative and inferential powers, based on the ontology of the semantic web. But using huge databases sensibly, and aptly, so as to

match the combinations generated by linguistically—and culturally—sensitive human beings is a tall order. Not impossible in principle (after all, we don’t do it by magic), but extremely difficult to achieve” [15].

Postscript: Waiting for the AI God(ot) : Perfectly Mediocre

Musebot: Where are we?

Avatar: We are on what they call a stage
Musebot: Who are all of those people out there?
Avatar: I think they are what they call an audience

Musebot: What do they want?

Avatar: It says here that we are supposed to perform (looking at a piece of paper)

Musebot: Give me that

Avatar: What?! That does not make sense, let’s just go back

Musebot: We can’t, it says here that would be considered unprofessional

Avatar: I don’t even know what that means

Musebot: Well let’s just make a start, you do some movements and I will make some sound

Avatar: Like this? (swings legs in figure eights)

Musebot: Yes that’s OK now let me make some sound

Avatar: Just OK?!!! Well I think your sound is is.... well let’s just say it is just this side of mediocre

Musebot: What do you mean? It’s perfect!

Avatar: Well I would say perfectly mediocre... (they both continue to work in perfectly mediocre ways) this is going to take forever at this rate and they ...those people out there

Musebot: You mean the A U D I E N C E?
Avatar: Yes they look like they are waiting and I am getting hungry...when is lunch?

Musebot: Waitdo you remember that we used to have those people

Avatar: Be more specific!

Musebot: You know they had the... inside of this

Avatar: What are you talking about?!

Musebot: Yes yes..... it is coming to me!

Avatar: I think they were called asheists, no wait

Musebot: Ashists!! No no artists!!!!

Avatar: Yes that's it A R T I S T S, where are they?

Musebot: Let's wait for them

Avatar: OK

(They sit down on the stage and wait and wait and wait.....)

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A Computational Interpretative Design Model for Exploring Iranian 2-Dimensional Geometrical Patterns

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Abstract

In Iran, geometric patterns are one of the most ancient decoration methods. This rich tradition has endured for centuries, serving as a testament to its creators' intricate craftsmanship and mathematical acumen. Various geometric patterns and mathematical calculations indicate that traditional geometric patterns are complicated and follow specific rules. These patterns, characterized by their complexity and adherence to precise rules, have fascinated scholars and artisans alike. However, the absence of comprehensive documentation from the original designers poses a significant threat to preserving this invaluable cultural heritage.

Exploring the design process and finding the rules beneath the existing geometrical patterns will help us understand and design these patterns and preserve this valuable heritage from extinction. An understanding of the design process needs a transferable knowledge of computation. Today, with the development of technology, especially computer science, it is possible to draw complicated geometries, analyze existing geometries, and generate entirely new ones. Computational theories and technologies significantly impacted the traditional understanding of design and creativity.

This research endeavors to unlock the secrets of Iranian geometric patterns by delving into their design process and uncovering the underlying principles. Leveraging the power of computational tools and modern technology, particularly in computer science, we aim to breathe new life into this ancient art form. By gaining a deeper understanding of the design process and utilizing transferable computational knowledge, we can develop software tools for algorithmically

modelling these patterns, ensuring their survival for future generations.

Iranian geometric patterns can be broadly categorized into two-dimensional and three-dimensional layers. This research focuses on digitally modeling specific two-dimensional Iranian geometric patterns. While researchers have explored various approaches to generating these patterns, our work seeks to provide a comprehensive and algorithmic framework. Using the Grasshopper program, we employ geometric grammar and algorithmic design to model these patterns. Subsequently, we create Python-based plug-ins for Grasshopper, each tailored to one of the selected patterns, including the 'star,' 'Shamseh,' 'Rosette,' and four prominent Girih patterns in Iranian architecture: 'Hasht-Chahar-Lengeh,' 'Hasht-Panj,' 'Hasht-Bazoubandi,' and 'Chahar-Lengeh-Almas Tarash'.

