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Art, Science and Technology:

Interaction between Three Cultures

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Preface

"Beauty will save the World." We chose this expression of the Russian writer Dostoyevsky as the slogan for the 1st International Conference "Art, Science, and Technology: Interaction between Three Cultures". The philosophy of the conference is elucidating and establishing the interrelationships between three cultures (Art, Science, and Technology), studying new inspirations and creativity in them, in order to show the young generation of artists, scientists and engineers how learning, education and our very existence may be interesting and beautiful.

These proceedings include 22 papers and 42 abstracts of famous scientists and artists who presented their works at the conference. Among them the Nobel Prize laureate Professor Dan Shechtman who received the award in chemistry 4 months after the conference.

Unfortunately, the papers and abstracts, in spite of their deep content, do not reflect the incredible atmosphere which was maintained during the conference. An unforgettable aura was created by musical performances, exhibitions ("Art in the eyes of scientists and engineers. Science and technology in the eyes of artists" and "Astronomy and Art") and exciting discussions. Natural interrelations of all this reflected the general mood and tone of the conference. We are planning to organize the Forum "Art, Science, and Technology" in Israel, and, of course, the 2nd International Conference "Art, Science, and Technology: Interaction between Three Cultures" in the near future.

Let me acknowledge the editors of these proceedings: Tatyana Kravchuck, Celestino Soddu, Enrica Colabella, and Gerry Leisman, who made efforts to convert all papers into a readable and interesting journey. Our particular thanks to Dr. Tatyana Kravchuck, co-chairman of the conference, who personally contacted all the authors and edited the final version of the proceedings; and Prof. Celestino Soddu for help in publishing the proceedings.

Special thanks to the sponsors of our conference: the Association of Engineers, Architects and Graduates of Technological Sciences in Israel, NIRLAT company, Bank Hapoalim, the Ministry of Foreign Affairs, IKA Laboratories, and AmiGad company. Unique thanks to the College of Engineering ORT Braude (Karmiel) who hosted the conference and helped to publish the proceedings.

We invite you to the incredible world of interaction between art, science and technology which is provided by the expression of Russian chemist Mendeleev: "*Science and art have common roots; and they solve general problems of cognition of the universe*".

Alec Groysman

Chair of the conference

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Art, Science and Technology: Interaction Between Three Cultures

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ABSTRACT

What do we live for? There may be different answers. We suggest a universal reply to this question: the search for beauty in every step of our existence. What is the place of art, science, and technology (engineering) in modern society? What are the aims and main functions of art, science and technology? Scientific – technological revolution was the favorite term in the second half of the 20th century. Where was art in this period? Where is art in our lives today? The development of computers in the years 1990-2010, new technologies and new materials drastically changed our world, our lives, and as a result, the interaction between three cultures (art, science and technology). Digital art and multimedia appeared. Today art is a very complicated field including various combinations of traditional art, sciences and technologies. The computer is the common feature, or platform, where our cultures have cross-sections. Our generation is eye-witness to many scientific and technological achievements previously described only in science fiction. Our century may be named scientific – technological – art - computerized epoch.

There is nearly no artist, painter, musician, sculptor, mathematician, architect, physicist, chemist, biologist, doctor, or engineer who conforms to the classic term and understanding, generally accepted even 30-40 years ago. We enter deeper and deeper into small compartments. There are specialists in every small field. On the one hand, we deepened our knowledge about each thing. On the other hand, we lose the general picture. Today there is no topic in science and technology which is dealt with by people of only one specialty. Chemists work together with biologists, physicists and mathematicians, etc. Each cannot work without the other. All achievements of science and technology have two-Janus faces. With the development of computers, we lose spiritual and cultural things. People have less and less meaningful discussions. People speak to each other less and less; go to performances, museums and exhibitions less and less. The modern world is divided into lyrics and physicists, humanitarians and naturalists, artists, scientists and engineers. How to unite them? Is the world one?

The philosophy of my paper is elucidating and establishing of interrelationships between three cultures, studying new inspirations and creativity in polyspheres meaning art, science and technology, searching and determining common aspects and differences in three cultures in order to show the young generation of artists, scientists, engineers and educators how learning, education and our very existence may be interesting, fascinating, creative, productive, exciting, attractive, rich, and, as a result, beautiful.

Introduction

"*Science and art have common roots; and they solve general problems of cognition of the universe"*
D. I. Mendeleev (1834 – 1907), the Russian chemist

The British physicist and philosopher Charles Percy Snow in 1959 differentiated two cultures, the arts or humanities on one hand, and the sciences on the other [1]. We mark out and add technology (and

engineering) as the third culture. Artists, scientists, and engineers… There are many common features and differences between them. It was suggested to use split culture instead of two cultures [2]. This is correct, but the real situation shows that specialization in the last two centuries led to the splitting of one general culture into many different disciplines, while most problems are complex and require interdisciplinary approaches [2]. What can bridge these split culture? The answer is the computer revolution. The usage of art-science connections appears at various levels: strengthening interdisciplinary thinking in general, and "beautifying" science (I would also add engineering) and "technologizing" art education [2]. Art, science and technology have in common that they do not have borders (as countries) and that they became the language of the 21st century. It is difficult to imagine our life without these three cultures. In order to discuss our topic we have to define the main terms art, science, technology (engineering), their origins, roots, and aims.

Art, science, technology, and engineering

"Scientists study the world as it is; engineers create the world that has never been."
Theodore von Kármán (1881-1963), the Jewish- Hungarian-American aerospace engineer and physicist

"I know that art is absolutely necessary, but I do not know why."
Jean Cocteau (1889-1963), the French artist and playwright

We should differentiate between art, technology, science and engineering. Historically they appeared separately. The history of human society shows that art was at the dawn of its existence and development [3]. Primitive man showed his relatives and friends what happened during the hunt, gathering of food or other events by means of pictures, signs, symbols, motions of his body and sounds. The proof is pictures and figures of animals and people in motion that were found in caves. Prehistoric people were the first artists. That was the reflection, representation, depiction, expression, imitation, and imprinting. They also documented by means of different symbols and signs. Thus, the main function of prehistoric painting was documentation and communication, and not creativity, which is an entirely modern ritual [4, 5]. I feel that education in the form of teaching and learning appeared in that period [6]. It was impossible to do pictures (art) without instruments (technology). Therefore technology most likely appeared before art as a requirement to survive and improve the lives of people. The word technology comes from the Greek words technología, téchnē (meaning art, skill, craft) and logía (meaning study of). Technology began from the conversion of natural resources into simple tools. The first technological inventions were made during the Paleolithic era 2.5 million–10, 000 BC: the making of stone tools, the discovery and utilization of fire, clothing, and shelter. The first representative art in the form of pictures found in the caves was dated 40, 000 years ago [4]. You feel the difference in the dates of appearing of technology (2.5 million–10, 000 BC) and art (40, 000 years ago) [7]. "*Labor is older than art*" [7, 8]. We should emphasize the difference in the meanings of art as skill and art as the creation of something beautiful as we understand today. Such transformations of terms with time occur often. Only then people began to think how one thing worked with another, what were the causes of phenomena around. People began research, endeavor, compare, analyze, synthesize and thus primitive science appeared. Primitive art was an embryo of primitive science (knowledge), namely, knowledge about the surroundings and man [7]. Science is derived from the Latin word scientia meaning knowledge. Science is an enterprise that builds knowledge about the universe. Science is the systematic attempt to discover and expose nature's patterns. In short, science appeared as satisfaction of curiosity of people.
What does engineering mean? How did engineering appear? Engineering is the discipline, art (meaning skill) and profession of acquiring and applying scientific, mathematical, economic, social, and practical knowledge to design and build structures, machines, devices, systems, materials and processes that safely realize solutions to the needs of society. The term engineering has a much more recent etymology, deriving from the word engineer, which itself dates back to 1325. An engineer is one who operates an engine, originally referred to a constructor of military engines [9]. In this context, an engine referred to a military machine, i.e., a mechanical contraption used in war (for

example, a catapult). The word engineer is derived from the Latin roots ingeniare (to contrive, devise) and ingenium (cleverness; innate quality, especially mental power, hence a clever invention) [9, 10]. The word engine was dated to 1250. The concept of engineering has existed since ancient times as humans devised fundamental inventions such as the pulley, lever, and wheel. When science and engineering appeared, they stimulated the development of technology. Historically, the first were military engineering and civil engineering. Electrical engineering, mechanical engineering, chemical engineering, biological engineering, etc. exist today. The distinction between technology, science and engineering is not always clear. Egyptians could be successful technologists without having any grasp of science. When they brewed beer, they were interested in the technological methods and results, but not why and how one material was being transformed into another [11]. Probably, the Greeks were the first real scientists, and the French mathematician, engineer and philosopher Jules Henri Poincaré (1854-1912) described this difference two thousand years later: "*The scientist does not study nature because it is useful; he studies it because he delights in it, and he delights in it because it is beautiful. If nature were not beautiful, it would not be worth knowing, and if nature were not worth knowing, life would not be worth living. Of course, I do not here speak of that beauty that strikes the senses, the beauty of qualities and appearances; not that I undervalue such beauty, far from it, but it has nothing to do with science; I mean that profounder beauty which comes from the harmonious order of the parts*". We will discuss later what beauty means because in my opinion beauty is the bridge between the three cultures. The Greek scientists began to build scientific logics – the main scientific principle. The scientist was like a creative artist, working not with paint or marble but with the unorganized sensations from a chaotic world [12]. It was later brilliantly proved that logics and intuition play essential roles both in science and art [13].

For supporting the epigraph by Theodore von Kármán to this section, I would like to cite: "*Engineering is quite different from science. Scientists try to understand nature. Engineers try to make things that do not exist in nature. Engineers stress invention. To embody an invention the engineer must put his idea in concrete terms, and design something that people can use. That something can be a device, a gadget, a material, a method, a computing program, an innovative experiment, a new solution to a problem, or an improvement on what exists ... Most often, they are limited by insufficient scientific knowledge. Thus they study mathematics, physics, chemistry, biology, and mechanics. Often they have to add to the sciences relevant to their profession. Thus engineering sciences are born*" [14].

Usually people think that science predates technology and engineering. Human history showed that technology predated both science and engineering. I will give only two examples where technology and engineering appeared long before scientific understanding of these phenomena. The first example concerns the invention of steam engine [3]. The steam engine was invented and worked long before (130 years!) the explanation why and how it worked. American scientist Lawrence Joseph Henderson (1878-1942) said in 1917 that "*Science owes more to the steam engine than the steam engine owes to Science*" [12]. Another example is the invention of the daguerreotype process of photography in 1839 by a French artist and physicist Louis-Jacques-Mandé-Daguerre (1787-1851) long before the scientific explanation of how it works. Both inventions resulted in drastic changes in our life, in science, in technology, in engineering, in industry and, of course, in art.

Now we discuss different meanings and definitions of the word art. First, art (the Latin term ars) is any skill or ability that can be learnt by practice (i.e. for practicing of a profession). We should mention that the Greek word ars means téchnē, translated as skill or craft. Probably, that was the first use and meaning of the word art and people did not differentiate art and technology in the ancient times. There is today a second definition of art. The Encyclopedia Britannica defines art as "*the use of skill and imagination in the creation of aesthetic objects, environments, or experiences that can be shared with others*" [15]. In another encyclopedia by Brokgauz and Efron, we read that *"art is a field of human activity related to satisfaction of spiritual and noetic needs of a man, namely, love to beauty"* [16]. Thus, we can define shortly that art is skill in the creation of something beautiful. The third use of the word art is cunning, trickery, trick, or wile. We will denote only the second meaning. Art is something that stimulates the individual's thoughts, emotions, beliefs, or ideas through the senses. Generally, art is made with the intention of stimulating thoughts and emotions. According to Tsion Avital [4, p. 266], "*art is an expression or embodiment of certain basic attributes of* ***mind*** *by means of the composition of aesthetic elements such as color, form, and so on*" (for instance, motion

and sound – my addition). Then the author wrote that "*I have called these basic attributes* ***mindprints*** [4]. *These metastructures are fundamental attributes of mind and reality, such as connectivity, complementarity, open-endedness, recursiveness, hierarchy, transformation, symmetry, and their complementary opposites*." A similar situation occurs in engineering and science. Why does art exist? What are the functions of art? Let me emphasize only its main functions [13]: reflection of the spiritual and material world, to give pleasure, communicability, to get to know, aesthetics, education (teaching and learning) of people, documentation, and even political purposes (for instance, as was in the former USSR: social realism, placates, etc.). As we see, the aims of art have been expanded since ancient times when they were used only for documentation, communication, and education.
It is not simple to evaluate the place and the role of art in the modern society where scientific and technological revolution plays a dominant role. We will be able to do this in 10-20 years. We can name our time as scientific-technological-artistic computerized revolution. Two important constructions of our beings exist: mind and emotion, science and belief. They are not the same, but a man cannot live without both science and belief. Because science without belief is inhuman, and belief without knowledge is blindness. A relationship exists between them. This is art [6]. Nowadays technology satisfies the requirements of art and gets an impulse after every new discovery in science.

Mutual influence of science, technology, engineering and art

"*…Ars sine scientia nihil est" Art without science (knowledge) is nothing*.
The Latin proverb
"*Science and engineering without art are boring and non-productive endeavors*"
(The author of this paper)

I would add that art without science and technology is nothing; but the opposite is also true. In order to understand the interaction between the three cultures, we should investigate mutual influences. First, how inventions in science and technology influence art is exemplified by the creative work of the Spanish painter Salvador Dali (1904-1989) who had special interests in materials science, nuclear physics, optics, biology, psychoanalytic theory of Sigmund Freud (1856-1939) and new technologies. The painting "The Persistence of Memory" can stand as an illustration of Dali's theory of hardness and softness [17]. The principle of hardness involved such things as the rocks and cliffs at Cape Creus, where the Pyrenees meet the sea. Time (soft watches) symbolizes softness, similar to changeability and current sea water. The invention of holography by Dennis Gabor (1900-1979), a Hungarian – British electrical engineer, is found in a stereoscopic painting by Salvador Dali. Holography is opening the third dimension for the artists. Thus Salvador Dali combined art with the most modern technologies. As a result we can enjoy the stereoscopic picture "Sleeping Smoker" and others. Another example is the picture "The Three Sphinxes of Bikini" of Salvador Dali which was painted after the dropping of the atomic bombs on Hiroshima and Nagasaki in 1945. As a result, nuclear and atomic painting in the creative work of Salvador Dali occupied nearly 35 years. Another example concerns the painting "Starry Night" (1889) by Vincent Van Gogh (1853-1890). It was suggested that this painting which appeared to show a spiral nebula with an accompanying swirl was inspired by the sketch of the Whirlpool Galaxy (nebula M51) made in 1845 by the Irish astronomer Lord Rosse (1800-1867) [11, pp. 183-184].
Here is an opposite example: how art influences science? The Steady State model of the universe as an alternative to the Big Bang model of three British physicists Fred Hoyle, Hermann Bondi and Thomas Gold was inspired by the circular plot of the film "Dead of Night" which they had watched together in 1947. The plot is that something takes place in some village, but everything remains the same at the end of all the changes. In brief, the movie was a ghost story that ended the same way it started. This got the three scientists thinking about a universe that was unchanging yet dynamic. This is similar to the river in which water flows but in general the river remains unchanged.
We can conclude from this example that we should teach any child, young man, pupil, student, engineer, scientist, artist and educator to grasp and perceive art, as we teach reading, writing and calculating. Who will win? Every person, because his life in this case will be incredible. As a result people will be more creative in any field. We know from ancient times that scientists may be and

should be artists for the development of science. And … engineers also should be artists for their creative work. Thus, science and technology need art. One of the examples is blending of art, architecture and engineering in education [18, 19]. We should popularize art (among scientists, engineers, educators, and students – my addition) which promotes formation aesthetic and high moral (spiritual) principles mobilizing aspiration for self-knowledge and self-realization [20].

Development of technology, science and art

"Technology, like art, is a soaring exercise of the human imagination."
Daniel Bell (1919-2011), an American sociologist and writer

"Science calms; art exists for not to calm."
George Bracque (1882-1963), the French artist

We have some questions related to our spiritual condition. Where do science and technology develop? Are we always happy and satisfied with their achievements? What do we lose? Scientific – technological revolution was a favorite term in the second part of the 20th century. All achievements of science and technology have two-Janus faces. Let me mention the case from the Bible when Tuval Cain (not the same as Cain!), son of Lamech and Zillah, made the first metallic instruments from iron (probably, carbon steel) for agricultural work. His wife said to him once: "*I am afraid that your achievements can be used against people*". We know well that not all technology (engineering and science too!) has been used for peaceful purposes. The development of weapons from clubs and swords to nuclear bombs has progressed throughout history. Many artists and philosophers reacted positively or negatively to achievements of science and technology, and development of the industrial world.

We live during a computer revolution. Everything around us is computerized. Computer is the common feature, platform, where our cultures or polyspheres have cross-sections. Our generation is eye-witness to many scientific and technological achievements, described before only in science fiction. I remember well how we were amazed when hearing on October 4, 1957 on the radio about the first artificial satellite, the sputnik. Four and a half years later on April 12, 1962 Yuri Gagarin was in the Cosmos. We felt that a man could do anything. Interaction, interrelationships, mutual penetration of these three parts (technology, science and art) of our beings occupies an important, probably a central place in the lives of many people. Man is at the center of all these interactions.

We can find common features between art, science and engineering. The people of the three cultures widely use a system of attempts and experiments, as well as their organs of sense for the study and understanding of phenomena in the universe, their explanation and prediction. The words of Leonardo da Vinci that "*all our knowledge begins from sensations*" may be related by the same manner to art, science and technology. This is very important in education which must begin in early childhood. Intuition plays an important role in art, science and engineering. For artists, the feelings are most important. Scientists are close to artists in such approach as logics and intuition which occupy an important place in their work and life [13]. In spite of many common features in three cultures and development of science and technology, "*there is no progress in art*" [21, p. 10]. Any scientific and technological achievement is based on predecessors. We can improve any achievement in science and technology. But … nobody can improve paintings of Leonardo da Vinci, Raphael and Botticelli, sculptures of Bernini, Rodin and Archipenko, musical compositions of Chopin, Tchaikovsky and Schnittke. Development of science and technology, of course, depends on the personality of people at a particular time. If Galileo Galilei, Isaac Newton or Albert Einstein were not born, other persons would have replaced them. Inventions in science and technology are inevitable. But … nobody could replace great artists. What is the most common feature in three cultures? In my opinion, searching for beauty – this is the main task of our existence. This is the reply to the question why do we live? We search for beauty in any step of our existence, in art, in science, in technology, and in engineering.

Beauty is a meeting point of three cultures

"*Everything has its beauty, but not everyone sees it*"
Confucius (551-479 BC), a Chinese thinker and philosopher

Beauty belongs to a philosophical aesthetic category and many definitions exist. Many philosophers, people of art and scientists discussed what beauty was. There are many researches about beauty in art and science, beauty of soul and character of a person (described in literature and poetry) and its place in the lives of people. But … we did not find researches about beauty in technology, engineering and industry.