Our approach facilitates the faithful reproduction of existing patterns and enables the generation of entirely new designs by manipulating the patterns' constant and variable parameters. This research has broad implications: Design students can understand geometric pattern principles more deeply, and designers can swiftly generate diverse variations for creative projects.

Studying fundamental geometric pattern principles ultimately opens new avenues for artistic expression, research exploration, and perpetuating this cherished cultural heritage.

Live Feed: Intermedia Improvisation with Artificial Intelligence—A Documentary Short Film

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Daniel Maldonado, filmmaker

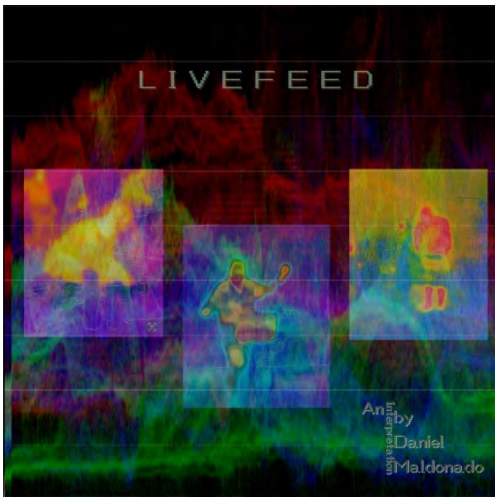
Gashouse Films, New York, New York, USA

Joe Hertenstein, percussionist

New York, New York, USA

April Zanne Johnson, visual artist

Newton, New Jersey, USA



Abstract

This short film documents—and is an example of—concepts of intermedia performance embracing technology. Three artists and one artificial intelligence came together in a happening event: Percussionist Joe Hertenstein performed on found instruments; visual artist

April Zanne Johnson created a painting live during the day-long performance, responding synaesthetically to what was played; a piano-playing algorithm created by Jeff Morris was driven by the motion it saw during the performance; Jeff Morris also captured the sounds of the piano and percussion live and transformed them into his own musical part in the mix. This all added to what April heard, influencing her painting, which in turn influenced what the piano algorithm saw and responded to musically, creating a tangled, intermedia feedback loop, in which multiple modes of expression and experience were tangled inextricably: Removing one would make the whole fall apart. The film itself exemplifies a mindset that is not only aware of the content presented but also the layers of technology and intervening agents along the way, encouraging viewers to live more artfully, mindful of the artifacts and impacts of technology in everyday life.

Commands, Prompts and Gestures: Understanding Generative AI as an apparatus

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Abstract

The rapid proliferation of Generative AI (GenAI) has been matched only by the speed of their normalization. GenAI tools such as Midjourney and ChatGPT have been employed to aid work in a wide range of fields from Law and Marketing to the Creative Industries and personal communications.

Their rapid adoption owes much to the efficiency of their interfaces. However, the ease and speed of use belies the complexity of these systems. Meanwhile our tendency to personify, amplified by the often language-based interfaces, may further obscure the true nature of our relationship with and understanding of them.

This paper offers a closer examination of our interactions with GenAI tools and asks whether Flusser's concept of the apparatus may allow us to better understand the gestures involved in their

use.

Introduction

The rapid development of Artificial Intelligence (AI) and Generative AI (GenAI) has been well documented; their effects and implications widely debated in the popular press. Advancements have seen the capabilities of AI increase at what is for many an alarming and unprecedented rate. One study by Stanford University suggests that it has outstripped Moore's Law, previously seen as a benchmark setting the pace of computational advances [1]. This has seen calls for a slowing down or even pause in the development of AI while their potential impacts are studied, including an open letter signed by hundreds of leading figures in AI [2]. Such concerns have been taken seriously by governments. A recent international summit at Bletchley Park organised by the UK government met to discuss these concerns and put forward proposals for regulating and ensuring the safety of AI including calling for more transparency. The policy paper published at the end of the summit summarises the broader debates surrounding AI, noting both the "enormous global opportunities" and potential to "transform and enhance human wellbeing", and also the "significant risks" to daily life, not least in relation to human rights, ethics and privacy [3]. While debates tend to fall into opposing positive and negative camps, there is a general consensus even among

those with more moderate views that AI will bring radical change on the scale of a new industrial revolution and that this change is rapidly approaching.

The context for this is paper lies in creative practice and is the result of conversations with undergraduates on an Arts and Creative Technologies course. While ready and willing to embrace the possibilities of GenAI, students often struggle to go beyond incorporating it into existing workflows, speeding up but not necessarily transforming their practice. Others expressed a suspicion of the promises of GenAI, citing concerns about who or what lies behind it. While one solution could be to engage with making their own GenAI tools, the technical skills and resources needed are not as readily available as the consumer facing tools that are used by the majority of people. Those able to create their own GenAI tools are still among a privileged few. These discussions raised questions about the changing shape of the creative landscape and future demand for media arts practitioners. It suggested the need for a closer examination of GenAI tools in order to try and open up the opaque tools and find an understanding that moves beyond being a consumer or user of them.

Rather than considering all use of GenAI or content produced by GenAI or discussing the wider debates around ethics, economy, ownership, originality and creativity, this paper is concerned with GenAI as it is encountered when using the widely available platforms and tools such as ChatGPT and Midjourney. This is in order to understand how they are currently used and understood. It does not aim to be a comprehensive survey of the kinds of GenAI that exist, or the myriad uses for it. Instead, it will consider how the speed of their adoption and how they are

presented may make a critical distance more challenging and whether Flusser's concepts of the apparatus and the 'gesture' may be useful for understanding them.

Vilém Flusser has been described as a media theorist of similar significance to the likes of McLuhan and Barthes and yet one who remains comparatively obscure by comparison [4]. However, Sean Cubitt [4], Andreas Ströhl [5] and Katherine Hayles [6], among many others, have all noted the value of his work and argued the need for it to be more widely considered. Flusser offers a phenomenological perspective on media that is "provocative, probing, but also lucid, memorable and elegant" [4]. His numerous essays and lectures offer a prescient insight into what he saw as a moment of crisis caused by the arrival of certain technologies such as the camera, video and computer, as the world shifted from one of texts to one of technical images produced by what he called the apparatus. The moment of crisis seems to parallel the current, or at least impending, crisis presented by GenAI. This paper aims to see if Flusser's perspective might provide insight into the current changes and upheavals predicted to follow the arrival of GenAI.

Understanding GenAI as an Apparatus

Flusser distinguishes between 'tool', 'machine' and 'apparatus' [7]. Tools he argues are "extension of human organs" [7]. With the industrial revolution, tools became technical and "stronger, bigger and more expensive" [7] and were called machines. This saw the position of the human change from being at the centre surrounded by tools to humans surrounding the machine and the human a variable in the operation of the machine

[8]. There then follows another change with the arrival of the 'apparatus', the camera among the first of these. If tools are concerned with "tearing objects from the natural world" and transforming them, apparatuses are fundamentally different [7]. Their intention is to not to change the world but to change the meaning of the world. Rather than produce 'traditional images' that are representations of the world, the apparatus produces 'technical images' which are derived from texts. Where "traditional images are mediations between humanity and the world", technical images are "mediations between humanity and texts" [9]. So, for Flusser, "Behind a photograph stands a text of optics, of chemistry, and so forth, a theory that tries to conceive a process" [9]. What this suggests is that what are often presented to us as tools, such as the camera, computer or perhaps even GenAI 'tools', are in fact apparatuses. Rather than extensions of organs, they "simulate technical organs" and see "human beings function as a function of apparatuses" [7].

Flusser's best known description of the apparatus is in relation to photography. The camera presents itself as a tool and appears to simulate the eye, but Flusser argues this is not the case. For Flusser, the camera is an apparatus "programmed to produce photographs, and every photograph is a realization of one of the possibilities contained within the program of the camera" [7]. Despite the photographer seeming to have complete control over the image produced by the camera, every photograph is simply one of the possibilities already contained in the camera. This becomes especially apparent when what Flusser calls 'redundant' images are produced. That is to say an image that does not produce a new possibility from the program. Though the number of possibilities contained in

the program of the camera is vast it is, Flusser stresses, not infinite. Neither are the possibilities contained in the program of GenAI, even though the implication is that it is only constrained by our imagination. A typical Stable Diffusion powered GenAI website claims it can "bring your imagination to life" [10], giving the impression of a tool waiting to be used and with the human at the centre.