People perceive and feel beauty through their organs of sense, including intuition. Beauty is a quality which is impossible to measure and give a quantitative estimation. There is no scale for beauty. The variety of the objects of beauty has been used as an argument for beauty's subjectivity [22]. Elaine Scarry wrote a manifesto for the revival of beauty in our intellectual work, as well as our classrooms [23]. Which neuro-psychological processes occur in the brain of people, when they say beautiful tree, beautiful picture, beautiful sculpture or beautiful music? We are far from the deciphering of biochemical processes occurring in our organisms during perception of beauty. Beauty in any context is not simple to define, but we all know it when we see or hear it.

Beauty and symmetry play an important role in our lives. Symmetry is an important element and phenomenon in assessing beauty. Symmetry is considered as a main bridge between art and science. Based on general concepts of symmetry, beauty and harmony, it was shown that theoretical physics can be borderline between science and art [24]. This is correct for any discipline. For instance, mathematics was the basis of searching for symmetry, harmony and beauty [25]. Then the same principles of symmetry, harmony and beauty were found in physics, chemistry, physical chemistry, and biology. Then similar things were found in corrosion science [26]. We consider beauty as a main bridge between art, science and technology, especially in education (including teaching and learning).

Physicists and mathematicians are often motivated in their theorizing by a desire for beauty. There is the consensus that the laws of physics and mathematics should be elegant, simple and harmonious, and these factors often act as excellent guides for pointing physicists and mathematicians towards laws that might be valid and away from those that are false [11]. The mathematicians in Ancient Greece were probably the first who connected different principles in mathematics with the aesthetic philosophical principle of beauty. Then physicists contributed to understanding of beauty of physical laws, and now chemists with elegant, harmonious and beautiful chemical reactions, chemical forms and structures including different smells.

We can illustrate how the historical evolution of science and technology influence philosophy and art, and as a result conception of beauty as a philosophical category. The ancient Greeks (~ 4^{th} century BC) were famous for the science of mathematics which was in the centre of its philosophical scheme [27, 28]. Art and all life in ancient Greece were a reflection of this mathematical philosophy. This approach is seen in any work of art (sculptures, architecture, music, theatre): proportions and harmony (symmetry, golden section, Fibonacci numbers). Accordingly, beauty was based on the same conceptions, namely, the physical beauty of the body was considered as harmony and correct (beautiful!) mathematical proportions. Sport in ancient Greece was organized in the service for reaching such beauty. We can even say that art was in the service of such philosophy of mathematics.

The term beauty was specific in every civilization. Jews did not create works of art because it was forbidden to depict people. An achievement of beauty in Jewish architecture was the Temple built/enlarged by Herod the Great in Jerusalem in the 1^{st} BC: "*One who has not seen Herod's Temple, has never seen a beautiful building*" [29]. The concept of beauty among Jews was concentrated on morality, thinking, soul, philosophy, on the spiritual state of a person.

The Middle Ages in Europe (12^{th}-16^{th} centuries) were marked by the development of theology, and this relationship between God and human being was reflected in art and philosophy. Most works of art (painting, music, sculpture, architecture) in this period were created on Biblical motives or were devoted to God. Accordingly, the concept of beauty shifted in the direction of God and Bible motives.

In the 16^{th}-19^{th} centuries natural sciences began flourishing in Europe, presentations and ideas about the world and the place of man began changing. Accordingly, philosophical thinking, art and the

concept of beauty changed. We can see the beginning of a strong mutual influence and reciprocal penetration of science, art, and technology in this period.
The 20th century was marked by intensive development of science and technology, and in 1990 to 2011 our civilization became a computerized society. This computer revolution immediately influenced art and philosophy. In spite of these drastic changes, we did not find an objective definition of beauty until now. Therefore, our findings about the use of the concept of beauty in art, science and engineering are subjective. We discussed also how beauty relates to engineering (technology). We revealed a new realm named art engineering where principles of art penetrated into engineering. Here are some examples: coating of industrial structures from an aesthetic point of view, use of music for productive work of employers, spreading of good smell in toilets and offices, flowers and sculptures outside and inside offices and factories. We are eyewitnesses how beauty enters and achieves an important place in engineering (technology). An elegant engineering decision may be beautiful, simple and harmonious, similar to mathematical, physical, and chemical laws, rules and equations.

Conclusion

"*Where do you gallop, my proud horse?And where will you lower your hoofs?* "
Alexander Sergeyevich Pushkin (1799-1837), a Russian poet, "The Copper Horseman"

We live for searching for beauty in every step of our existence. People saw different places and aims of art, science, and technology (engineering) in society. Therefore**,** splitting of three cultures occurred**.** Historically, they appeared separately. Differences between art, technology, science and engineering were explained. In spite of these differences, they "*have common roots and solve general problems of cognition of the universe"*. The common denominator in these cultures is searching for beauty. The mutual influence of science, technology, engineering and art was shown, but there are not many examples. Development of science and technology takes place, but there is no progress in art. Probably this was the cause of splitting of physicists and lyrics, humanitarians and naturalists which occurred during the history of mankind. The meeting point of the three cultures is beauty which makes our work and everyday life enjoyable. Thus convergence of the three cultures will help the young generation of artists, scientists, and engineers to ensure that our existence is interesting, fascinating, creative, productive, exciting, attractive, rich, and, as a result, beautiful. This process is not natural and educators should take a very active part in this convergence.
What is important, that the interaction between three cultures should more and more enter into education.

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The Spiritual in Postdigital Art: Creativity/Biofeedback/Kabbalah

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Abstract

Postdigital art in our networked world creates an earthbound spirituality that sanctifies all aspects of everyday life while reaching out to all humanity in a circumglobal embrace. It locates spirituality in the humanization of digital technologies. Contemporary spirituality is explored through research on psychology of creativity in art and science coupled with mind-body-spirit biofeedback research and research on kabbalah as a model of creative process at the interface between art, science, technology and human consciousness.

In his book *Concerning the Spiritual in Art*, Kandinsky uses a triangle moving *forwards* and *upwards* towards a spiritually elevated abstract realm of color and form as a metaphor for modern art. Postdigital art in our networked world turns the triangle around so that its movement *downwards* and *outwards* creates an earthbound spirituality that sanctifies all aspects of everyday life while reaching out to all humanity in a circumglobal embrace. It locates spirituality in the humanization of digital technologies.

This paper integrates my research on psychology of creativity in art and science with my mind-body-spirit biofeedback research and my research on kabbalah as a model of creative process at the interface between art, science, technology and human consciousness. My research on the psychology of creativity at New York University and Columbia University led to the development of a conceptual model of aesthetic experience in creative process derived from analysis of my in-depth interviews of prominent artists and scientists. My research at MIT's Center for Advanced Visual Studies led to the creation of biofeedback-generated visual imaging systems through which people form dynamic digital self-portraits through internal body changes detected as brain waves by electroencephalograph and blood flow in capillaries by plethysmograph. At Bar-Ilan University and Ariel University Center, my research focused on kabbalah as a symbolic language and conceptual schema that facilitates understanding creative process as a choreography of the interplay between mind, body and spirit.

I applied this kabbalistic model in tracing the creative process in developing my *Inside/Outside: P'nim/Panim* biofeedback artwork that creates a flowing feedback loop in which internal body processes trigger changes in digital self-portraits and these self-portraits, in turn, trigger internal body

changes. This model is a metaphorical way of thinking that reveals a progression that draws inspiration down into the material world from a higher source where originality emanates, from a place that no "bird of prey knows, nor has the falcon's eye seen" (*Job* 28:7), "that no man has passed, nor has any person dwelt" (*Jeremiah* 2:6). Kabbalah explores SPIRiTuality as inSPIRaTion drawn down in physical reality through ten stages called SPhIRoT. The first stages "Wisdom, Understanding, Knowledge" are derived from two parallel biblical passages, one describing human creation and the second describing divine creation. "God selected Betzalel son of Uri son of Hur of the tribe of Judah, and filled him with a divine SPiRiT of Wisdom, Understanding, Knowledge and artistic skills." (*Exodus* 35:31) "God founded the earth with Wisdom, established the heavens with Understanding; through Knowledge the depths were cleaved and the heavens dripped dew." (*Proverbs* 3:19). The next seven sphirot are presented in *I Chronicles* 29:11: "Yours, God, is the Compassion, Strength, Beauty, Success, Gracefulness, everything in heaven and earth (Foundation). Yours, God, is the Kingdom [of time and space]."

The first stage in the creative process is the sephirah ***Keter/Crown***. *Keter* is (*ratson*) intention to create, (*emunah*) faith that one can create, and (*ta'anug*) anticipation that the creative process will be pleasurable. Without this will to create, self-confidence, and hope for gratification, the creative process has no beginning. *Keter* sets the stage for the *sephirah* of ***Hokhmah/Wisdom*** that requires (*bitul*) a selfless state, nullification of the ego that opens gateways to supraconscious and subconscious realms. When active seeking ceases, when consciously preoccupied with unrelated activities, when we least expect it, the germ of the creative idea bursts into our consciousness. We need to become an empty vessel in order to receive (*l'kabbel*) a sudden flash of insight that kabbalah calls *Hokhmah*. It is the transition from nothingness to being, from potential to the first moment of existence. In biblical words, “Wisdom shall be found in nothingness” (*Job* 28:12). When I asked prominent scientists and artists where they were when they had their most profound insight, none said they were in their laboratories or studios.

In synagogue on Shabbat, I was absorbed in the rhythm of the chanting of words from the Torah scroll following them with my eyes. I was far removed from my studio/laboratory at MIT when I suddenly realized that the word for face *panim* and for inside *p’nim* are written with the same Hebrew letters. I sensed that I needed to create portraits in which dialogue between the outside face and inside feelings become integrally one. When I told my son what had just dawned on me, my mind left the *sephirah* of *Hokhmah* for the *sephirah* of ***Binah /Understanding***. The shapeless idea that ignited the process began to take form in *Binah*.

The first three *sephirot* represent the artist’s intention to create and the cognitive dyad in which a flash of insight begins to crystallize into a viable idea. The fourth *sephirah*, ***Hesed/Compassion***, represents largess, the stage in the creative process that is open to all possibilities, myriad attractive options that I would love to do. *Hesed* is counterbalanced by the fifth *sephirah* of ***Gevurah /Strength***, restraint, the power to set limits, to make judgments, to have the discipline to choose between myriad options. It demands that I make hard choices about which paths to take and which options to abandon.

I thought of a multitude of artistic options opened to me for creating artworks that reveal interplay between inner consciousness and outer face. As an MIT artist with access to electronic technologies, my mind gravitated to creating digital self-generated portraits in which internal mind/body processes and one’s facial countenance engage in spirited dialogue. As I felt satisfaction with my choice, I departed from the *sephirah* of *Gevurah* to the next stage, the sixth *sephirah*, ***Tiferet/Beauty***. This *sephirah* represents a beautiful balance between the counter forces of largess and restraint. It is the feeling of harmony between all my possible options and the choices I had made. The *sephirah* of

Tiferet is the aesthetic core of the creative process in which harmonious integration of openness and closure is experienced as beauty, loveliness, splendor and truth.

The seventh *sephirah*, ***Netzah /Success***, is the feeling of being victorious in the quest for significance. I felt that I had the power to overcome any obstacles that may stand in the way of realizing my artwork. The Hebrew word for this *sephirah*, *netzakh*, can also mean "to conduct" or "orchestrate" as in the word that begins many of the Psalms. I had the confidence that I could orchestrate all the aspects of creating a moist media artwork that would forge a vital dialogue between dry pixels and wet biomolecules, between cyberspace and real space, and between human consciousness and digital imagery. The eighth *sephirah*, ***Hod /Gracefulness***, is the glorious feeling that the final shaping of the idea is going so smoothly that it seems as effortless as the movements of a graceful dancer. The *sephirah* of *Netzah* is an active self-confidence in contrast with the *sephirah* of *Hod*, a passive confidence that all is going as it should be.

The ninth *sephirah*, ***Yesod/Foundation***, is the sensuous bonding of *Netzah* and *Hod* in a union that leads to the birth of the fully formed idea. It funnels the integrated flow of intention, thought, and emotion of the previous eight *sephirot* into the world of physical action, into the tenth *sephirah* of ***Malkhut /Kingdom***, the noble realization of my concepts and feelings in the kingdom of time and space. It is my making the artwork. I constructed a console in which a participant seated in front of a monitor places her finger in a plethysmograph, which measures internal body states by monitoring blood flow, while under the gaze of a video camera. Digitized information about her internal mind/body processes triggers changes in the image of herself that she sees on the monitor. She sees her face changing color, stretching, elongating, extending, rotating, or replicating in response to her feelings about seeing herself changing. My artwork, *Inside/Outside:P'nim/Panim*, created a flowing digital feedback loop in which *p'nim* effects changes in *panim* and *panim*, in turn, effects changes in *p'nim*.

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The logic of curatorship: between displaying and representing as a matter of selection


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Abstract

In the course of curating an exhibition, curators face two main alternatives. The one is displaying which suits mainly Historical museums, Archeological museums as well as Toy museums. The purpose of these museums is to display their objects in an inductive pedagogical way. In other words, the display method is meant to exhibit a gradual development either of the history of a nation, its archeological findings, or in the case of toy museums to point at its history and development.
The other method of exhibiting objects in a museum is the method of representation which is mostly typical to Art museums. Art museums, in particualr major museums in the world, tend to exhibit art under a certain ideology, theory or philosophy, which practically means that only certain items will be represented from an available collection. In this case a curator picks and chooses those items suitable to represent his or her ideas, whereas in the History museum, Natural museum the curator endeavors to display as many items as possible.
The purpose of my paper is to shed light on these two practices – the display and the representation.

The ideas I intend to put forward in this paper are intuitively known and practiced by each and every one of us, even without a title of a curator. After all, we all decorate our houses by hanging paintings, posters, photographs, by placing statues and all sorts of furniture – chairs, tables, cabinets, cupboards, as well as lamps, stereo sets, telephones, computers, etc. to make our private intimate surroundings agreeable, pleasant and cozy.
Unknowingly, we all act as curators facing by each and every choice we make a dilemma of selection - should we use all or most of our collection of paintings, posters, furniture we own and display them in our private homes, or should we choose and pick those we consider important, representing taste, autobiography, political inclinations, etc., and put emphasis on those articles we find significant. In short, should we *display* whatever is available, or exhibit those pieces which *represent* an idea, an inclination, an ideology.
The question I want to raise, is not so much on the praxis itself – *displaying* or *representing*, which to my mind are both legitimate and customarily practiced by prominent professional curators. The question I intend to explicate has to do with the logic behind the two: what does each one of them entail, what are their epistemological and ontological implications vis-à-vis the objects exhibited, and which of the two is suitable for exhibiting art, archeology, natural history objects, toys, fashion, etc.
But before elaborating, let me make a personal note. I consider myself a museum-freak who obsessively visits again and again museums of all sorts: history museums, archeology museums, toy museums, horror museums, fashion museums, natural history museums, and art museums. I never discriminate or prefer one on the other, and I find them all interesting, appealing and educating. Yet I noticed in the course of years that museums not only differ in their exhibiting material, but also by their practice of presentation – the one I label *display* the other *representation*.
My purpose, therefore, is to weigh and evaluate these two options of exhibiting objects and shed light on their nature. To do so I will incorporate two different and opposing points of view: the one

advocated by Quine in his well known paper 'natural kinds', and the other is Wittgenstein's notion of 'family resemblance'.

A display

A display is defined by the Oxford dictionary as a "description; something intended for people to look at; an exhibition; a show; a manifestation; a visual presentation of data". In light of this straightforward definition it would not be incorrect to say that a display is a method, or may I say – a medium, with the help of which a collection of available data is exhibited for people to look at. To make my point clear, let me for a moment, take the Oxford's definition for the word 'representation' and compare it with 'display'. A 'representation' according to the dictionary has an added value, i.e.: it is defined as a presentation of a collection of data with the intention to "convey a particular point of view and to influence opinion or action".
Would it be correct to say that a 'display-action' has to do with forms of exhibition typically exemplified by archeology museums, natural history museums, fashion museums, etc., whereas a 'representation-action' is an open texture action, and as such it is typically exemplified by art museum?
To answer these questions, let me start by analyzing the first of the two, and look upon the logic behind a display exhibition, and at its implications on the status of the curator.
The notion of grouping objects under a specific well defined category goes back to antiquity. It was Plato, and then Aristotle, in spite of the differences between the two, who have agreed that one can not see, talk, nonetheless think without a pre-conceptual framework of forms (Plato) or categories (Aristotle). In his well known Cave Allegory (the republic book vii 514a-520a), Plato tries to convince us that the source of knowledge depends on being exposed to what he later labels as the *agathon*, the form of Good, which stipulates Truth and Existence. The sun (which symbolizes the Good in the allegory) – is the source of knowledge, without which one can not proceed knowing and understanding. Those confined in the Cave, exposed to shadows of light are ipso facto limited in the scope of their knowledge, and as such are unable to see and absorb genuine data. If we translate Plato's idea to modern language we would say that in order to have knowledge (*nous*) and truly (*aletheia*) select relevant data, one needs to have the ability to denote the real by his or her conceptual abstract ideas. Without an *agathon* (the Good), and its derivative forms, we would not be able to sort and cluster objects, phenomena, and events.
Aristotle took a step further by classifying all aspects of reality under ten categories (*Categories chap. 5*) such as substance, quantity, quality, relation, place, time, posture, state, action, passion. One can not use language without referring to these categories, nonetheless, one can not apprehend reality and be able to see, recognize and define data, without them. A precondition for forming the notion of colour, of a plant, of an animal, etc., is to have the ability to use these categories. A horse is identified as an animal not by language itself; a horse is identified as an animal because it materializes a suitable category of *horseness*. To identify a horse as a furniture, or as an art object (as does Maurizio Cattelan) would be considered by Aristotle as a categorical mistake, and yet if we look at it from a wider angle, we could say that breaking a category, as done by Demian Hurst and Cattelan, is an expansion of a category without violating its boundaries.
The legacy of Aristotle is still relevant today. Indeed, our craving to give meaning to reality, compels us to cluster objects, phenomena, events, under specific and determined categories. Only those objects, phenomena, etc., which conform to this principle of categorization, labeled by Quine – *natural kinds*, are allowed to be clustered under a group. An object is considered a *table* if and only if it materializes the category of tables, i.e.: it resembles those objects found suitable within the category of tables.
The question now is how a category, i.e.: a natural kind is determined. Quine[1], though reluctant to admit the power of induction, bases his idea of natural kinds on the assumption that if a, b, c, are of the same manifested feature (black), they are all ipso facto a group. That is to say – in order to be able to identify a group of objects and understand their featured characteristics, let us say – archeological relics, toys, fossils, etc., their grouping under one roof should conform to the logic of natural kinds, i.e.: inductively resemble each other. It would not be a far fetched conclusion to say that induction entails a display form of presentation, and one can not display objects, point at phenomena in nature,

or at historical events, without assuming their similarity of each natural kind respectively. For example: a display of fossils in a natural history museum is based on the assumption that the next table of the exhibition will show something similar, close to the family of fossils, minerals, etc. but not a collection of fountain pens. Sorting for Quine (as well as for his predecessors – Plato and Aristotle) is a key word for knowledge, and the fact that sorting is based on similar natural kinds, puts the act of selection carried out by curators, in a very tight position. That is why exhibitions of anatomy, history, natural history, toys, archeology, ethnic and fashion, are all considered a display, based on induction and natural kinds. Choosing objects in a display framework, is a non-open game, i.e.: the rules of induction and natural kinds should strictly be carried out dictating the curator's picking and the choosing. That is why an object in a display framework manifests features presented by its very existence; omitting an object in a display is a lacuna of features which can not be reconstructed by another object. Take for instance an exhibition in a natural history museum: a stuffed bird of a certain species can not be replaced by another stuffed bird of a different species. Either that very bird is shown in the exhibition, or it does not. The same goes with archeological objects, articles of fashion, etc. – each one of the exhibits has its own merit, un-replaceable by another one.
That is why a selection of objects rendered in a display presentation denotes the content of the exhibition. Natural history, fashion, toys, can not be exhibited without a straightforward reference of objects specified for that purpose, which allows for original as well as surrogate objects to be displayed. To display a heart in an exhibition of anatomy, one does not need to display a real heart; a simulated heart either by a poster or a plastic model will do. That is the reason why a display allows for artifacts, surrogates, and pictorial representations by posters or photographs, as a means of an exhibition, whereas under the framework of a representation rendering of exhibits, artifacts and surrogates would not be allowed for replacing real and original exhibits. To represent an idea like freedom, and replace the Guernica with a poster or a model, would no doubt abuse the very idea of the exhibition, nonetheless the merit of the curator.
With this in mind we can conclude that a display exhibition is an archive of knowledge and the power and status vested upon the curator are retrieved by and from the items found in the collection of the museum.