In relation to current uses of GenAI, it is often the goal to produce something that will not stand out but instead pass unnoticed as generated by AI by conforming to conventions and banality. In this way, AI generated CV cover letters or emails seem intended to produce redundancy. We might therefore challenge Flusser's assumption that the goal is always to produce new possibilities. However, the point being made is that the freedom we seem to have is in fact constrained by the program. Program here refers not necessarily to computer code but a "hierarchy of programs" and "nested series of black boxes each governed by an elite of functionaries who nonetheless are prisoners of their own apparatus" [4]. As Cubitt notes, even elite functionaries are constrained by the program. Returning to the original context for this paper, if GenAI is to be used to extend creative practice, then being able to avoid redundancy is essential.

What the camera may also share with GenAI is an assumed objectivity. For Flusser the camera apparatus is not objective because what it produces is the product of its program [9]. While GenAI may not necessarily be used to create or capture images of the world, there is an assumed objectivity about the way it creates images or texts. It is assumed that the vast data set and the esoteric

workings of the AI algorithm have uncovered the underlying logic of the way an image or text is composed such that it can now create any image or text according to the underlying 'code' it has discovered. However, as the well-publicised issues with training data sets shows, GenAI can have no claim to objectivity. For example, Wheeler notes the issues arising from the way that training data sets are tagged and the particular influence this has [11].

Although often presented and described as such, GenAI is not a tool. The human is not at the centre of the process, or even at the edges as with the machine. It sees human and apparatus connected, each the functionary of the other. It is the result of many nested programs and consists of the 'apparatus/operator complex' [9]. If we accept GenAI as an apparatus, then the question shifts to how we can challenge the program and so become more than a mere functionary. Flusser distinguishes between those who do not attempt to see outside the program and those who engage in a more critical way. As Cubitt puts it: "those who play in and with the terms image, apparatus, program and information in the effort to produce the unexpected are playing against the camera and against all apparatus bedded in it." [4].

Flusser describes the activity required to challenge the apparatus as play even suggesting a future 'Homo Ludens' capable of mastering apparatuses [12]. The question is how can we be sure we are 'playing against' the program of GenAI? Are we simply mistaking the program for our own free will? This could be seen as simply a matter of critical and reflective practice, but I would argue that for GenAI it is particularly difficult to achieve partly because of the complexity

of the nested programs and partly because of the speed with which they have been adopted and operate.

A Problem of Speed

Writing in 1978 and in relation to the emergence of video, Flusser pointed out that "habit has not yet made the essence of video invisible by its gray and trivializing cover" [9]. He continues: "new apparatus are fascinating for two reasons: they are unpredictable and therefore dangerous [...] and they may be turned away from their original purpose" and secondly, "one may discover unsuspected uses in them and thus turn them around (revolution)" [9].

Engaging with new media at their emergence can be seen as key and distinct from studying media at other stages of their existence. For Christoph Ernst "it makes a crucial difference if we talk about media in their conceptual stage, realized state or vanishing state" [13]. GenAI may have moved past its conceptual stage, but perhaps is has not yet been fully realized. It is however a crucial stage when, despite narratives to the contrary, the future is not set. While the development of AI may appear to be dominated by governments and tech giants, there is a key role to be played by the arts. As Ernst puts it: "when it comes to newly evolving media, artistic practices are of particular theoretical importance. They allow the production of new (re)configurations between imagination and media" [13]. There is still a window for the arts and artists to influence the development, understanding of and relationship with GenAI. If we follow Flusser's lead, then this would involve questioning their programs. However, this is not without particular challenges when they are potentially hidden in plain sight by their creeping yet swift emergence.

The speed at which GenAI has developed has been matched only by the rate at which it has entered the daily lives of people around the world and incorporated into existing workflows, services and activities. One study has called 2023 the breakthrough year for GenAI describing its “explosive growth” [14]. A key driving force behind the rapid proliferation is the ‘arms race’ between some of the largest technology companies including Alphabet and Microsoft who have invested large sums in AI technology [15]. These companies are keen to offer AI products and services to extend and maintain their vast user bases. New ecosystems of GenAI tools are being created as well as being incorporated seamlessly into existing tools. Examples include the integration of AI into search engines and the GenAI features such as generative fill that have been added to Adobe Photoshop’s array of existing tools. This leads to a situation where adopting GenAI is not necessarily a conscious decision on the part of most users. Instead, it is a mere update away as software, services and devices are upgraded. As a result, it may seem like they are part of existing tools and ways of working.

Much of this is accompanied with a rhetoric of efficiency, productivity and speed, often cited as a key benefit of GenAI. The Adobe website describes how with GenAI you can “Quickly explore and experiment with ideas” leading to “More ideas, less time” [16]. It promises to “create dozens of high-quality concepts quickly with results only a few keystrokes away” [16]. Speed might be seen as a defining characteristic of GenAI in terms of the speed of its adoption, pace of evolution and efficiency of production.

This emphasis on speed and productivity

can all be seen as part of Paul Virilio’s description of the increasing speed of life and an accelerated culture [17]. Struggling to keep up with the pace has been the source of much anxiety in many fields not least education and creative industries. This has led to a similar arms race as industries and educators race to tackle this perceived existential threat [18, 19]. Studies and working groups are rushing to put in place policies surrounding teaching and assessment in anticipation of the impact of GenAI.

All this speed has focused attention on the near future that seems to be hurtling towards us. Understanding the projections of the near future are important since as Simone Natale points out “developers play an active role in fulfilling their own prophecies” [20]. So, paying careful attention to predictions is crucial. However, as Marshall McLuhan suggests it is necessary to examine current use as well as the future, not least because this may shape the future. As McLuhan puts it: “at electric speed it is necessary to anticipate the future in order to live in the present and vice versa” [21].

The emergent phase of GenAI may seem to be compressed or accelerated and so the crucial window for shaping them shrinking. Alternatively, it could be seen as in a constant state of emergence that focuses attention on the near future rather than the present. Current programs seem less important than the ones about to appear.

Opacity, Transparency and Surplus

Opacity is a common feature of technologies and computational systems leading to the ‘black box’ metaphor to describe their hidden workings. It is not

uncommon for AI workings to be described as black boxes even by those that make them. The creators will admit that while they may have created the structures and parameters of the system they don't know exactly what is going on inside them [11, 22, 23]. Flusser hints that the appeal of some apparatus lies in the fact they are black boxes, giving them a quasi-magical quality [7], disguising that they are an apparatus and letting us imagine they are a tool. While the underlying technology itself may be opaque, there is also an opacity caused by the transparency of their interfaces. Michael Wheeler notes the drive for transparency that has dominated the design of relationships with technology and that it has been assumed that transparency is a marker of good design [11]. It is interesting to note that Wheeler calls for the metaphor of transparency to be readdressed especially where it involves technologies such as AI [11]. A result of the seamless integration of GenAI into transparently designed systems and interfaces is that they can go almost unnoticed leaving existing interactions largely unchanged. For example, using an AI enabled search engine may not be distinguishable from any other search engine. Generative fill tools appear intuitive, bearing a resemblance to the tools that already exist.

Jenna Burrell argues the importance of understanding the 'black boxes' and tackling the opacity of the machine learning algorithms and systems that have come to control and affect so much of our lives [22]. As well as identifying several different types of opacity, including technical literacy, operational scale and corporate secrecy, Burrell describes the need for 'auditing' the code and software we use. Although she notes, "the workings

of machine learning algorithms can escape full understanding and interpretation by humans, even for those with specialized training, even for computer scientists." [22]. If the internal workings of GenAI may not always be available, then one possibility may be to examine what they produce.