A representation

As mentioned earlier, representation is defined by the Oxford dictionary as a "presentation of data with the intention to convey a particular point of view and to influence opinion or action". If we adhere to the Oxford definition, i.e.: that representation is a collection of data with the purpose to convey a particular point of view, then picking and choosing data are subordinated to the interests, motivations and experiences of the curator. Only those items that are found by the curator contributing to the cohesion of the collection and manifest a shared interest with the group at large, are allowed to be exhibited. To admit an item to an exhibition simply means that the very item manifests a shared trait with the collection already agreed upon, or with the idea behind the exhibition, which is determined by a network of similarities overlapping and criss-crossing, better known as family resemblance advocated by Wittgenstein [2].
Family resemblance entails that though there are no features of similarity in a group of objects, they may nevertheless be considered a group due to their multitude relationships and shared interests vis-à-vis each other. Take for instance an adopted child who by no means does not resemble the bulk majority of the family he is in, and yet he is considered an equal member of the family on the basis of his shared goals, motivations, interests with the group he is in. An adopted child may under certain circumstances represent his foster family not on the basis of genetics or phenomenological resemblance, and yet he may legitimately forward the family's values, motivations, shared goals, business, due to his subjective identification with the group he is in. It seems to me correct to say that one can not manifest a shared interest of a group and represent its multitude relationships, without being carefully and meticulously picked and chosen. That is why an art object may cohesively function in a certain exhibition on the basis of its multitude relationships representing an ideology, aesthetic values, political messages, etc., and the very same item would in another context become a member in a totally different exhibition, representing opposing values.

Choosing objects in a representation-action framework is, therefore, an open texture activity, exercised by the power, interest, belief, values of the curator. Another curator, a different context of values, would no doubt change the picture and constitute ad hoc new, unfamiliar and even bizarre rules of representation.
Though by a representation of values we deepen our experience, broaden our sensitivity, and become aware of the environment we live in, the fact that the same item may acquire under a different selection a totally new and unexpected interpretation, bring to the open epistemological questions as to the effectiveness of an exhibition. Would we not prefer long term exhibitions as in the case of a *display* of anatomy, archeology, and the like, instead of *representation* exhibitions based on undercurrent motivations? Do we go to see exhibitions just for the sake of exposing ourselves to new, intricate interpretations? Or our motivation to learn, broaden our knowledge are incentives to visit museums?
I am not sure I could answer these questions in this short note, and yet I feel, as an obsessive visitor to museums, galleries, alternative shows etc. that the space hosting the exhibit, and the curator as an agent of culture, implicitly obey to my two major concepts: representation and display.

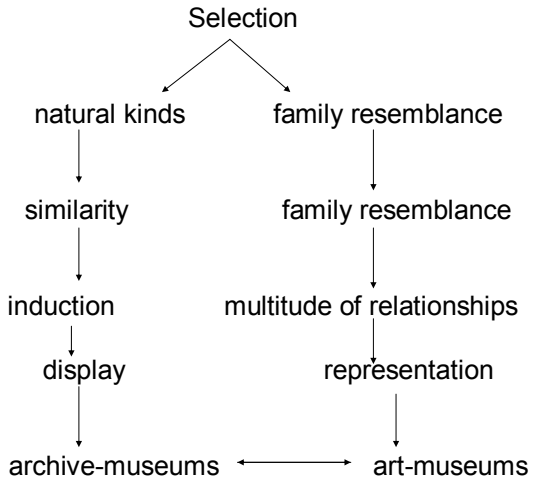

Figure 1: A table describing the two acts of selection.

Conclusion

By distinguishing between the 'display exhibition' and the 'representation exhibition' our knowledge and understanding of museums as vehicles of data is broadened.

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[2] L. Wittgenstein, 1963, Philosophical investigations, paragraphs 65, 66, 67. Oxford u. press

Inter-relation between absolute and relative in science and art via relativity principle to means of measurements

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"How, What For and Why does Absolute become Relative; Unchangeable, Infinite and Eternal become Transient, Finite and Changeable? This is the basic question of the philosophy."

Jnanakrishna [1]

1. Problem Statement and Approach. There are no other sources of knowledge other than experimentation. The knowledge base from different spheres of human activities (e.g., Science and Art) was woven from the enormous abundance of facts derived from experiments, either planed or spontaneous.

Facts form the starting point for Science and Art and partially overlap (e.g., a strip of color which we see is a fact for both physicist and painter). However, diversity of our world and variety of interests has led to a situation that can be defined as interdisciplinary incomprehension: representatives of Science and Art develop their own methods of study and are accustomed to different methods of thinking. The main stumbling blocks in the way of contact between the disciplines are terminology, unusual concepts, different estimation of the authenticity of facts and understanding of methodology.

In spite of the differences, at all times throughout history the best intellects of humanity attempted to find what stays invariant (*absolute, unchangeable, eternal*) and what is relative (*changeable, transient*). They intuitively understood that Absolute on one side, and Relativity and Uncertainty on other side are inevitable complementary parts of human existence.

In modern Science, there are three Relativity principles: Galileo, Einstein (considering relativity to different frames of reference), and Bohr-Heisenberg Complementarity/Uncertainty principle (accounting the relativity to the observer/measuring device). All these principles can be unified by Relativity Principle to Means of Measurements, where Mean of Measurement implies both frame of reference and measuring device properties. The unified Principle allows us to distinguish what stays invariant (absolute, unchangeable) and what is relative (changeable, transient, uncertain) for enormous variety of Subjects, Objects and their Interactions.

As human history shows, the general principles established for one field of knowledge, can be applicable in another. In this work, the Relativity Principle to Means of Measurements is applied to the Arts, namely – painting and sculpture from ancient Egypt/Mesopotamia, Greek/Roman periods, through Middle Ages/Renaissance till Impressionism/Modern Art. Relying on unprejudiced scientific approach, via unexpected but convincing comparisons, the place of the Relativity Principle to Means of Measurements in Science, Art and general human values is demonstrated.

The relationship between Absolute, Unchangeable, Invariant on one side and Relative, Changeable, Transient on the other side, as well as their inter-conversion through human history from ancient times till modern era is traced.

2. Mental Experiment. In everyday life people are guided by visual images in their mind: images of so-called perceptive space. Along with a "subjective" visual perception also exists an "objective" space in which people live, but which is not immediately seen. In order to give visibility

to this statement, let us conduct a simple mental experiment. Let us ask several people in different parts of, let say, Notre Dame de Rouen Cathedral, to paint what they see as it looks from the place where each of them is located (Figure 1). In addition ask each of them to draw a plan of the Cathedral. Obviously, drawn plans will look more similar one to another than the pictures, drawn from different perspectives.

Figure1. Illustration for the mental experiment: (a) appearance of the Notre Dame de Rouen Cathedral, France, from several different random perspectives (changeable, transient, relative visions); (b) schematic plan of the Cathedral (invariant vision we all agree on it).

People, therefore, deal with two different spaces: “perceptive” and “objective”. But what is more "real": various figures drawn from different perspectives (showing multiple realities that people really see) or abstract plan (showing something that in practice no one sees, but performs a useful function)? Besides, what is the inter-relation between these two realities? Understanding of how we sense and perceive the world will help us with the answer.

3. How do we sense and perceive the world. Philosophers of all times and countries agree on one thing: all information about Reality (external world and ourselves) we obtain through our 5 senses. Signals coming to the brain through the senses serve as the primary "building blocks" in our knowledge of the world.

For convenience of description of the cognition process, let us divide entire world into three interrelated components: (1) a Subject (our "I"); (2) an Object (all which is "non-I", multiplicity of objects and phenomena of Reality), and (3) Method by which Subject perceives and cognizes the Object. Let us consider the relationship between the *Subject*, the *Object* and the *Method* in the process of cognition.

In the process of evolution, we have learned to see (perceive through the eyes the radiation in the “visible” part of the electromagnetic spectrum), listen (capture acoustic vibrations in the "audible" part of the spectrum), etc. The Subject perceives signals coming from Object in Spatio-Temporal coincidences in which Reality (facts surrounding us) manifests itself (see Figure 2).

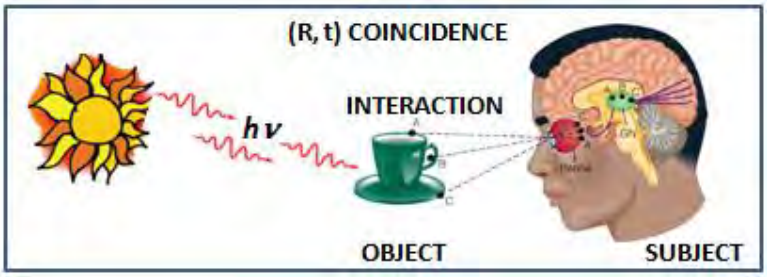


Figure2. Reality (e.g., cap) manifests itself in Spatio-Temporal (R, t) coincidences of signals from Objects with senses of Subject. For seeing, light from the source is partially reflected from the object, reaches an eye lens, inverted and projected on the retina, converted to electrical charge and transferred through axons to neurons. Similar processes take place for all 5 physiological senses.

Five human physiological senses possess limited sensitivity and detection limits. In spite of this, and *led by ego and desire, man has always aspired to extend the limits of its "I" in the process of cognition, and comprehend the nature in its two extreme forms: very small* (Micro-Nano-Picocosm, etc.) and *very large* (Macro-Mega-Gigacosm, etc.).

As a result, through the centuries of study the world around us can be allocated qualitatively into different systems of objects constituting an *hierarchy*: elementary particles (hadrons, leptons), nuclei (system of protons and neutrons), atoms and molecules (nuclei and electrons), macro-bodies (huge complexes of atoms and molecules), the solar system (a bunch of planets and massive stars), Galaxy (collections of star systems), and the Universe (agglomerates of Galaxies) (Figure 3).

Figure3. Different systems of objects constitute a hierarchy and possess unique features that characterize Subject-Devices-Object interactions.

Common to all objects (regardless of their position in the hierarchical scale) is that our judgments about their characteristics are based on the analysis of interaction of object with measuring devices. These *devices are an essential intermediary between our perceptions and the objects, and serve as an extension of our five limited physiological senses*. The opposite is also true: human senses can be considered as instruments installed into human body.

The use of devices allows us to penetrate previously inaccessible spatio-temporal areas of the universe. In the space, we have learned to operate at intervals from 10^{-15}m (diameter of a proton) to 10^{26}m (the distance to the most distant photographed space object), ($\Delta\sim10^{41}$!). In the timeline, we have learned to operate at intervals from $\sim10^{-22}$s (proton vibration in the nucleus) to $\sim10^{16}$s (~age of the universe).

Each link in the hierarchical chain reflects historical milestones in the research stages of human cognition and possesses unique features that characterize Subject-Devices-Object interactions. Transition from one level to another is usually accompanied by changes of paradigms.

4.a. Means of Measurements in classical and relativistic physics: Relativity principles of Galileo and Einstein. Let us start with the unique features typical for Subject-Devices-Object interactions at macro-level. Based on "common sense" and macroscopic experience, the classic description of physical processes or phenomena is characterized by a number of abstractions and assumptions, namely: (1) independence of phenomenon from observation conditions: *the process of measurement does not change the state of macroscopic objects*; (2) an error (or uncertainty) of measurements can be unlimitedly decreased (accuracy increased), and (3) precise measurement of one physical parameter in specific state does not exclude simultaneous precise measurement of other *in the same state*.

Let us consider a moving macroscopic object (Figure 4.a), the position of which is measured by a "ruler", and time is measured by a "clock". Two sequential measurements at (R_1, t_1) and (R_2, t_2) (Spatio-Temporal coincidences) are needed to determine the speed of the object, $V=\Delta R/\Delta t$. Measurements of coordinates and speed of the body is accompanied by errors δR and δV, so $R=R_0\pm\delta R$, $V=V_0\pm\delta V$.

In classical physics these errors (*uncertainties*) are attributed to the imperfection of the methods of measurements: unlimited improvement of the methods can make the errors small enough providing high enough accuracy ($\delta R/R_0<<1$, $\delta V/V_0<<1$). Ability to perform accurate measurements at the same time of coordinates and velocities in arbitrarily close to each other points allows determining the trajectory.

The only circumstance associated with conditions of observation (measuring device) and taken into consideration in classical physics is the *choice of a reference system*. The perception that the phenomenon should be described relative to a reference system was clearly formulated by Galileo: *the movement of the body (trajectory, speed) as appears from different moving relative to each other laboratories looks different and has relative character*. For example, the drop of a ball looks like a

"free fall" for the observer located on the sailing ship. At the same time, the ball moves along parabola for the observer located on the coast (Figure 4.b).

However, despite of these "visible" distinctions, the laws of classical mechanics are the same in all inertial frames of reference. The relativity of mechanical movement and sameness (invariance) laws of mechanics in different inertial frames of reference compose the principle of Galilean relativity: *within infinite diversity of our relative systems of references, "relative visions", Galileo found what stays absolute, invariant, and unchangeable.*

In Einstein's Relativity theory it was proved that there is no absolute time and space, and each frame of reference K' moving with V~c (speed of light) with respect to the reference system K has its own "clock" and "ruler". The faster speed of K' vs. K leads to the distance shortening ($\Delta L' < \Delta L$) and clock slowdowns ($\Delta t' > \Delta t$); events simultaneous in one frame of reference are not simultaneous in other (relativity of simultaneity). In spite of this variability, the interval, $dS = (dR^2 - c^2dt^2)^{1/2}$, remains invariant.

In Relativistic theory, similarly to the classical physics, the measurement performed by the Subject does not change the state of the Object. Thus, for both theories, *in order to characterize the mean of the measurement it is sufficient to characterize the frame of reference. However, in contrast to Galileo, whose interest prevailed on establishing of what stays absolute, invariant, and unchangeable, Einstein mostly focused on establishing of what is variable and changes from one frame of reference to another.*

4.b. Means of Measurements in Quantum Physics (microscopic objects). Bohr-Heisenberg Complementarity principle. Let us make a step on the hierarchical scale (Figure 3) towards the microcosm and consider the unique features typical for Subject-Devices-Object interactions at the micro-level. Consider a quantum particle, electron, moving along the axis R (Figure 4.a).

In classical physics, two consecutive measurements of coordinates (R_1 and R_2) during the time interval (t_2-t_1) are required for determining the speed of the macroscopic body. Let us try to measure electron's coordinates and speed by analogy with the classical physics by using a photon, quantum of light, as a ruler. However, the interaction of an electron with photon in the first act of measurement, (I), causes a change in the status of electron: it receives energy and momentum from a photon, and changes direction from R to R´. Therefore, the second act of measurement, (II), is not possible for electron *in the same state*. Electrons are so sensitive that *it is impossible to observe their movement without changing their flight path*.

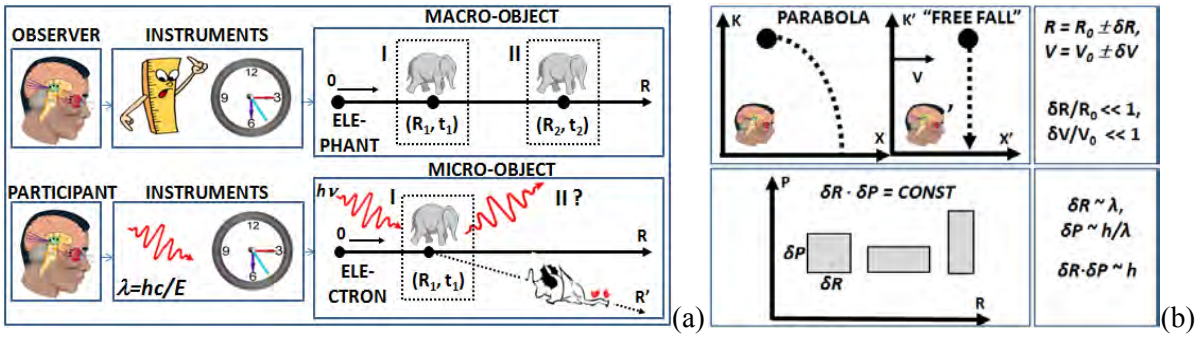


Figure4. (a) Schematic showing differences in acts of measurements for macro- and micro-objects; (b) For macro objects, the measurement does not affect an object, but the same event looks different in different frames of reference (e.g., straight line vs. parabola); for micro-objects, the trajectory is affected by measuring device (photon). Thus, "objective observer" exploring macro-cosm becomes "participant" when explores the micro-world.

The accuracy of electron's coordinate measurement is defined by the wavelength of reflected photon ($\lambda \sim \delta R$). In principle, by reducing of photon's wavelength, λ, (or increasing its energy which is the same), we can determine the position of electron precisely. But photon scattering in clashes with electrons changes the electron's momentum causing uncertainty in the value of its momentum $\delta P \sim h/\lambda$

(comparable to photon energy), where h stands for Planck's constant. Product of uncertainty in coordinates ($\delta R \sim \lambda$) with the uncertainty of the momentum ($\delta P \sim h/\lambda$) yields $\delta R \cdot \delta P \sim h$.

This equation is known as Bohr-Heisenberg uncertainty principle and means that *in microcosm, unlike macrocosm, it is impossible to arrange a measuring process that does not affect the behavior of measuring object*. Interaction that localizes a quantum particle at any coordinate creates uncertainty in the value of complementary momentum, and vice versa.

If in the classical physics the term "inaccuracy" implies that "accurate" measurements are possible, quantum mechanics points to the principal impossibility of simultaneous and arbitrarily accurate measurements of complementary parameters of quantum objects.

The impossibility of such simultaneous and "accurate" measurement, or *uncertainty*, constitutes a base for particle-wave duality of an electron, where *different manifestations of the object do not appear at the same time* (e.g., electron's abilities for localization and interference).