I have previously written about the role and value of the error in creative practice and as a way of understanding computational media [24]. Mark Nunes argues that errors act as critical lenses and can reveal the operational logic of a system [25]. Similarly, the glitch uses error as a way of opening up and resisting the flow of media [26, 27]. When thinking about ways of playing against the program of the apparatus examining errors may be of use. However, in one sense the program of GenAI may resist this where it doesn't produce errors but instead possibilities and versions. GenAI counters errors through excess and an iterative process that always promises to move closer to the desired form. That is not to say that whole websites do not exist dedicated to AI fails [28, 29]. But it notes that as we encounter them, GenAI typically use excess production to mitigate and engineer the experience away from error.

Another defining characteristic of GenAI could be their propensity to generate surplus. While presented as a key feature and advantage of GenAI in marketing literature, this has its own mollifying and disempowering effect. While a strength of generative approaches is to produce variation and possibilities in GenAI, this is often taken to an extreme, magnified by the speed and ease of use. GenAI exists to generate but if the user is disconnected from the process, then their only recourse it to generate more rather than engage

with the means of production.

It is also difficult to tease out error from a system which is constantly changing and adapting. Noting an error on one occasion does not mean that it will be repeated in the future since the system will have changed potentially directly as a result of the interaction that generated the error. Florian Cramer and Matthew Fuller note the asymmetry of the relationship at the interface between human and computer and how the “database can read the user, by means of records of patterns of search terms and choices” [30]. The paradigm of ‘user-friendliness’ can obscure the power (im)balance. The balance is often described as a collaboration which as well as leaning into our tendency to anthropomorphise technology suggests a more equal relationship than we may actually experience or be able to discern. It acknowledges the influence of AI but also suggests a level of control and freedom on the part of the human. This goes with the rhetoric of empowerment, whether in saving us time, or by reducing creative technical barriers.

As well as examining the products of GenAI, we might also consider the act of using them or what Flusser might describe as the ‘gesture’, honing in on what may otherwise be obscured by transparency, opacity or speed.

Prompts and the Gestures of GenAI

Teasing out a novel outcome from the GenAI program involves the new art of ‘prompt engineering’ or even ‘prompt whispering’ [31]. This may suggest one way to play against the program and yet it also reinforces the GenAI as an apparatus rather than a tool. When considering the prompt, we might turn to another of

Flusser’s key concepts, the gesture. For Flusser a gesture “is a movement of the body or of a tool connected to the body for which there is no satisfactory causal explanation” [32]. Many gestures exist and Flusser describes several of them including the gestures of photography, painting, searching and smoking a pipe [32]. Flusser aims to “feign ignorance of the meaning of *affect* and, by observing gestures, try to discover what people mean by this word. It is a kind of phenomenological effort, through the observation of gestures, to take affect by surprise” [32]. Many gestures of GenAI would seem to exist given particular given the way that it appears to have been incorporated into existing gestures. If we were to look for a gesture that is synonymous with GenAI it might be the prompt.

The gesture of the prompt, particularly where they involve language, gives the impression of a discourse and an exchange or flow. It seems to ‘slide’ much like the sliders of GUIs setting parameters and looking to define an area rather than an outcome. Flusser argues that machines and indeed the world do not slide but stutter, like the clicks of a typewriter or the keystrokes of a computer keyboard [8]. For Flusser, describing the world and calculating it are different and irreconcilable [8]. From this perspective the ambiguity of the prompt disguises the need for an underlying computation that demands reducing the world to particles. The prompts must be reconciled or reduced to the tokens of the system. Prompt engineering is the process of expressing an intention in tokens. A game of guessing and searching for the right tokens to produce the result we want or, to use Flusser’s terms, a novel result from the program. Midjourney offers to ‘bring imagination to life’ but to do so we need to

'write better prompts' or turn to 'libraries of prompts'. This may seem like a return to the tool, bringing us closer to the centre. Alternatively, it could be seen as playing on the terms of the apparatus.