In quantum physics (as opposed to classical) it is no longer enough to set the frame of reference, but we must also specify a measuring device type. *Different measuring devices applied to the same object yield different results which are "incompatible" with each other* (e.g., particle-wave dualism). *These results should not be seen as contradictory, but rather as complementary. The truth is that the description of the phenomenon will be complete only when both complementary aspects are monitored*. Giving preference to wave model vs. corpuscular one is as ridiculous as saying that thermometer says more about the truth than barometer.

During the micro measurement, the observer (Subject), monitoring instrument (Device) and the observed phenomenon (Object) become interdependent and constitute a single non-breaking complex. Previously "objective observer", as appears in macro measurements, becomes "participant" when exploring microcosm. The complementarity/uncertainty principle of Bohr-Heisenberg (or relativity principle to measuring device) is one of the cornerstones of modern physics.

All the above principles (Galileo, Einstein and Bohr-Heisenberg) can be generalized and unified by Relativity Principle to Means of Measurements [2], where Mean of Measurement includes macroscopic observer possessing human senses enforced by measuring devices, and frame of reference. The unified Principle allows us to distinguish what stays invariant (absolute, unchangeable) and what is relative (changeable, transient, uncertain) for enormous variety of Subjects, Objects and their Interactions in macro- and microcosm. Let us apply consistently this principle to the Art.

5.a. Means of Measurements in Art: Ancient Egypt. Analysis of reliefs and sculptures of Ancient Egyptian masters shows that the objects are depicted in their most meaningful and recognizable aspects (Figure 5). In some cases the features are more obvious if the object is depicted in profile, in others – if it is rotated towards the viewer: e.g., the head appears in profile, the eye is drawn as if we looked directly at the person rather than in profile, shoulders are rotated to the viewer, etc. Typically there is no horizon and perspective. *This method resembles modern technical drawing using orthogonal projections followed by convergence of visible from different sides on a single plane* [3].

In addition, drawings of Ancient Egyptians are dispassionateness. The ancient masters sought to remove from their work any emotions: a smiling or angry person or dynamic postures are unimaginable and everything that can change in a moment is unacceptable. Their attention is focused only on constant essence of the object (invariants) which is not associated with immediate circumstances or ever-changing moods or poses in life.

A significant fact is that the "ancient Egyptian" approach is not local but common to almost all cultures of the same stage of development, e.g., Mesopotamia, ancient Hittites and Minoans (Figure 6). It looks as if ancient masters felt as a part of the whole, "We" and not "I", and their egocentrism was not prevailed yet. Thus, *in accordance with the prevailed perception (spirit of time), depicting methods of objects and shapes (existing independently of the observer and common to all people) were dominant*. In some sense, this approach is conceptually similar to that one developed by Galileo, who also examined what stays invariant, unchangeable in constantly changing world.

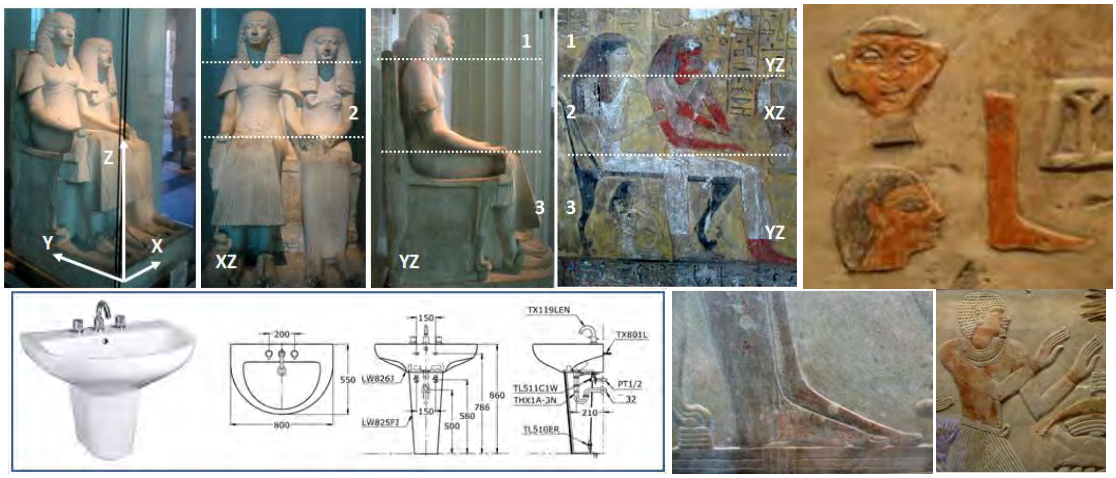


Figure5. In order to demonstrate the most common unchangeable features of the object, superposition of the orthogonal projections (as appear from sides of interest) was widely used by ancient Egyptians. This method is similar to modern technical drawing developed by engineers to demonstrate how "We" (not "I") see the object. Examples of ancient art used in the paper are collected by the author in British (London), Metropolitan (New York), Louvre (Paris), Vatican (Rome), and Heraklion (Crete) Museums.

Figure6. (a) Mesopotamian Chariot's side view is combined with top view of dead enemy (~X century BC); (b) Minoan's top view of sacrificed bull is superposed with side view of the table (XIV century BC).

5.b. Ancient Greece/Rome, Middle Ages and Renaissance. However, the described approach underwent revolutionary changes during ~VII-V centuries BC. During this period, so called *phenomenon of simultaneity* took place [4]: over a few centuries, nearly simultaneously and independently Upanishads were written, and Buddha and Mahavira preached in India; Lao-tzu, Confucius and Chuang-tzu taught in China; Zarathustra sermonized in Iran; Elijah, Isaiah and Jeremiah prophesied in Israel (period of the 1st Temple destruction); names of Heraclitus, Parmenides, Anaxagoras, Democritus, Empedocles and countless others arose in Greece.

During this period, for the first time man felt as a person that placed in a special position in relation to the outside world, universe, and began to be of interest by himself.

The revolutionary transition in self-perception from "We" to "I" was accompanied by increased interest to relative, changeable, transient features on account of an absolute and unchangeable one. This led to revolutionary changes in the drawing methods*: instead of objective, independent from the observer geometric space, ancient masters depicted subjective space of visual perception, mostly moving bodies and objects from the closest environment* (Figure 7).

Degree of body's dynamisation increased from periphery towards head (Figure 7.a). The faces, however, were still static, with no emotions. The body dynamisation mostly explored in Greece was completed by Romans (including faces) only during I-II centuries AC (Figure 7.b).

Figure7. (a) Switch from "Objective Drawing" (static orthogonal projections depicting "unchangeable" features) to "Subjective Perception" (accompanied by increasing degree of dynamisation from body's periphery towards head); (b1) Static Greek vs. (b2) dynamic Roman/Fayum faces;

Furthermore, during this period the methods utilizing superposition of orthogonal projections were replaced by using *parallel perspective (axonometry),* (overlaps with the period when 2nd Temple was destroyed). Pompeian and Etruscans painting are the most famous examples of using axonometry (Figure 8.a). The described approach with minor modifications (which are beyond of the scope of this paper) was used through the middle ages until the next paradigm became dominant.

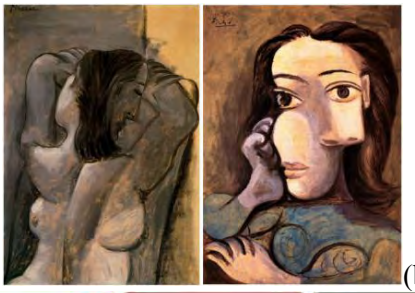
Figure8. (a) Using of axonometry (parallel perspective) instead of combined orthogonal projections: table, chair, column base; (b) Shift from parallel to the Renaissance perspective reflecting further expansion of perception limits of "I" from immediate environment towards horizon, "infinity".

The new paradigm is associated with the Renaissance period, and attributed to human needs to expand further limits of their "I", ego, from their immediate environment towards the horizon (transition from macro- towards mega-, giga-, etc., as depicted on Figure 3). The method of

Renaissance perspective was developed replacing parallel perspective, orthogonal projections, and their mix (Figure 8.b).

5.c. Impressionism and Modern Art. Further human evolution, as reflected by Art, is associated with further continuously growing interest to relative, changeable, transient features on account of unchangeable: "*catch the moment" approach becomes dominant and is completely opposite to the ancient (e.g., Egyptian) perception of the world*. This change of paradigm is analogous to transformation of interests from unchangeable (Galileo) to relative (Einstein). Extreme examples of such approach are shown in Figure 9.


(a)


(b)


(c)

Figure9. (a) Claude Monet, the Notre Dame de Rouen Cathedral at twilight, morning, full sunlight and in the evening (see Figure 1 for comparison); the interest to the same object as appears from the same reference point at different times: (*R = const, t ~ variable*); (b) Pablo Picasso, the interest to the same object as appears at the same time from different points: (*R ~ variable, t = const*); (c) Hokusai, 36 views of Fujiyama: the interest to the same object as appears from different reference points at different times: (*R ~ variable, t ~ variable*). Means of Measurements are equivalent to the frame of reference for all cases.

When this approach was also exhausted, next revolutionary and dramatic leap took place in Art: problem statement "how do "*i*" perceive the *WORLD*" is replaced by "how do "*I*" perceive the *world*". This is associated with the switch from macro to microcosm (e.g. from classical physics to quantum mechanics) made by scientists. Indeed, as was described before, when exploring microcosm, the observer (Subject), monitoring instrument and the observed phenomenon (Object) become interdependent and constitute a single non-breaking complex. As a result, *each act of consciousness at the same time becomes an act of self-consciousness*. The only difference is that in Subject-Device-Object complexes, scientists are still focused on the changes made to quantum Objects (e.g., traces left by particles in Wilson camera), while artists are mostly interested in the changes experienced by Subjects (themselves). Examples demonstrating "quantum" perception and uncertainty principle in Art are shown in Figure 9.

Figure9. (a) M. K. Churlionis, "Truth": uncertainty in approaching the truth is complementary to uncertainty in clarity; *Δ(truth)·Δ(clarity)~const,* which is analogous to *δR·δP~const* (Bohr-Heisenberg relation); (b) silent Buddha - extreme private case of (a): closer to truth – more difficult to express it; (c) Salvador Dali: "Voltaire-twins" dualism; the result of observation depends on the observer ("measuring device", participant) – in analogy with the quantum mechanics particle-wave dualism; (d) "lady-flower" dualism demonstrates Relativity Principle to Measuring Device, where Means of Measurements are equivalent to the Measuring Device type (observer).

In summary, from all the above, it is believed that *people always live simultaneously in two worlds: "We" (attributed to Absolute: Unchangeable, Eternal and Invariant) and "I" (associated with Relative: Changeable, Transient, and Uncertain)*. Sense of "We" is correlative to human's altruism, while "I" is opposite and can be attributed to egoism.

The proportion between these two aspects of human nature is changed through history from ancient world till modern days. The major driving force for changes is lead by human ego [5, 1]. As a result, the methods/approaches satisfying constantly expanding desires and interests are developed.

Let us define the *coefficient of human egoism* as $\varepsilon = (\text{"I"}/\text{"We"})$, where $0 \le \varepsilon \le 1$. In contrast, complementary *coefficient of human altruism* can be defined as $\alpha = (\text{"We"} - \text{"I"})/\text{"We"}$. Thus, $\varepsilon + \alpha = 1$. Idealizing human history as reflected by Art and using the above definitions, *four major stages in evolution of human ego* and "We"-to-"I" inter-conversions can be distinguished:

(1) The first one is associated with transition from Ancient Egyptian period (characterized by $\alpha=\alpha_{max}=1$, when method of orthogonal projections was dominant) to the Ancient Greek miracle (corresponds to the period when ε started growing on account of α: this period is accompanied by increased degree of body dynamisation on account of objective "unchangeable" features).

(2) The second stage is associated with expansion of interests from human body towards its close environment: ε continued to grow, and parallel perspective (axonometry) was invented and widely used.

(3) The third stage is associated with further growth of ε through middle ages/Renaissance; this was accompanied by expanding interests from depicting immediate environment using parallel perspective towards imaging of middle range/far objects/infinity with Renaissance perspective.

(4) It looks as if ε approached its maximum value, $\varepsilon_{max}=1$, during near past/modern ages, which is characterized by extreme interest to constantly changing features and quantum perception (*when the Subject itself becomes an Object*).

More detailed sub-division is possible, which is beyond of the scope of this paper.

Similar trends can be distinguished in Science (see Figure 3), where transition from classical to quantum physics can be considered as a turning point from extreme "I" back to "We". Indeed, as follows from Bohr-Heisenberg Complementarity principle, the description of the phenomenon will be complete only when previously "incompatible" and "contradictory" results (individual "I"-perceptions) are considered as complementary (unified "We"-vision). Such transformation, however, requires revolutionary change in the *structure* of thinking and mutual accepting of contradicting visions [6, 7].

For both Science and Art, the unified Relativity Principle to Means of Measurements allows distinguishing what stays invariant (absolute, unchangeable) and what is relative (changeable, transient, and uncertain) in the stream of human development.

There is a legitimate question: what will be the next leap (paradigm) in development and self-realization of our "I"? It looks as if, at some point, we have to turn back to absolute, eternal, on account of relative, transient. As said by Shri Shankara Acharia (creator of Advaita Vedanta, teaching

about non-duality): "*People constantly and undoubtedly make sure, that transient cannot satisfy them*".

With this in mind, we can expand the basic question of philosophy, as formulated by Jnanakrishna in the epigraph by the complementary question: "*Why, What For and How does Relative become Absolute; Transient, Finite and Changeable become Eternal, Infinite and Unchangeable?"* But this is an object of another research.

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Interdisciplinarity in the eyes of equal treatment ethics

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Abstract
This article tries to show that all kinds of "equal…-ity" work and interdisciplinary success go hand in hand and that a lot of understanding and efficiency in the long run might be lost by forgetting the meanings of the core notions. In this field, the connotations, practices and traditions of equality and equal treatment are as important as the understanding of interdisciplinarity.

Equality as a concept, *equal treatment* as a set of administrative regulations and *equal treatment ethics* as an underlying understanding of what should be done have to be put into practice through interdisciplinary work and cooperation. Interdisciplinarity itself is much more than a mixture and collection of various disciplines bound together for a certain project (however long it should last). Inter-disciplin-arity from a deeper understanding means that a multitude of approaches are not only combined under a certain concept of know-how. Rather, it means to fuse and synthesise, to intertwine and mix all parts of a working project, just like stirring the individual ingredients until they literally become a new chemical substance.

Underlying this idea of cooperation is the view of acknowledging all intellectual and practical members of a project equally. This is seen as the only way to overcome contemporary challenges: to stop calling for universal truth(s) – as if there'd never been experience in multi-cultural, multi-professional teams before – and to build up mutual understanding on every site of cooperation from the beginning. Otherwise sustainability of the project or of its outcome is endangered.

Context
In contemporary debates and discourses concerning design and development of societies and the world there are some issues talked about more prominently than others: amongst those, *equality / sustainability / interdisciplinarity* seem to be equally important. Sometimes one of these three is seen as more important or more urgent or more useful for a long-term positive effect than the others. Mostly these three approaches and strategies of activism and policy tend to be taken into account parallel to each other, or by adding one of them to one or two of the other tasks on the political agenda (either of economic or societal undertakings). Mostly, such programmes and projects in the world of work-life seem to be just practical, up-to-date activities for a better economic performance in a period comprising several decades. Some of them seem to come from a general ideological turn towards what is called higher social responsibility and/or ecological awareness on the part of the top management of companies, universities and governmental and nongovernmental bodies. Most of these new ideas can be found in advertising campaigns under slogans like "our new understanding of economy" or in self-presentation media under the *Corporate Identity Link* on their websites, etc. Practically everybody seems to talk about and work for these goals so there should be no more reasoning about them – or should there? When looking into detail and comparing various practices of performance there is a wide variety of ways and methods – and possibly of understandings what these three keywords really mean and should lead to.

So, as author of this contribution I try to develop and explain how and why it is most important to not only combine but to intertwine and synthesize the very approaches of *interdisciplinarity* and *equal treatment* in order to build up cultures of cooperation under the goal and perspective of sustainability. *Sustainability* is used here as the overall term for the *development (effects) that can provide the basis for an ecologically and politically maintainable future for many generations (7 or more) that the earth as a biological body can deal with as well*.

Furthermore the argument goes that there is no question which of the three goals might be (more) important than the others and that *equal treatment procedures of administrative procedures* often fall short of an overall view so that there is also the need of an *equal treatment ethics* which can be described as the intellectual and value-oriented foundation of the other two parts in this triangle of equality.

Fig. 1: the world is complex

Equal…-ity

As is well-known, on the one hand the idea of *equality* among people is rather old: we encounter it in ancient communities and in contemporary, mainly rural cultures such as the Xuchitán community in Latin America and in most religious beliefs where there is no difference in value of humans before the eternal/divine/God. On the other hand, the notion of *being equal* is rather young when used as a phrase and a topic of general discussion – we can say that this started in the 19th century. Until then many struggles for equality emerged and succeeded for a lot of people who had been less privileged than others before those changes. And still in our times, we can observe and feel differences and inequalities among many groups within the societies, under various aspects of inequality of status and of opportunities to participate in certain spheres of social and so-called private life. So the concept of a society based on equality still is an aim to reach, meaning that some day, in this world there shall not be any discriminating between people that leads to different privileges or opportunities, to discriminating against someone. Instead, individuality and diversity might be observed without leading to inequalities of status/power/possibilities for participation (diversity meaning a multitude of variations of what humans are, might look like, feel like, talk like etc.). So the underlying ideal of equal-ity measures (such as Positive Affirmation Acts) still is working for the goal of an equally liveable life for all, even that it might be called naïve or over-idealistic. Even though it is often neglected, this ideal has always survived the change of political systems.

Bearing in mind that there were centuries of fights for the rights of the less (or the dis-) privileged groups we have to carefully differentiate between the notions of being equal and being alike (or even the same). *Being equal (=equal-ity)* refers to the symbol of the scales of justice (also the word equation stems from that archetype) meaning that at birth any person has the same importance for the world and the same right to life experiences than any other. *Being alike* is an idea that comes later in life and in human history, meaning something like "All who resemble us are friendly and potential members of our group, but all who seem to be different are strangers to us and tend to become enemies". Such an enforcing of features of identity among group members might lead to inter-group conflicts that can escalate, with war as the worst outcome. So in the field of ideas and basic thinking & understanding it is crucial to find out how different and diverse members of a working team can be without feeling estranged to one another.

Fig. 2: how many fruits are the same / similar / of equal worth?

When going deeper into debates and reflections on the ideas of "equal…" we soon will discover that we tend to look for, and set up criteria for determining whether we can talk of similarities, of looking alike or of being put on an equal level while being different as individuals in a certain situation or in a certain way. This also is the fact for general political and legislative history as we can observe for instance in the suffrage fights for the right to vote of black people, people living in the conditions of serfdom and women, from the late 19th to 20th centuries on.

Which aspects should be equated with others and accepted to be equally important is not easy to determine when answering spontaneously. It is due to the complexity of aspects that a lot of cultural research and thinking, experiments and legislation has been set up worldwide in order to find out how to best describe and explain, handle and govern the fact that humans are equal and different at the same time, even in the same moment and context. We all come from the greatest variety of backgrounds and bring in a vast multitude of abilities, experience and capacities as well as ideas, ideals and wishes and have the same basic needs and general longing to lead a life under humane conditions in a similar way, even if never exactly the same. But the way and style in which the amount of ingredients and the fabric of that mixture of single similarities is combined is unique and singular for/in everyone. Therefore, everyone is similar and unique at the same time. In part, this understanding is not only familiar to policy people within and beyond governmental bodies but also to managers of international companies and technical / environmental project teams: how does one best combine and manage all of the diverse tendencies under a given – common – goal? To give an example, a technical project mostly will be designed prior to hiring participants. Many obstacles and conflicts can come up while the work on site develops and might challenge the art of management. When working proactively in the policy field it is not advisable to first design a project and then try to find the respective specialists and practitioners of various disciplines to put it into practice. The legal design of a special policy is as much part of the negotiation processes as its aims, proceedings and outcomes. So there it is absolutely necessary to work from a common ground of shared concepts such as international conventions in order to build up confidence and acceptance among the future partners.

Equal Treatment

In the world of politics the notion of *equal treatment* is seen as the general and operational way of confirming *equal chances* for all – either participants at the workplace or in social life. It is grounded in General Acts of individual states as well as in the Declaration of Human Rights or in declarations of international political bodies such as the United Nations (e.g., CEDAW, the UN Convention on the Elimination of all forms of Discrimination Against Women). At the same time *equal treatment* is a concept of bureaucratic behaviour towards citizens and inhabitants (often with different rights granted to the two groups) as well as a body of administrative regulations at the workplace that shall ensure fair and clear procedures of hiring and proceeding within a professional career scale. The slogan says: *Equal opportunities for everyone*. But as that ideal has proven not to be so easy to achieve it became

necessary to go deeper into discourse. In the course of time many special professions were created in order to make it possible for decision makers to rely on expertise concerning that field. Even competent control and counselling in the sphere of *equal* ... no longer functions without a specialized body of knowledge. So working groups and commissions on equality treatment, equal opportunities, equal pay, equal education etc. have developed parallel to individual trainers and experts on the mainstreaming of (gender) equality and fairness of diversity. Their informal discipline of a special body of expertise now provides help for understanding and intellectual work in general as well as for basic management measures or step-by-step procedures. So by this, a broad notion of *equal treatment* nowadays describes how governments and other leading *players* of the world such as companies, unions or non-governmental organisations should act through their administrators towards "the clients" or "the population" of their respective systems – workers, citizens, pupils, refugees, migrants, genders, ages, sexualities, abilities etc.. The standpoint that mostly is taken there is viewing policy from the so-called *top-down* perspective: (personnel) managers and responsible decision makers start from an understanding of equality as an *aim* to reach. By aiming at that goal many try to promote the chance for an equilibrium among different groups of people (such as gender or race equality) in general. Others stress the idea of equality among all citizens irrespective of their social description as being discussed in the discourse of *diversity*.

When looking at administrative politics in detail, it can be seen that some regulations focus more on the outcome of laws and others on the process of performing an act of administration in the right (correct) way, so there is still a lot of questions to be discussed between followers of both ideas. And as the majority of regulations for administrative acts show, behaviour on the same hierarchical level at the workplace is rarely seen under the notion of equal treatment. In most cases peer-to-peer conflicts and problems are discussed with reference to "fairness" or "acceptance" which both could be misunderstood as "being content with the differences of hierarchy that exist at a given time at a given situation". And there is no answer to the question when, how, in which way and to what extent society will become as equal & open, multicultural & multifaceted as humans themselves / ourselves actually are.

Equal Treatment Ethics as a means of everyday life

In the meantime, acknowledging each other *as equals* might develop such a necessary kind of a *culture of acceptance* before understanding equality in all its aspects, before finding common grounds and goals, prior to any common sense of the ideals and modes of cooperation. This would be a kind of *consensus of everyday behaviour* which is grounded on an *ethics of equal treatment* as a principle and an ideal much more than a formula. Behaving as friendly, as politely and as respectfully to everybody in the team and around the office might be conceived as an outdated ideal of behaviour in comparison to everyday competition at workplace in our times. And billions of tons of gold are invested in conquering new markets and in suppressing small and traditional economical structures worldwide, as in imperialist times. But still, I would like to stress that this situation hinders sustainability and is leading to a multitude of life endangering problems.

The theory of evolution has shown that an overall competitive attitude does not lead anywhere. Instead, many people rely on a basic misunderstanding of the notion of the *ability to survive*. There is no survival of the fittest in nature – "fit" meaning to cruelly overcome every competitor as a lone "winner". There is only survival of the most collaborative in nature – collaborative meaning to build groups of inter-species teams, such as the symbiosis of (different) plants, plants & animals, of various animals among each other, or of animals & humans. This description of cooperation also brings up the questions of power difference and of domination of one species over another or over several other individuals. This has to be taken into account when thinking of interaction among groups of people. And it is very important to bear that in mind in any inter-human interaction. Whenever interrelating among disciplines and groups of people it is possible to overcome hierarchies that result from various (power) differences of participants due to their individual set of criteria of human traits which constitute their individual status (concerning gender, age, ability, colour of skin, race, (sexual) orientation, religion or beliefs etc.) – And, in the reverse form, building up equal status might be forgotten in that process of interrelation and thus would lead to an even more unequal situation than

before because domination or power-over someone still is happening but has been hidden under a blanket of "cooperation".

The *tonality* of honouring and acknowledging everybody with equal respect, equal fairness and equal honesty can be seen as the kernel of what I try to describe by the notion of *equal treatment ethics*. The concept of this notion is grounded in an understanding of life and of people to be simple and complex and structured, chaotic and great and weak, intelligent and stupid and average at the same time, none of these traits being more trustworthy, none of these facets being more true than the other ones. Behaving in a way that tries to take all of these aspects to be equally real and equally acceptable it becomes possible to deal with the behaviour of others with equal self-confidence and (self) respect. At the same time it gets easier to accept their emotional state of being, at a certain moment. The good news about this concept is that there is no pre- or de- scription of what the acoustic tone of that *tonality of honouring* should sound like when it is aimed at a *tonality of equal acceptance*. The bad news is that there is no common sense of what *equality* means in detail still. So how can we see humans in the light of similarity and promote diversity/individuality at the same time?

Maybe this question is much easier to solve than we might expect. If we observe ourselves with cats or other animals familiar and dear to us, we can see how interactions with different individuals of them will be similar, but not perfectly the same in every slight movement. It will differ, but not too much. We will not make identical moves when petting each of them, the gestures will only be rather the same, but not get repeated exactly. We will treat these cats e.g. according to their personality, and at the same time we will not exaggerate our differentiation of words, movements or feelings toward them so much that we'd start treating them as dogs or as birds or as humans. So within the range of similarity instead of sameness there is an *equal treatment (ethics)* towards all of the cats we interact with.

Interdisciplinarity as a means of cooperation

Rather similar to the notion of *equal-…ity* there is some common sense of what interdisciplinary work means, and some diverse ideas on that concept can lead to misunderstandings within the field of intercultural cooperation among various disciplines.

First of all it is important to state that interdisciplinarity is much more of a mutual, day-to-day process of communication and negotiation of understanding than the ideal of transdisciplinarity is – the latter aiming rather at a development of new concepts and ideas that go beyond the boundaries of the given traditions of scientific, technical etc. schools of knowledge. Secondly, both of them are linked and inspire each other in practice. So as a third step here we'll concentrate on the ideas and questions of interdisciplinarity, of how to work together to find a common way of cooperating within the broadest boundaries of all disciplines involved. In this, it is easily possible to acknowledge both the new and the old concepts to the same extent and to use what has been valuable, tried and tested before as functional, practical and efficient with equal respect as avant-garde ideas. Interdisciplinarity in this sense means to accept and cross the boundaries & gaps and differences & similarities & incommensurabilities of the disciplines at stake.

In more than ten years of work for a commission on equal treatment issues in the interdisciplinary field of a university of technology in science and research I have been able to observe and participate in multiple forms of cooperative administrative interactions in that field. That has proved to me that interdisciplinarity is not only normal but also important for practising equal treatment procedures. This means that in every situation of cooperation in a multiple disciplinary organisation (=multi-cultural system) there are only few parts of common logic and language: in their ways of everyday communication, the technical professions differ from the legal professions or the experts on equality issues themselves, both of the latter differing from each other as well. Sometimes such broad diversity of concepts and understandings may lead to mutual misunderstanding and conflict, forgetting that all are standing on the same grounds within their common field.

Fig. 3: … only on top there are many ways out.

Interdisciplinarity as an inter-im

In order to concentrate upon the core essence of interdisciplinarity now, I want to stress some aspects of its linguistic and therefore historic background: The old Latin word of inter-est = *inter esse* shows what our so-called modern approach of *inter disciples* ("among the learning") is about. Whoever tries to be (*esse*) between and in the middle (*inter*) of something has got to really interact and deal with what is happening, with the issues at hand, with those parts of reality that are important, the core – be it hard facts or cultural or emotional phenomena. There is no abstraction and no refraining from reality when feeling *inter-es(t)*, there's a lot of empathy in the meaning of *esse inter* and so there are several typical ways of dealing with it: persistence, exaggeration and loosening/losing interest. So in life and in theory, interest is a notion and a concept that might be discussed as well, and it can have a lot of connotations like the positive, negative, ignorant, affirmative, intellectual, critical (etc.) kinds of interest. Whatever the individual experience with *interest* might be, it is always at the core of interdisciplinary communication. It is the trigger and the aim for meeting and coming together in the professional world and for trying to really understand each other and to find common grounds of working and developing cooperative projects and initiatives.

Provided that this mute and mutual consensus of cooperation between different "families" of "active people" is a need for a successful way of working there should be no question about it. There should be no boundaries to multi-perspectives at all, one might think. Still, as can be tested in any workplace (in a kitchen, on a probe drilling site, on an ocean ship, in a hospital, in the musical field etc.), there are always individual cultures and modes of behaviour typical of a given professional system, let alone of individuals. Some of the traditions in a workplace will be openly known and form some kind of a *body of consensus*, others might get talked over or even disputed about so that they get changed in a managerial process to a new *code of conduct*. Others still might get strongly negotiated about until a common *reglément de traitment / treaty of regulations for the treatment of participants* has been found. In the world of law and politics it is even much more common to build up everyday interaction on the laws and acts of governance than on a (moral) consensus of behaviour. This is easy to understand in multicultural societies and in fields of cooperation where identical procedures seem important for the functioning of the task performed – just imagine situations of danger, with only a short time for possible action.

So, sometimes the need for accuracy and prompt understanding of each others' actions and perspectives is accepted. When trying to find general terms for repeated processes (like in computer manuals) it becomes apparent that now it is necessary to find out how to best combine all of the cultures of working into a common *language*. Former management strategies of a more hierarchical understanding might have imposed one or another *logic of performance* or a special *language of procedures* to the whole staff and tried to do likewise to partners. And all of them failed in one way or another, which sometimes has proven to be minor, sometimes drastically lethal, as when an oil platform crashed because former cooperative and single-disciplinary standards had not been met as

expected and needed (just think of the recent gulf disaster). Some managers learned that cooperation only can work on the basis of mutual instead of mute understanding, that cooperation would mean some kind of equality of team members and that an equal status of all of the part-ici-pant (!) [1] parties including stake holders needs an environment of interaction where all have the same possibilities to express their interests and ideas. So translation was found to be a basic tool for international gatherings and multilingual bodies to find consensus on understanding a situation and the common aim to strive for in order to find and produce overall solutions.

For a sustainable mending of problems an equilibrium between the interests of individuals, groups and humanity's and the globe's interests, needs and aims has to be set up. And as every individual is so different from all others in many respects there is much higher complexity within and between groups of people and even bigger social clusters such as societies than seems to be possible to think of. So some *thinkers and activists for the better* feel it is nearly impossible to find a general description of what humankind is like and of what humanity needs for survival from the ecological = economical crisis. Probably there is no way but by finding out answers and strategies, understanding and working hand-in-hand by human(e)s themselves, every time beginning from the very beginning by inventing new solutions and by using well proven strategies.

Fig. 4: we're all sitting in the same boat on high tides of times.

I want to stress that no way of building a culture of cooperation is stronger or bigger or better than others. Any time a group of people coming from mixed backgrounds (e.g. of disciplines and branches, of fields of work and of traditions of performing work, of individual diversity concerning their human traits etc.) really want to become partners and accept each others' approaches and aims there is huge potential to develop new ways of communication, going on strategically, chaotic, intuitively and reflexively. *Interdisciplinarity* and *equality* have not been regarded as similar cultures of interaction or even as comparable cultures that look alike somehow by most theorists of both discourses so far. But they should be viewed as twins – different & discernable and at the same time equally important for building up a sustainable community of humanity that is able to cooperate cross-culturally and worldwide/worldwise.

Only if we learn to cooperate on equal levels of interaction is it possible for interdisciplinarity to work. Only if we learn to treat each other equally on an interdisciplinary mode of communication is it possible to really promote an equal society on the basis of consensus.

Needing each other:
Equality Treatment & Interdisciplinarity / Interdisciplinarity & Equality Treatment
Research on and theory of communication has proved that there are various ways of listening and thus taking in what has been "said". People focus either on the message, on the challenge, on the meaning, on the intention or on the values and the feelings of the so-called sender when receiving an

information, a question or a remark. Each individual will interpret the same sentence in a different way – not only depending on the *ear of listening* that is most familiar to them and on the moment of interaction but also depending on the "music" that has given sound to the language spoken. Just let us remember how acoustic advertisements work for us as listeners: mostly the voice is much more important to evoke emotions than the words being said or sung or even the picture (film) that comes with it. So it could be very important to talk not only clearly but also in such a way that can best be heard at every level of communication.

From the example of how communication works we can see that successful information depends on the *way* of interaction, of interdisciplinarity. What will be the outcome of co-operation (here, *cooperation* happens between the sender of an advertisement and its receiver) relies very much on the *tonality* referred to above. And as this is true for any kind of communication it is also true for any kind of (inter-)action, it is true for any single act in life and therefore also for a process of *equal treatment* steps. So, the necessity of performing such procedures by fixed standards is only one part to reach the goal of behaving in a way that is equally fair to all participants. The other part is to ensure that cooperators, representatives and administrators are willing and able to bring in creativity and openness into their acts in order to help communication work in the best way according to the goal of transmitting information on all levels of communication available in the sense described here. One of the most crucial parts may be called the *core part of interaction,* it is the underlying *tonality of communication* that is being shared when information is sent. – As we all know from everyday experience among dear ones: music is the basis of life.

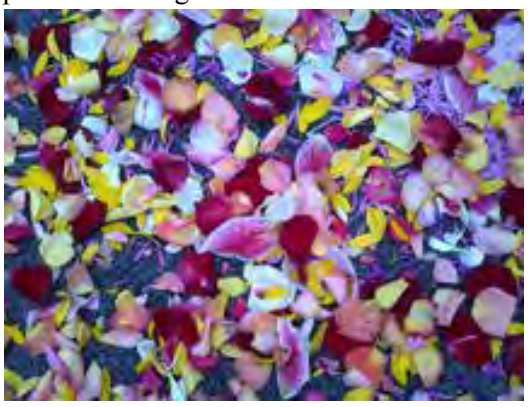

Fig. 5: how many colours does the world contain?

Summary

In order to find out *why things work as they do* it can be helpful to dig into history, so as to find out *how things were put into practice* in the course of time. In order to find out *how things could work as we'd like them to* it is necessary to work on another time span, it is crucial to dream of other ways of reality to emerge and be created in our times. In order to find out *what might be the chances for change at the moment* we'd have to think and experiment on possible ways of future scenarios if things continue to develop in a similar way as they do now or according to the possibilities that we have found out so far or that we are able to invent in creative discourse.

Creating and inventing ever new ways of interaction, being able to deal with changing realities and situations that depend on who takes part in the "game" at a given moment is not only a very complex task. It is a challenge and playful undertaking that cannot be codified in fixed abstract procedures only. It will further develop traditions and regularities that will form *codes of conduct* and *cultures of cooperation* that might be based on mutual inter-standing (in contrast to under-standing) and on inter-esting and on mutual inter-preting (instead of single-sided interpret-ation of each other) and on inter-change (in contrast to ex-change).

The intention of this article is to show some further aspects that might be taken into account when going in for interdisciplinary projects of smaller and wider scope. It is nurtured from the conviction that we are all "sitting in the same boat on high tides of time" – dealing with the understanding and

need of *equality treatment ethics* and being aware of the fact that there is much more to understand still.

From that point on there seems no way left to ensure sustainability but what I dare to call the *way out by the way in for a way through*. Humans have discovered and developed more and more wisdom and knowledge about how crucial it was/is to find out similarities, identical traits, differences, variances and divergences and dis-harmonies between the various participants and parties of the world. So, in order to find out what was/is common and what was/is irreconcilable between two or more of the partners of cooperation and interaction, multiple possibilities have to be offered for various kinds of getting to know each other's view of the world. Even if and given that there are really a lot of conferences called inter-disciplinary, there will have to be many others still, taking into account that the broader the focus of interest the more complex it will be to find *inter-standing* and consensus (possibly even upon dissensus). The same is true for activists striving for the promotion of equality (of age, race, gender, …) throughout time. And as I have tried to hint at – both fields of activity not only need each other to really reach their goal(s). All in all they are two sides of a coin – sustainability being at its core.

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[1] in French "ici" means "here", "on site"

* Much of the inspirations and ideas draw from my experience within and aside of my professional work at Vienna University of Technology: all I try to conceptualise here is being said by me as a private individual and not as an official representative of an administrative unit at VUT.

** Thanks to discussions with professionals in the technological disciplines I decided to refrain from using footnotes in order to "explain what is said above"

*** © of all photographs and the recycling art object owned by the author, for Fig. 4 see: http://www.unet.univie.ac.at/~a8401943/sustainability/2_3H2O/boat_pictures/album/index.html

Humanities and engineering universities

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Introduction

What are Humanities? In many French engineering universities, you can often find either a department of Humanities or a department of Humanities and social sciences. In the French context, these expressions have not the same meaning. The insistence upon Humanities refers to the semantic origin of this word. The word "Humanities", coming from the Latin expression "*humaniores literae*" insists upon the dimension of critical education which is necessary in any formation in general and in the engineers' formation in particular.

At the INSA (National Institute of Applied Sciences) of Lyon, we have a department of Humanities. When this institute was created in 1957, this department was of deep originality. The INSA Lyon was created by Gaston Berger who was himself a non-typical philosopher. After being a business manager, he began the study of philosophy, wrote a thesis on the conditions of knowledge and, after WWII, became the director of higher education in the French Ministry of education. By the way, he was the father of Maurice Béjart, the well-known choreograph.

Fifty years later, everyone in the French education system agrees that engineers must have courses of Humanities. But what kind of courses and in which perspective? The teaching of Humanities in engineering universities often seems taken into a narrow alternative: Humanities courses are taught with the aim of giving students a free, cultural spirit opening thanks to courses such as literature, history of art or, on the contrary, in an adaptive perspective, with courses such as "expression and communication", foreign languages etc.