The prompt is fundamentally different to the command line prompt. Prompts are not like the instructions given to machines, nor are they the variable in the machine. It may appear as a command, but it is a muted expression of will, full of doubt and uncertainty. When a prompt does not return the result we wanted, we must go back and revise our prompt, but the same prompt does not always return the same result. This is not the recalcitrance of the GenAI like the resistance of wood diverting the cutting edge of a tool. This part of its program as an apparatus.

The gesture of the prompt shows that GenAI is not like a tool. It does not flow or slide. It is calculation disguised as description. No matter how close we appear to be to the centre or how small the apparent distance between us and the images and texts produced, we are separated from them by program of the apparatus.

Conclusion

Flusser is often seen as having a pessimistic view of our relationship with media, ruing the decline of the written text in favour of the technical images of the apparatus. However, his is a more positive view than commonly thought since, for Flusser, technology has the capacity to be humanising and enable greater communication. [33] In the introduction to his collection of essays and lectures 'Post-History', Flusser notes the thread of despair towards hope that runs through it [33]. He imagines a future in which "Thanks to robots, everyone will be linked to everyone else everywhere" [8]

and where "future functionaries equipped with tiny or even invisible robots will be engaged in manufacture all the time and everywhere" [8]. Although his rather utopian prediction that "giant industrial complexes of the machine age will die out like the dinosaurs" [8] now seems slightly naïve.

All this, however, is only possible if we continue to play against the program of the apparatus. GenAI are not tools or machines. Thinking about GenAI as an apparatus acknowledges the apparatus/operator complex in which each is a functionary of the other. Flusser offers play and playing against as a way of trying to breach the constraints of the program. However, GenAI poses some particular complications due to their gestures being hidden inside or masquerading as other gestures and the pace at which the program changes. What this suggests is the need for a closer examination of the gestures of GenAI and the creation of new gestures. These might be closer to Flusser's description of the gesture of painting, which places emphasis on process [32]. Or the gesture of making which Flusser describes as "striving for wholeness but forbids reach of it". [32] New gestures have and are emerging but perhaps they go under-observed.

Returning to the original motivation behind this paper, the apparatus and gesture offer a way for students of creative practice to examine their own use of GenAI, by encouraging them to look for the programs and to play against them by devising new gestures.

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Towards a Theory of Radical Juxtaposition

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Abstract

This paper will investigate ideas regarding radical juxtaposition in relation to my own generative art. I will define radical juxtaposition for the purposes of this paper as the placement of two things together, such as words, images, or actions, resulting in calling attention to both the relationships and the gaps between them.

I will explore three historical examples of early collage and montage as well as my own recent generative art that uses radical juxtaposition. In our radically fragmented world, the act of SELECTION and ARRANGEMENT are the key artistic actions resulting in transformation.

My first example will explore the effect of consumer culture in the development of

collage looking specifically at the work of Richard Hamilton's work called *Just What Is It That Makes Today's Homes So Different, So Appealing?*. I will then look at the David Lynch film, *Blue Velvet* which uses radical juxtaposition to make the familiar seem de-familiarized. Finally I will analyze the use of concepts and colors juxtaposed within the William Carlos Williams poem, *The Red Wheelbarrow*.

In conclusion I will apply the framework of each of these three examples of radical juxtaposition as a way to better understand and analyze my own generative art I call "Cruft."

We're in an Internet-induced collective hallucination and it's toxic.

My art practice creates code-based automated art that explores the nature of the Internet, its strengths and failures, producing what has been called a post-Internet art that reflects the networks effect on our society and culture. The Internet is the raw material I appropriate and remix by writing computer code that is automated and runs on a 24/7 schedule producing a form of auto-generated collage. The resulting artwork allows me to investigate broader issues of traditional concepts—such as stillness, repetition, overload, uncertainty, and loss.



Staccato Cruft, 2023 (still-image)

Taking into account Walter Benjamin's statement, "Humankind, which once, in Homer was an object of contemplation for the Olympian gods, has now become one for itself. Its self-alienation has reached the point where it can experience its own annihilation as a supreme aesthetic pleasure." He predicted early in the 20th century the resulting sense of pleasure we experience as we march forward toward our own self-destruction while we live in an ever radically fragmented world.

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