Are we prisoners of this dilemma or is it possible to overcome it? And isn't it possible, by reference to the title of this paper, to think new links between art, science and technology which may interrogate the concept of Humanities?

I) What kind of Humanities?

A) A false dilemma

The opposition between "adaptive" or "cultural courses" in engineering universities is a false dilemma. On the contrary, I think teaching Humanities in such universities implies to operate an epistemological rotation. We do not have to teach academic disciplines by themselves, out of the context of engineering universities. We have to wonder which elements of engineer's formation can bring these academic disciplines. In such a perspective, we can overcome the contradiction between adaptation and gratuity. In this way, Humanities can play an active part in the definition of the engineer's education. Engineering students will act in the world or transform it not only by developing and using technologies but also by being able, thanks to Humanities courses, to communicate with others, to speak foreign languages, to know the

main rules of management etc…At the same time, Humanities will help students to think the meaning and the consequences of the engineer's action: since the engineer has an action upon the world, what world is it? What science does he use?

B) What world, what science?

Humanities courses will help students to raise the main questions which will give them the ability of thinking our world: for instance, what is globalization, which elements of geopolitics are necessary to understand our world? What are the main aspects of the ecological problem, what are the new technological risks, what do we call a crisis etc…

Besides, one of the main characteristics of our world is the fast development of sciences which modify our vision of things. It is necessary to show students that science belongs to culture. A dialogue between Humanities and sciences has to be developed in order to introduce a symbolical, historical, philosophical, epistemological dimension in the scientific courses and, reciprocally, to show the part played by science in the development of art and philosophy and the elaboration of new visions of things.

For instance, it is a well known fact that the invention of perspective has to be linked with the development of science and more especially with the geometrization of space. Perspective is a way of measuring space which takes place in the scientific attitude which consists in measuring nature. And the action of measuring space in cartography is contemporary to the action of measuring time thanks to mechanical clocks (as we know, Brunelleschi who invents perspective is also a manufacturer of clocks). Besides it is obvious that, during the twentieth century, the revolution in physics, from Einstein's theory of relativity to Niels Bohr's quantum physics, has completely changed our definition of time, of causality, of reality and has a deep philosophical impact. This is why it is necessary to give students the philosophical tools and the background in philosophy, anthropology, history which will permit them to think the relationships between science and culture.

But, concerning engineer's education, another question is meaningful: what are the impacts of technologies upon the world? How to think technologically? I think such questions can give us the possibility of re-thinking the role (or a part of the role) of Humanities and in this paper, I will develop this hypothesis.

C) The forgotten question concerning technology

If engineers have to develop technologies, they also have to think them, to think their impact upon reality, the way they are designed, the process of design itself. This is all the more necessary than technologies impact has been modified since the Industrial Revolution. Technology does not only transform our world and society, it conceives it.

We are facing a paradox: we are living in a more and more artificial world where the place of mankind has been modified. Human being is no longer just "as the master and the owner of Nature" as Descartes wrote. He is more and more the piece of a technological device which is our world itself. But, at the same time, we inherit a tradition which comes from Plato and considers that technical arts are out of *Logos*, out of science, out of thinking. As Bernard Stiegler, a French philosopher, pointed out, the technical arts were rejected from philosophy, from the *Logos*, which was viewed as an all-encompassing, essential and idealized knowledge: "from the very beginning, philosophy examined this techno-logical condition, but in a spirit of repression and denial[1]". Marcel Detienne and Jean Pierre Vernant, two French historians, for instance, underline that Plato "condemns knowledge and techniques that are based on stochastic intelligence. *Sophia* becomes contemplative wisdom; it is no longer the knowledge of the skilled craftsman, in the traditional sense of Homer's times, when *Sophia* described an organized know-how, with its rules and its processes, that was transmitted from generation to generation within guilds, such as blacksmiths or carpenters. All these skills are condemned and rejected by the philosopher of the *Republic*[2]". Similarly, in Aristotelian

thought, the technical arts do not qualify as instruments of knowledge. The technical arts find themselves rejected from the *Logos* and from science. Hence, according to Greek thought, the technical arts cannot be considered as an object of knowledge. They can only be an application of science. In France we have inherited this tradition.

II) Technology and Humanities

A) Engineering sciences and culture

First of all, I think departments of Humanities could be the places where the question of technology could be re-integrated into science and be a way of giving a new meaning to what we call "Humanities". Department of Humanities could be the places where a dialogue between the engineering sciences and culture could be established and developed, first because, as Gaston Berger underlines, "there is no creation without technology. (…) This is why it is perfectly vain to oppose the technological universe to the cultural one [3]".

But, more generally, if technology conceives our world and ourselves (thanks to the growing importance of medicine from our conception to our death), if the definition of humanity is any longer obvious as it is more and more difficult to make a difference between nature and artifact when we appear to be the elements of a huge technological device, questioning technology urges students to question reality itself and themselves.

This is why it can be very useful to set up new interdisciplinary courses which can give students the opportunity to question the multiple dimensions of artifacts, of technological inventions, the relationships between culture and technologies and to ask the question of ethics, of responsibility. For instance, I taught a course whose title was "what is science?" with other colleagues who taught chemistry, physics, mathematics. We used to start a dialogue upon the links between science and technology. It was a way of showing that the concept of science itself is problematic. That was also a way of leaving the definition of technologies as only mere applications of science and, on the contrary, of developing some elements of a science which could be named "techno-logy", a science of technique allowing us to conceive its foundations, forms and issues.

This science could give us the ability of integrating technical arts into *Logos* and Science in opposition with the Greek tradition we have inherited. It could help students to understand engineer's rationality and also focus Humanities courses on the question of creativity and innovation.

B) The engineer's creative rationality

Engineer's rationality is, by essence, creative. It can be referred to the skill which is called "*mètis*" by the Greeks: "*Mètis* is a true form of intelligence and thought, a way of knowing. It involves a complex but very coherent ensemble of mental attitudes and intellectual behaviors that combine flair, wisdom, foresight, mental flexibility, pretense, resourcefulness, vigilant attention, a sense of opportunity, a variety of skills, and long-acquired experience[4]".

This form of rationality, which has been rejected from the field of *Logos*, is the source of creativity and thereby analogous to Giambattista Vico's notion of "*ingenium*". As you know, at the beginning of the 18th century, in *De studiorum ratione*, Vico contested the primacy given to analysis in the innovation process in favor of what he called the *ingenium* by using a latin word: "invention is the distinctive quality of *ingenium* [5]". *Mètis* or *ingenium* are the ability to see and to make relationships between words and between things. The *ingenium* is opposed by Vico to the analytical rationality which is commonly used in science and divides a problem in many parts to solve it and is not a real source of creativity. In this respect, *ingenium* is the root source of both poetry and scientific and technological invention. Hence *ingenium* implies a philosophy of relationships, not substance; it implies a philosophy of

adventure which, by shaking up the commonly accepted order of knowledge, promotes openness to diversity and novelty. It implies a philosophy of knowledge that is open to the unforeseen, that is capable of deciphering the labyrinth in order to reach its goal.

C) New elements of techno-logy

I think departments of Humanities in engineering universities could be places where technology, the science of technologies themselves and of their specific type of rationality, could be taught. Such a program is full of ambition. It means going back on a Western metaphysical tradition that has rejected this type of rationality. It requires a rereading of the history of reason, a "U-turn" in a philosophy that turns the technical arts into a question and a principle of science. But such a rereading will allow engineering schools to become seats for establishing and experimenting with the kind of rationality needed in technological inventions that bring together the thinking and the doing.

Teaching technology is a way of giving a new meaning to Jacob Bigelow's attempt to define "elements of technology" (1829) in purpose of teaching the application of science to the useful arts, which he held from 1816 to 1827. It is a way of thinking again the question of ethics by articulating it with a knowledge of technology. But, teaching technology will, at the same time, lead to understand and teach creativity, inviting students to be creative.

III) Pedagogy of creativity

A) Elements of pedagogy

This is why, in department of Humanities, we could promote an approach to teaching that favors the learning of inventive skills and is far removed from the teaching of abstract knowledge. More especially, we could promote what we can call a "pedagogy of adventure". Such a pedagogy is a way of escaping the contradiction between adaptive and cultural courses. It is an example of the epistemological rotation which implies to start from the engineer's formation and not from academic disciplines without taking account the context of engineering universities.

In such a vision of pedagogy, students have to make the experience of "the otherness". Encountering other ideas and interacting with other people will allow students to experience other visions of the world, other paradigms, and other cultures. Such encounters will lead them to question their intellectual certainties and stimulate their creativity. In the same way, the frequentation of music, painting, sculpture, the practice of artistic activities will be for students the way of making experiences of creativity. In such a perspective, they will realize that creativity is the common aptitude of artists, engineers and scientists which can also share a same experience of the aesthetical dimension of reality. For instance, we have opened a new course which will try to define the connection which can exist between some contemporary painter's process of creation and engineers' creativity.

Students have to be ingenious in order to be engineers. Therefore the teaching of creativity must incite students to tear down the divisions of disciplinary specialization and to question their certainties. Students must be prepared to transgress the boundaries between fields of knowledge and to view knowledge as an adventure in which unfettered exploration will lead to creativity. In return this forces teachers to take a more adventurous approach and to consider knowledge not as an object but as a voyage that will make students question and adapt their certainties.

B) Engineer s' Odyssey

Thus the transmission of knowledge would be combined with the adventure of know-how. Such an approach could be likened to Homer's *Odyssey* for the quick-witted Ulysses

incarnates the *mètis*, the engineer's aptitude, through the way he uses ingenuity to overcome the perils he encounters on his island-hopping voyage back to Ithaca.

Pedagogy of adventure would urge students to experience the unknown and otherness by encouraging them to seek analogies between very different types of knowledge (science and art, technology and culture, etc.). This would require new ways of teaching and transmitting knowledge. For example, students could be encouraged to illustrate their projects through role-plays and acting, just as Ulysses used disguises to better exploit the *mètis* or to use stories and literary invention as a way of examining and appropriating the new approaches with which they are confronted. It could also involve swopping the familiar setting of the classroom for novel teaching environments where knowledge can be transmitted in new ways. Hence, the intellectual voyage could be reinforced by geographical, or even temporal, mobility.

As said before, such a pedagogy of adventure is a way of reintegrating the Humanities into engineering schools and abandoning the divisions between disciplines in order to return to the fundamentals, as Ulysses returned to Ithaca. This means taking a transversal approach to knowledge via an effective interdisciplinarity that introduces to a new cartography of knowledge as new as the archipelago of islands where Ulysses wanders.

Thus students will be invited to experience knowledge through a more adventurous mode of knowledge transmission capable of opening new horizons, inciting an intellectual shift and encouraging the individual appropriation of knowledge that can only be creative. As an example, fifteen years ago, at the INSA Lyon, I set up a new kind of formation I called the "PPH" 'personal project in Humanities" whose function is to give each student the possibility of choosing a subject of reflection, of giving it a personal dimension and treating it with originality and creativity. In other words, in such a formation, the action of knowing implies a personal knowing.

Finally, the encounter of the unknown and otherness could be an encounter with the essence of technique. For, precisely, technology which has been thrown out of *Logos* is perhaps the modern form of the unknown and the otherness. As a French Philosopher of technology Gilbert Simondon writes: "machine is the stranger; it is the stranger in which there is an underestimated dimension of humanity [6]".

This is why the question of technology can be the tool which enables us to give a new meaning to the concept of "Humanism". Discovering the unknown drives to discover the question of technology which is unthought whereas techniques produce a new, artificial world the cartography of it is new and which upset our categories of reality. In this new world, technologies and machines are not only unknown but strange as they are more and more autonomous. Humanism could be refunded through an interrogation upon the new relationships between man and machines, the new encounter of technology. Departments of Humanities in Engineering Universities could be the places where this humanism can be revisited.

Conclusions

The status of Humanities in engineering schools and universities is ambiguous. It often seems they are a way of escaping the engineering sciences as if they only were a supplement of soul given to them. Or, on the contrary, they are suspect of only being applicative. As we have tried to show in this paper, it is a false debate. The question concerning technique can be a way of transgressing this contradiction and helping to make bridges between engineering sciences and Humanities. It is a way to stimulate creativity among students, to develop "a pedagogy of adventure" or, in other words, an odyssey of knowledge. Helping young engineering students to become ingenuous themselves and to draw their way in the new artificial world which is built everyday by the development of technology is our challenge. It is also a way of showing that the question of technology is a way of refunding Humanism.

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Using ornaments for geometry and multi-cultural education: development, implementation and evaluation

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Introduction

The Israeli educational system gives high priority to mathematics as a basis for professional education in hi-tech technology. Studies indicate that teaching mathematics as a culture and value free subject causes difficulties and inequities, especially in multicultural classes. This problem is relevant for Israel with its diversity in languages, cultures, traditions, and mentalities. Educators pay growing attention to fostering self-identity and multi-cultural education towards living in an integrated society. Our goal is to contribute to this trend via mathematics education across cultures based on humanistic values.

There is growing understanding that reforming of mathematics education should be directed towards the principles of equity and pluralism in order to fit the cultural diversity of the contemporary society. In this trend cultural diversity of the classroom is viewed as a resource of mathematical learning, motivated by and stemming from cultural practices [1]. Therefore teacher education has to provide competences of teaching mathematics in cultural context.

The methodology combining mathematics education with cultural anthropology is ethnomathematics, which is "the application of mathematical ideas and practices to problems that confronted people in the past or are encountered in present contemporary culture" [2]. In the ethnomathematics approach, practices from the learners' culture and other cultures facilitate acquisition of mathematical knowledge and expose the learners to commonalities across cultures and societies [3-5]. Through involvement in mathematical activities that are traditional in different cultural environments, students may learn to value the mathematics and develop a greater respect for those who are different from themselves [6].

Implementation of the ethnomathematics approach in the classroom requires from teachers knowledge of the principles of multicultural education and skills of teaching mathematics in cultural context [7]. This includes the ability and motivation to establish personal connections with the students, awareness of their cultural backgrounds and following.

Geometry is in the heart of visual art and culture. Historically, geometric reasoning was associated with intelligence and truth. 11th century Jewish mathematician and philosopher Abraham bar Hiyya

expressed this view saying: *"Who wishes correctly to learn the ways to measure surfaces and to divide them, must necessarily thoroughly understand the general theorems of geometry and arithmetic, on which the teaching of measurement ... rests. If he has completely mastered these ideas, he ... can never deviate from the truth.*" According to the 14th century Arab historian Ibn Khaldun, "*Geometry enlightens the intellect and sets one's mind right. ...The mind that constantly applies itself to geometry is not likely to fall into error."* The world famous sculptor Auguste Rodin emphasized the connection of human emotional feeling to geometry: "*I have come to know that Geometry is at the very heart of feeling, and that each expression of feeling is made by a movement governed by Geometry. Geometry is everywhere in Nature. This is the Concert of Nature.*"

The practice of teaching geometry in schools is often far away from the above views. In Israeli high schools geometry is a theoretical subject usually presented as a collection of axioms, theorems and proofs. Many students face difficulties in Geometry and do not see its manifestation in the real world.

This paper proposes an approach to teaching geometry in cultural context and presents results of its implementation in the teacher-training course "Issues in Ethnomathematics: Teaching Geometry in Socio-Cultural Context".

Course Description

The course development started from an in-class experiment of teaching geometry with different applications, in which we found that constructive activities in cultural context attracted the students mostly. Following this experiment we developed an approach to teaching geometry through involving students in the multicultural inquiry into ethnomathematics. In this approach, geometry is studied through mathematical analysis and construction of ornaments, and inquiry into their cultural meaning. Here ornaments are patterns of cultural value used as decorative details, sacred symbols. An ornament is composed of a basic unit that repeats under different transformations. We see the following advantages of practice with ornaments:

- Geometric ornaments are a rich source of creative applications of geometry.
- Ornaments are part of the world cultural heritage, created in folk art and crafts throughout the history of nations [8].
- For peoples of the Middle East, ornaments traditionally served a means to express spiritual believes related to their cultural and religious identity.
- From our experiments, practice in analysis of ornaments and their construction can attract pupils and students and serve an effective way for teaching mathematics with applications.

The course "Teaching geometry in socio-cultural context" has been developed and implemented by the authors as part of the Technion teacher-training program. It is given to pre-service and in-service teachers and is directed towards developing competence of teaching multi-cultural groups in our country. The 42-hours (3 hours/week, 14 weeks) course has five parts, each involving the students in different learning activities:

1. Acquisition of basic geometrical skills required for construction and analysis of ornaments.
   Ornaments are introduced from the geometrical and cultural perspectives. Basic geometrical concepts are applied through hands-on and problem solving activities guided by an assistant. Students practiced construction of geometrical objects by compass and straightedge and proved that the constructed objects have the required geometrical properties. They applied this knowledge while analyzing and constructing a typical Islamic ornament. As a home task, the students were asked: to define geometrical problems related to the ornament constructed in class, and to construct and analyze another ornament using symmetries and transformations.

2. Building a background for teaching geometry in cultural context by studying mathematical, multi-cultural and didactical concepts.
   Principles of teaching with applications and cognitive mechanisms of learning in context are presented, including the Realistic Mathematics Education approach and Mathematics as a Service Subject approach. Their use in introducing ethno-mathematics into formal and informal education is practiced. We show that ornaments embed on one hand a variety of geometrical concepts, and on the other hand are symbolic graphical expressions deeply rooted in cultures. The value of multi-

cultural education in modern society is emphasized. The course readings are directed to multi-cultural education didactics. Each student is assigned to select a certain culture and perform inquiry into ornaments in the culture.

3. Development of instruction plans and supporting materials for guiding multi-cultural groups of school students in the analysis and construction of ornaments related to a certain culture.
   The students are exposed to the common historical, mathematical, and cultural roots of ornaments. They study ways in which cultures historically expressed their knowledge, beliefs, and traditions by means of visual symbols, most notably, geometric ornaments. Basic symmetric geometrical patterns (regular polygons, circular structures), were shared in ornaments throughout cultures yet representing different meanings. The common instruments for ornament construction were compass and straightedge.
4. Workshop "Joyful learning of geometry in multi-cultural context".
   The course culminates in a workshop "Joyful Learning of Geometry in Cultural Context" in which each student teaches a diverse multicultural group of pupils from Jewish and Arab high schools and guides them to perform the assignment of creating a poster on the chosen culture. The posters include designed and constructed ornaments, related geometrical problems and solutions, and cultural essays prepared by the pupils. At the end of the workshop the groups present their posters at a multicultural exhibition open to the public (see Figure 1).

Figure 1: Learning activities in the workshop

5. Analysis and presentation of findings of the workshop follow-up, and a final report.
   Data on pupils' learning activities and outcomes are collected by means of a questionnaire, observations, and posters.

Learning activities

Problem solving

Problem 1. In the ornament below, given $FB = FD = m$, m is a parameter which determines the width of the strips. Let $|OC| = R$. Find m as a function of R such that $\frac{|YP|}{|PK|} = \varphi$, ($\varphi = \frac{1+\sqrt{5}}{2} = 1.618$, the golden ration).

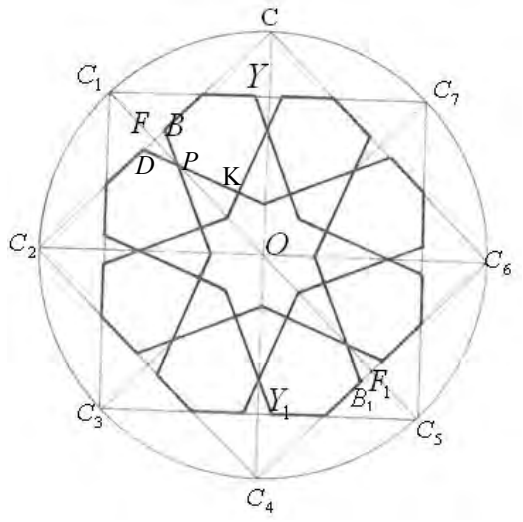

Figure 2: An Islamic ornament

Answer: $m = \frac{-2(\sqrt{5}-1)+4\cdot\sqrt{2}\cdot\sqrt{\sqrt{5}-1}}{2\cdot(9-\sqrt{5})}\cdot\left(1-\frac{\sqrt{2}}{2}\right)\cdot R$, $\quad m = 0.082\cdot R$

It turns out that the solution is in close proximity to a real ornament presented in the album (Talo, 2000).

Problem 2. Using geometric transformations prove that in the presented ornament $|YB_1| = |BY_1|$.

Solution. A rotation of 180° around O moves $C_1 \to C_5$ and $C_5 \to C_1$. Also C_4C_6 moves to CC_2. By choice, $F_1B_1 = FB$ and therefore $B_1 \to B$. Similarly, $Y_1 \to Y$. Hence, in the quadrilateral BYB_1Y_1, the diagonals are equal and bisect each other. So, BYB_1Y_1 is a rectangle. Therefore, $YB_1 = BY_1$ and $YB_1 \parallel BY_1$.

Cultural inquiry activities

Course lectures and discussions introduced the students into historical roots and symbolism of ornaments, the important spiritual role that they play in cultures of nations. The students had become more and more interested and personally involved in these issues. They willingly shared with us impressions about ornaments from their own and other cultures. One student brought to class examples of modern Jewish wedding notations (*Ketubah*). Another student described decorations of Islamic marriage contracts (*Aqd-Nikah*). One more student examined constructional similarity of the two typical Islamic ornaments.

Course follow-up findings

Some findings and illustrating reflections of students follow:

- The more the students inquired geometrical properties and cultural meaning of ornaments, they became more active and interested in the subject.

  "Teaching geometry with ornaments arouses interest and constitutes a learning challenge. When the pupils figure out that this ornament relates to their own culture, this fosters their sense of belonging and wish to explore and study. The same happens with the teacher."
- Some of the students demonstrated creative performances, i.e. constructing new conventionalized ornaments, posing interesting geometrical problems and finding different approaches to solve them.

  "The learning with ornaments was enjoyable. It adds color to the school geometry by means of colorful ornaments and by the stories behind them. Our experience, as learners, aroused the feeling of joy from doing. The workshop preparation was also very joyful because it gave opportunities for creativity. The course, in whole, benefits both teachers and pupils."

- The students gain motivation and became aware of the need to teach geometry in cultural context.

  "The next time I teach geometry, I will integrate the cultural issue. I am a teacher in a multicultural kibbuz school where pupils with western (Ashkenazim) and eastern (Mizrahi) cultural roots learn. So there is a possibility to touch the roots and teach in their context."

  "I am going to adopt teaching-in-cultural-context, because I liked to learn in this environment in the course. It increased my motivated and readiness to learn. The atmosphere was joyful and, despite being different, I felt accepted and equal. The course gave us feeling that each of us made important and unique contribution. The course motivated me by showing the importance of learning geometry and its practical use."

- The students pointed that due to in-class discourse they became more acquainted with their own culture, other cultures and commonalities across cultures.

  "All of us were exciting when told about our own cultures."
  "Due to the discourse in the course, I gained much knowledge about other cultures."

We introduce some of the reflections of the school pupils participated in the workshop:

1. The majority of pupils (82.9%) reported, that the first time they were exposed to cultural applications of geometry was at the workshop.
2. The majority of pupils noted the importance of integrating applications from the history and culture of their own nation (77.1%) and other nations (77.4%) in the geometry course.
3. The pupils mentioned that learning geometry with cultural applications can significantly help them to understand geometry concepts (90.0%), to reveal geometrical properties (88.6%) and to prove them (80.0%).
4. Through the participation in the multicultural groups, the pupils got familiar with other cultures (78.6%) and better understood the way other people think (80.0%).

Conclusion

Implementation of the course showed indicated that the proposed approach helps to develop students motivation and desire to make a deep inquiry in both mathematical and cultural aspects. Several student works demonstrated creativity in geometry and visual design. They developed interesting geometrical problems and found original solutions. Most of all, a conceptual change in the perception of geometry happened. The students became aware of ornaments in their environment, seeing them not only as decorations, but as culturally meaningful geometrical patterns possessing interesting geometric transformations and symmetries.

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Fostering visual and cultural literacy in middle school students through practice in geometric design and artwork

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"I look at geometry as art. When I think of geometry, I think of patterns and designs"

Karli McGowen [1]

Introduction

Educational systems look for new learning pathways, which connect school mathematics to practical and cultural needs of the modern society. Educators point out that many students have difficulties in studying geometry through the formal axiomatic approach and recommend to enrich the studies by productive activities in the real cultural context [2, 3].

Several papers published in the Nexus Network Journal propose environments for geometry education in cultural context. Bender [4] developed a program Math-Kitecture, in which fourth- and fifth- grade students learn geometric concepts through practice in computer aided drawing architecture plans of their school. Gentilin & Bettanello [5] developed a multimedia collection of materials analyzing geometric concepts, such as symmetry, golden section and regular polyhedra, which were applied by the Renaissance artists in their artworks. The authors worked in a vocational school as teachers of mathematics and art and taught the materials through collaboration. They note that this connection helped to motivate the student interested in one of the disciplines to learn the other one. Alati et al. [6] proposed to teach geometry to high school students majoring in visual and design arts trough practice in geometrical analysis, drawing and modeling of seashells. They demonstrate that observing natural forms and their mathematical inquiry are powerful sources for design and architectural solutions.).

Gullatt [7] and other researchers point out benefits of arts integration in school disciplines. The art studies foster students' imagination and creativity, open new perspectives for interaction with the world and show that there are many ways to solve a problem. The students realize that a problem can be approached and solved from the arts perspective [8]. Arts symbols and metaphors help students to communicate on patterns (in terms of line, texture, shape, space and color) and on the principles of their design (in terms of balance, rhythm, repetition, contrast, theme, variation, and unity). Cossentino and Shaffer [9] presented the Escher's World project, in which high-school students learned mathematics of symmetry and basic principles of graphic design using computer technology. The authors argued that the integrative learning approach, implemented in the studio environment,

enhances students' understanding in mathematics and design and arouses interest in both subjects. Post-course tests indicated significant improvement in students' ability to think visually. In addition, as noted by Shaffer [10], many of the students began to use visual representations as supporting tools for solving mathematical problems.

Eglash et al. [11] developed a web-based software package - Cultural Situated Design Tools (CSDTs) which allowed students to create computer simulations of arts in cultural context basing on mathematical principles of these arts such as fractals, symmetry and coordinate systems. Students created computer models of artifacts from traditional African architecture, using fractal geometry. They created geometrical patterns inspired by designs related to the Native American culture, using methods of analytical geometry. Thus, CSDTs helped students to discover connections between culture, mathematics and technology. The studies contributed to reifying the feeling of cultural identity in the students.

Massarwe, Verner & Bshouty [12] presented an experiment, in which tenth-grade students in an Israeli Arab sector school studied geometry through analysis and construction of geometrical ornaments from their own and other cultures. They constructed ornaments using compass and straightedge. Analysis of the ornaments included formulating and proving conjectures about their geometrical features as well as inquiry into their cultural roots.

Art educators point that though mathematics and art both deal with modeling abstract substances, the mathematical and art models are of different nature [13]. The authors considered similarities and differences between the two types of models with regard to such characteristics as creativity, analogy, aesthetics, and expression. They call for establishing connections between mathematics and art education similar to those existing in other areas of human experience.

This paper proposes an approach which mathematical connections in a middle school art course are used to foster visual literacy, enrich artistic design and provide additional tools for artistic expression.

Interaction between Art and Academic Subjects

Art studies have been introduced into the school curricula in the form of self-dependent courses or as components of academic subjects. In the first case the art course poses its own educational objectives [14], while in the second case art serves a mode of expression in the process of all learning academic subjects, i.e. mathematics, history, English, science, and foreign languages [15].

In Israel, visual art is studied as a compulsory subject in primary school, as a mandatory subject in middle school and as major subject in high school. Performing the function of exposing students to cultural values, it is often disconnected from other subjects. The goals of the art education stated in the primary schools curriculum are: fostering creativity and self-expression, development of skills.

The new art curriculum for middle schools suggests a vision of the role of art and its relation to other subjects, considering art as a layer of today's visual culture. The curriculum suggests wide opportunities for creating learning environments that foster visual literacy and artwork skills. In senior high school art studies are considered as a way to integrate different fields of knowledge such as humanitarian and social sciences, science and technology. They introduce students to visual understanding in different contexts by combining a formal class environment with informal environments such as museum or art gallery.

Visual cognition in school education

Many educators point out that visual literacy is an integral part of modern school education. Visual literacy involves thinking critically and analytically about visual information in order to assess both the meaning and the intention of that information as well as using these skills to create new forms of visual communication [16]. According to Bamford [17], visual literacy involves problem solving and critical thinking, and these can be applied to all areas of learning. Visual education provides a foundation for understanding and evaluating aesthetic intention and artistic skills. It also makes students more resistant to manipulation by visual means.

Duncum [18] notes that today, more than at any time in history, we are living our everyday lives through visual imagery. Visual culture has become a hot new trans-disciplinary term, and many art educators use it to describe their primary focus. Visual culture involves three strands that are of

interest to art educators: a greatly expanded but not all inclusive range of imagery, visuality, and the social contexts of imagery, including histories of imagery.

Educators believe that nurturing early visual literacy fosters development of basic skills in geometry and mathematical thinking [19, 20].The prominent Israel artist Yaacov Agam contended: "The education we give our children causes them to be visual illiterates" [21]. Agam Program for Visual Cognition is intended for preschool and lower primary school. Its central goal is to help children develop their visual skills and improve their cognitive development. The Agam Program includes units dealing with different visual concepts. Special attention is paid to the development of visual skills such as identification, memorization, reproduction and reproduction from memory. Research indicated that children participated in the Agam Program improved their visual abilities [22].

According to Sims et al. [23], "to be visually literate, all students must "speak" and "read" the visual language". Sims suggests to acquaint the learner with the principles of visual communication and to practice their implementation in different settings and subject areas. McMullen & Woo [16] propose to foster the students' capability to effectively articulate their thoughts and believes through visual language, and to understand thoughts and ideas of others, as well as facilitate understanding of the relationship between the purpose and reality of images. Raney [24] notes that it is important to develop in students abilities to visually perceive and represent the world in the ordered and systematic way, as well as through intuitive expression. Avgerinou [25] identifies eleven most pertinent abilities related to visual literacy: visualization, critical viewing, visual reasoning, visual discrimination, visual thinking, visual association, visual reconstruction, constructing meaning, meaning reconstruction, and knowledge of visual vocabulary.

In the aspiration to develop visual literacy art education goes hand in hand with mathematics education. The fundamental role of geometry in visual art is widely recognized. In this regard, it is appropriate to quote Albrecht Durer: "And since geometry is the right foundation of all painting, I have decided to teach its rudiments and principles to all youngsters eager for art". The mathematics curriculum for Israeli primary schools suggests teaching spatial transformations and symmetry in the cultural context, creating and analysis of artwork with application of geometry.

Rees [26] teaches the courses which introduce scientific ideas to arts students through discourse about scientific visualizations. He uses geometry to define art concepts (i.e. spiral) and introduce elementary mathematical formulae--all relying on graphic visualizations to make fundamental ideas clear. His goal is to provide a means by which visually sophisticated persons may think with geometry about culture.

Study framework

The goal of our ongoing study is to develop, implement and evaluate an approach to fostering visual literacy, cultural and aesthetic perception through learning practice in geometric design and artwork. Our research is conducted as a multi-case study in which we develop, implement and evaluate "Visual design and geometry" courses for different groups of learners. Throughout the case studies we develop and examine the common approach that underlies the courses. Data are collected by means of qualitative methods. Research population included three categories of learners:

- 7th graders from a high school in Haifa, in the framework of art classes.
- 8th graders from other high school in Haifa, participated in the Excellence in Science program.
- Prospective teachers participated in the Technion course "Issues in Ethnomathematics".

Leaning environment was created for the study includes the following elements:

1. A collection of geometric ornaments in architecture, art and crafts with material on their cultural and historical roots – for inspiration and exploration.
2. A collection of artifacts developed by learners and the researchers – to illustrate techniques and criteria for artwork.
3. A collection of geometrical and cultural inquiries into ornaments – to help learners in performing assignments.
4. Technological tools, including drawing tools and computer graphics and visualization software – to support design work.

5. Exhibitions and display systems. For example: a multi-display system at the Israel National Museum of Science, Technology and Space.

In the following sections of the paper we present two experiments in which activities in artistic design of geometric ornaments were integrated in a course for teachers of mathematics and in a course of art and technology for middle school students.

First case study

The first experiment was conducted in 2009-2010 in the framework of the Technion course "Issues in Ethnomathematics" for prospective teacher students (N=12). The course involved the prospective teachers (most of them major in mathematics education) in visual artwork. Each of the students in the course developed: an electronic gallery of ornaments from a selected culture, and PowerPoint presentation of geometric ornaments, their cultural sources and symbolic meanings.

The students used the gallery and the presentation when teaching groups of senior high school students in the workshop "Joyful Learning of Geometry in Cultural Context" at the end of the course (Figure 1).

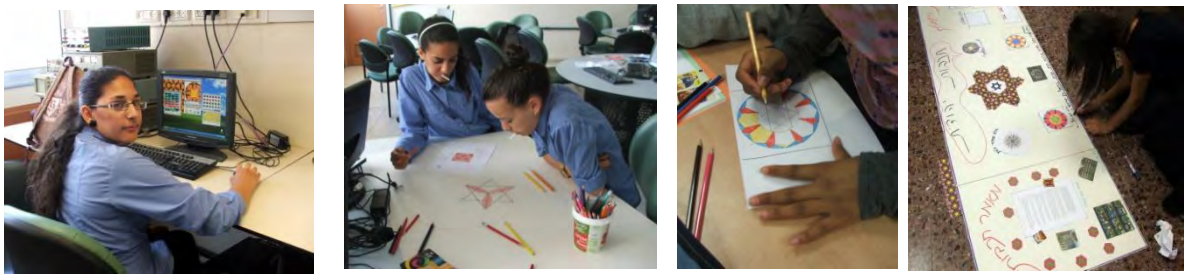

Figure 1: At the workshop “Joyful Learning of Geometry in Cultural Context“

The artifacts created by the students were posters and PowerPoint presentations of geometric ornaments from different cultures. Visual learning in the course was connected with mathematical learning and multi-cultural education. The posters and PowerPoint presentations consisted of visual cultural and geometric parts. The students' artworks were accepted for presentation at the Netrix Interactive Exhibition Center of the Israel National Museum of Science and Technology, MadaTech (see Figure 2).

Figure 2: Multi-screen presentation at the Netrix Center

Results of the course follow-up are as follows:

1. Most of the students have become challenged and attracted by the opportunity to use computer visualizations in teaching mathematics.
2. The students have become interested to learn about different cultures.
3. The students have become aware of importance of learning design topics in order to construct learning materials.
4. The students appreciated the visual design as supporting in learning geometry.

Second case study

The second case study was conducted in 2010 in the framework of the art and craft course for seventh graders of an urban school in Haifa (N=13). It was the 18 hours workshop "Geometrical properties and cultural roots of ornaments". As different from regular classes, in our lessons, the students not only performed visual artworks but also learned geometrical concepts and applied them to design of geometric ornaments. We found that assignments of drawing geometric ornaments (Figures 3A, 3B) and creating articles based on the Op-Art technique (Figure 3C) were challenging and motivating for the students.

A. B. C.

Figure 3**:** Creating ornaments: A. Computer graphics; B. Manual drawing; C. Op-Art artwork.

Analysis of outcomes indicated students' progress in visual design, geometry and cultural perception. After the course the students successfully participated in the workshop "Joyful Learning of Geometry in Cultural Context" organized by our Technion Ethnomathematics Group and together with elder peers developed posters representing geometric ornaments from different cultures.

During the workshop the students were exposed to topics and activities which are presented here.

1. Ornaments and their place in culture and artwork.
2. Geometric design based on hexagon and hexagram shapes.
3. Performing artwork using Op-Art techniques of Yaacov Agam.

Some of the workshop activities were performed using computers, others with physical tools (ruler, compass, etc.). The workshop collective product is a poster which presents students' artworks.

The workshop follow-up findings indicated that for 83% of students the use of geometry was important for accurate drawing ornaments, that the students preferred constructing ornaments using computer rather than by compass and ruler. 41,7% of the students were positive about experience of ornament construction using the physical tools. Some students found it difficult to use a compass. A vast majority of the students preferred to construct geometric ornament in cooperation with the teacher or other students. All the students positively evaluated the workshop, 66.7% of them gave highly positive evaluations and noted that enjoyed it.

Third case study

The third experiment was conducted in 2011 in the framework of the art and craft course for seventh graders of an urban school in Haifa (N=11). It was the workshop "Geometry and visual design". The mainly idea of this 20 hours workshop based experience, was introduce the students to

the design activities using physical tools (compass and ruler), as well as computer-aided design. During the workshop the students were exposed to performing visual artworks. They also learned geometrical concepts and applied them to design of geometric ornaments and 3D models. During ten meetings of the workshop the students were exposed to the following topics:

1. Ornaments and their place in culture and artwork.
2. Geometric design based on hexagon and hexagram shapes.
3. Introduction into the pre-Columbian American history and culture.
4. Discussion and analysis of visual art and design works of different Indian tribes.
5. Geometry of the "teepee" – a cone-shaped Indian tent.
6. Creating a conic paper model of an stylized Indian teepee (folding as a 2D -> 3D spatial transformation)
7. Creating stylized Indian ornaments using MS Word Picture Tools.
8. Development of final poster which includes student artworks inspired by decorated cone pattern.

The workshop follow-up findings indicated that the students have become interested to learn about their own and other cultures. They found interest in drawing both by computer and with compass and ruler. The students appreciated the novelty of the course and have become motivated to do artworks. An example of a teepee model made by one of the students is presented in Figure 4.

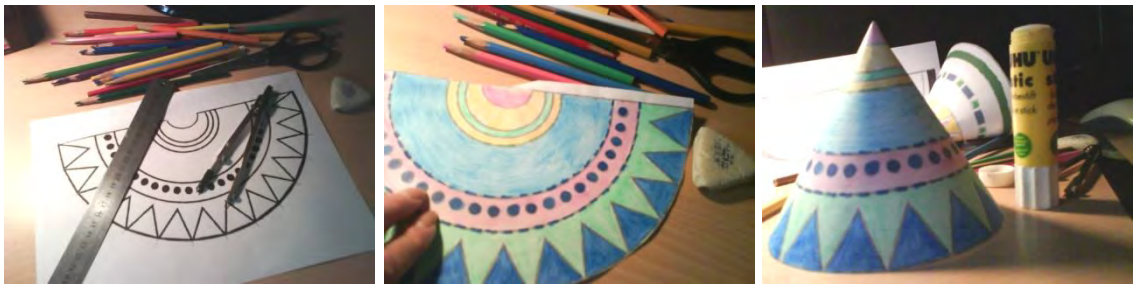

Figure 4: Geometry of the teepee – a cone-shaped Indian tent.

Conclusion

In this paper we propose an approach aimed at fostering visual literacy, creative work skills and cultural perception by learning practice in geometric design of culturally meaningful visual patterns. Activities in artistic design of ornaments were integrated with analysis of their geometrical properties and cultural roots. The proposed approach was implemented for different groups of learners, from middle school students to prospective and in-service teachers of mathematics. Throughout the case studies we observed its important advantages:

- Most of the students have become challenged and attracted by the opportunity to construct geometrical ornaments using traditional compass and straightedge as well as by means of computer graphics. They found these activities helpful for acquisition of visual skills and learning geometric concepts.
- The students have become interested to learn about different cultures, curious about the meaning of visual symbols and colors. For most of them this was a new subject.
- The prospective and in-service teachers have become aware of the importance of design in the development of learning materials.

The authors continue to conduct case study and further investigate the proposed approach to answer the following research questions:

1. What are characteristics of learning for fostering skills of visual literacy, cultural and aesthetic perception, through geometric design activities and artwork?
2. What are indications that point at developing visual literacy during learning practice in geometric design and artwork performance?
3. What are students' attitudes toward practice in geometric design and artwork?

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Art and science combined in storyline key questions

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Abstract

The aim of a three year period of field studies 2008-2011 into school contexts in an urban community in Norway was to contribute to the knowledge basis regarding the potential of combining art and science. This was done in order to develop design for learning models which open up multimodal, motivating and engaging learning spaces. During intensive periods the students elaborated issues connected to water as threat and hope at a local, national and global level through the Scottish storyline method [1;2]). The research question we seek to answer in this article is: What kind of key questions add value to the learning processes by being explored through art as well as science? We present characteristic features of key questions which might offer a space for exploration in art as well as in science.

The explorative study is informed by multimodal learning theory [3]. The research and development project has an ethnographic approach, which implies that the context as well as the culture is the object of the study. This study is a part of an EU-FP 7 project called S-TEAM (Science Teacher Education, Advanced Methods)[1]) and the results will be shared within the consortium of 25 participant teacher education institutions throughout Europe.

Introduction

The focus in this article is on the importance of key questions in storyline projects. The focus is not on key questions in general, but on key questions that invite multi-layered explorations through the use of artistic as well as scientific means. We will give examples from storyline projects where arts and science are combined in exploration of natural science issues in the educational context in Norway. Before we focus on the key questions we will draw some lines connected to the historical context of a project method like storyline in education.

[1] In 2009 our project became part of a European EU funded project, S-Team 2009-2012 (https://www.ntnu.no/wiki/display/steam/About+S-TEAM).

When the American pragmatist and educational philosopher John Dewey [4] almost a hundred years ago suggested inquiry based teaching, he was considered very progressive. He wanted the students to work in projects, to solve problems, to actually elaborate hands on and to reflect upon the problems they solved. About a half century later (in 1965) a curriculum reform in Scotland was carried out. In this reform one main feature was that teachers should work in teams in cross-curricular ways. The Scottish art teacher Steve Bell, together with some colleagues, formed the Scottish storyline method at University of Strathclyde. This method contained the main characteristics of Dewey's suggestion for a progressive pedagogy. The Scottish group added one characteristic feature by introducing a fictive frame for the students to work within. They also made a substantial contribution through a firm structure: a storyline planning scheme was introduced. In this planner the key questions became the main structuring elements. The key questions were open-ended questions which needed exploration in order to be answered. The key questions opened up for inquiry-based teaching and learning methods. The questions were connected to the topic chosen for exploration, and connected to the competence goals sought in the curriculum.

In the twenty-first century the focus on literacy has opened the possibility of forming a third space for learning, where knowledge formation as well as aesthetic experience are given value in meaningful learning processes. This literacy is multimodal and it includes use of digital media, video, music and visual expressions of different kinds. In this multimodal literacy context, storyline has again become an interesting study form, because it has a holistic approach, it is engaging for the students, and it is definitely inquiry-based. In a research and development project from 2008 to 2011 we carried out and explored designs for good storyline projects. The developmental research included prospective teachers in placement periods and a teacher team in one secondary school, together with a group of students aged 12 to 15 in a Norwegian urban school. The aim of this extensive project was to contribute to increased science literacy through examples of best practice regarding inquiry based methods in order to promote science (teacher) education. Our contribution to this project was to combine arts and science in inquiry-based teaching and learning through the R&D project "Storyline @quarelle".

Storyline @quarelle

During three subsequent grades in secondary school a group of about thirty students participated in storyline periods lasting from one to three weeks. About 25 lessons were used for one storyline period. In Norway secondary school encompasses grades eight, nine and ten. The students are 15 years old when they graduate from secondary school.

The topic chosen for the four storyline projects were all connected to water; first locally, then nationally, and finally globally.

The science topic explored in the first project was the local cycle of water, based on fictive families living in houses in their neighborhood. They investigated the consumption of water in different families, and visited a water purification plant in the local area. They were in contact with a Tanzanian schoolteacher. This schoolteacher in autumn 2011 carried out a storyline project with students exploring the same key questions in Tanzanian urban and rural contexts.

The second storyline project was based on a novel where the students were framed as "clan members" from the Stone Age. Through Michelle Paver's fantasy novel "Wolf brother" the students explored an ecological way of living, their dependence on water, threats from glaciers and avalanches. They created clan rules for the different clans and finally performed a yearly meeting for all clans, where they decided upon common rules to help every clan on earth to survive.

The third storyline project was based on a national conflict in the late seventies and early eighties, known as "The Alta controversy". It brought forward the rights of the indigenous Sami people. The controversy was triggered by the construction of a dam in unspoilt nature in northern Norway in order

to produce electrical power from water. The students were framed as politicians, local people, Sami people, environmental activists, eco philosophers, dam builders, policemen and journalists.

The fourth storyline was "Water as threat and hope". In this project we tied together the threads from the previous storyline projects, and focused on the future effects of possible climate changes. The students were framed as families encountering a disaster caused by water. The families created were (1) Norwegian families struck by clay slides (which are continuous threats in many places); (2) families in the Maldives affected by the tsunami in 2004; and finally (3) families in Pakistan encountering polluted water spreading cholera during the flood. The students learned how to find people buried under snow and give them first aid. They experimented with wet clay; they explored simple and cheap ways to clean water. The final performance was formed as a talk show "Directly from the Catastrophe" performed for another group of students from a neighboring school.

The lesson plans regarding these storyline projects were created as a delivery in the S-Team project, and they can be found at this internet address: http://www.storyline-scotland.com/water.pdf

After this overview of the natural science content of the storyline projects we will dwell on the contribution of arts in these projects. In the final paragraph we will elaborate which kinds of key questions we have found especially rich to explore by artistic means as well as scientific ones.

Arts in cooperation with pedagogy in learning

Art in itself does not have one defined educative aim, but art of course contributes to knowledge and education. Art cannot per se be defined to have specified aims, because the personal meaning-making is tentative and exploring. An encounter with art is risky, and it can be provocative and it can turn things upside down. An encounter with art can change ways of thinking. Art functions through people's actions. Art functions by being present, and being allowed to make an impact on people through interaction [5]. Pedagogy, on the other hand, has an educative intention, aiming at defined educative aims. In cooperation between art and pedagogy the prerequisites are a pedagogical context, art and learning persons – and a wish to cooperate. This voluntary wish, and a pre-understanding about the equal value of art and pedagogy, opens up for the contribution of art in learning processes. The Finnish dance researcher Professor Eeva Anttila articulates the potential of art in the following way:

> Art is an open and multi meaningful phenomenon in the human life. Art opens up alternative perspectives on the world and on interpretation of human experience. Art fills out; it challenges and poses question marks regarding existing knowledge and opinions about reality [5] (authors' transl. from Finnish).

Learning through and in art builds upon an acknowledgement of the importance of feelings in learning processes, of embodied and sense-based learning as building blocks in learning, together with personal and cultural experience. The multimodal learning theory opens up for acknowledgment of aesthetic experience as a learning path.

Multimodal learning theory

Multimodal theory gives different semiotic resources equal cognitive value [6]. Multimodal theory has destabilized existing thought patterns regarding how people learn. A modality can, among other things, consist of music, sound, voice, image, film, dance, drama, artifacts, spaces, or teaching. The research on multimodality builds according to the English researcher Carey Jewitt upon four pre-understandings, which are the following. Language is part of a multimodal ensemble. This implies that representation and communication always make use of many modalities in meaning-making. Every modality contributes in a specific way to communication. People orchestrate meaning through their choices and configuration of the modalities. The meaning that is created by means of multimodal resources is always social.

In storyline the transformation of semiotic resources from one modality to another is called transduction or remodalisation [7]. This remodalisation has a potential for broadening the meaning of the phenomenon studied. In the storyline projects which were carried out many different forms of

remodalisations were given as explorative tasks for the students involved. The students painted, used photo shop; they danced, they formed dialogue in drama, in debates; they produced texts in poetic ways. They produced videos and power points and digital stories – in combination with scientific explorations of the topics under study. In these combined explorations by scientific means and by artistic means, we have been able to categorize at least three types of key questions which invite multilayered explorations. In the last paragraph we will present and discuss these three categories of key questions.

Key questions in storyline explored through art and science

In the previous paragraphs we have outlined a theoretical horizon of understanding regarding the value of combining art and science in inquiry-based teaching and learning of science. Science and technology are of utmost importance for all people on earth. The knowledge already existing can be used to destroy the earth, but also to promote health and our wellbeing [8]. It is not enough to be able to understand scientific phenomena in a one-dimensional way. There is a need for a multidimensional understanding of consequences of choices and actions. That is why we in the research project have asked: What kind of key questions add value to the learning process by being explored through art as well as science?

We have so far identified three major categories of questions, which in their exploration benefit from multidimensional artistic as well as scientific exploration. These categories are: (1) questions regarding ethical dilemmas, (2) questions considering socio-scientific issues, and (3) questions on future. Some of the dimensions in each category overlap, because there is always the aspect of choice to consider. Through the choices people make some aspects come to the foreground, while others are invisible, not noticed or are given lesser importance. Some questions might imply all three categories, like this one: What are the consequences of damming up a river in untouched nature?

Through entering into drama and creating characters and situations the complexity of the theme studied can be illuminated from many perspectives. In drama, students study the human condition and develop their insight in the very different circumstances for different groups of people.

Ethical dilemmas

How do we in sustainable and fair ways deal with water as a scarce natural resource?

Socio-scientific issues

How do we deal with problems connected to polluted water?

Questions on the future

What kind of heritage do we leave to future generations?

The key question represents a major challenge for the teacher team designing storyline projects. The key question chosen opens up a learning space which invites the student into active exploration. The characteristics of a good key question are that it is open-ended, and that there exists some previous knowledge about the theme to explore. A good key question is placed in the gap or in-between-space between what we know and what we do not know (Darsø, 2011).

In innovative pedagogy, creative exploration can be supported through qualitatively good relations in the team of students, and by powerful and value-giving questions. We suggest that a broadening of the meaning potential is better achieved as a result of the multidimensional exploration by means of key questions challenging the students into inquiry-based explorations.

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Bridges between mathematics, natural sciences, architecture and art: case of fullerenes

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The discovery of C_{60}, a third variety of carbon, in addition to the more familiar diamond and graphite forms, has generated enormous interest in many areas of physics, chemistry and material science. Furthermore, it turns out that C60 is only the first of an entire class of closed-cage *polyhedral* molecules consisting of only carbon atoms - the fullerenes (C_{20}, C_{24}, C_{26}, … C_{60}, …C_{70}, … $C_{1000000}$- carbon nanotubes). This paper presents concepts and terms of fullerene science in a historical context, with main emphasis of its interdisciplinary character and interrelationships of various branches of cognition and, in particular, exploration of *polyhedra* in mathematics and fine art. It is discussed how Nature uses fullerene-like structures to minimize energy and matter resources in molecules and nanoclusters, viruses and living organisms. Examples of achievement of such goals in architecture are also presented.

1. History of Discoveries of Fullerenes. Long before experimental discovery of fullerenes, few scientists from different countries predicted an existence of molecules, which would consist only of carbon atoms, located in the vertices of a polyhedron, in particular, a truncated icosahedron (fig. 1). Exploration history of such polyhedron lasts more than two millenniums and will be discussed below.

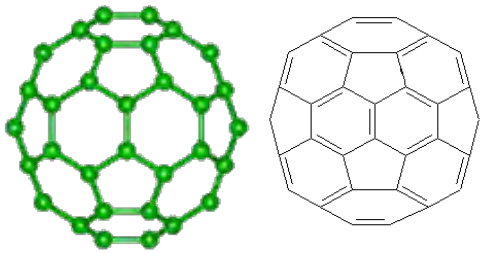

Figure 1: Molecule of buckminsterfullerene, C_{60}.

In 1966, D. Jones had conjectured that if pentagonal disclinations could be introduced into a graphene sheet, consisting of regular hexagons, the sheet would close into a giant hollow molecule of carbon [1]. In 1970, Japanese chemist E. Osawa - published a short article in Japanese [2] on a possible existence of a molecule of 60 carbon atoms, C_{60}, in a shape of truncated icosahedron. Osawa named the molecule '*soccer-ball'*. In 1973 D. Bochvar (1903-1990), E. Galpern and I. Stankevich, performed computer simulation of electronic structure of the C_{60} molecule, which quantitatively proved its stability [3].

…This way or another, by 1985, none of the theoretical predictions mentioned above was truly appreciated by scientific community. It did happen so many times in a history of a human thought in general and in a history of science in particular. The destiny of ideas that are ahead of their time is usually quite tragic. From one point, the society, or in this case scientific community, should be mature for these ideas. On the other hand, the demand for an idea, hypothesis or theory has to evolve as well. In our case, a "trigger" that caused a tremendous, practically explosive "crystallization" of a common interest in the fullerene-like molecules was an experimental discovery

of self-generated molecule of C_{60} in a hot carbon plasma by a joint group of Harold Kroto, Richard Smalley (1943-2005) and Robert Curl in 1985 [4].

Kroto's idea was to compare radio-astronomy data with the spectroscopic characterization of carbon clusters produced in the laboratory. This was a motivation for the joint experiment performed by Kroto, Kearl and Smolly in September 1985, that led to an absolutely unexpected result – the discovery of the novel C_{60} molecule. Studying the evaporation of graphite disk under the impulse laser radiation in helium atmosphere, and analyzing the mass-distribution of the generated carbon clusters by a mass spectrometer, scientists detected a dominating peak with the mass of 720 atom units (a. u.). It meant nothing else but self-creation of a stable molecule consisting of 60 atoms of carbon, C_{60} (remember that mass of 1 carbon atom = 12 a. u.). The peak of C_{60} always neighbored by a less intense peak of C_{70}.

Researchers took a risk and answered much more complex question – how to construct a molecule of C_{60} in a way so that all carbon atoms would have satisfied normal bonding (four bonds per carbon atom). Such a requirement would follow a fact of the chemical stability of the molecule. The team (remember they didn't know about the early theoretical predictions!), suggested a structure of truncated icosahedron This polyhedron has 32 faces (20 regular hexagon and 12 regular pentagons), 60 vertices (carbon atoms) and 90 edges. In such a structure, each carbon atom is in equivalent position, but carbon-carbon chemical bonds are of 2 types (fig. 1b): (i) single bonds (C-C), represented by edges between hexagon and pentagon; (ii) double bond (C=C), represented by edges between 2 hexagons.

Figure 2: Buckminster Fuller. The US pavilion at the EXPO-1967, Montreal.

In 13 days after the beginning of experiments, the article about the discovery of C_{60} was sent to "Nature" magazine [4]. The article suggested a name for a new molecule - buckminsterfullerene - after an American architect Buckminster Fuller, the author of a concept of *geodesic domes* – polyhedra buildings (Fig.2). In 1996 Kroto, Smalley and Curl got a Nobel Prize in chemistry for the discovery.

2. Polyhedra in science and art.

Mathematics is the key and door to the sciences.
Galileo Galilei

2.1. Platonic and Archimedean solids

Let no one unskilled in geometry enter [here].
Inscription over the entrance to Plato's Academy.

Archimedes (287 b.c. - 212 b.c.) is often acknowledged as a 1st researcher of truncated icosahedron though one may reasonably suspect that icosahedra had been truncated long before Archimedes.

Truncated icosahedron is one of 13 semiregular polyhedra. These polyhedra are called Archimedean because they were described by Archimedes, even if we have only "second hand" references to his writings on this topic from Heron of Alexandria and Pappus of Alexandria.

The knowledge of Platonic and Archimedean polyhedra was disseminated through the Arabic culture by means of translations made during the VIIIth and IXth centuries, among which the most outstanding one is the account of Abu'l–Wafa (Baghdad, 940–988). Most of Archimedean polyhedra were rediscovered, described and incorporated into the world of Art during the Renaissance, except

for the snub dodecahedron, that was described later by Johannes Kepler who in 1619 in his book "Harmonice Mundi" ("Harmony of the Worlds") described the entire class[1] of Archimedean polyhedra or Archimedean solids (fig. 3) - highly symmetric, semi-regular convex polyheda composed of two or more types of regular polygons meeting in identical vertices (please recall equivalent positions of carbon atoms in C_{60} molecule).

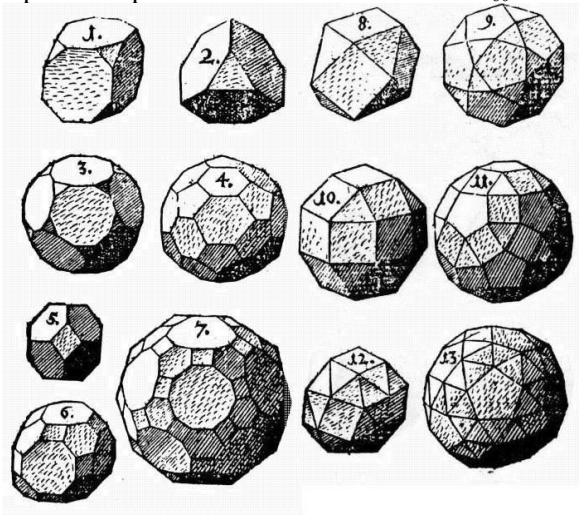

Figure 3: Images of Archimedean polyhedra from Johannes Kepler "Harmonice Mundi" ("Harmony of the Worlds") (1619): polyhedron # 4 is truncated icosahedron.

The fact that Archimedean solids consist of at least 2 different types of polygons that makes them distinct from the *regular polyhedra* or *Platonic solids* which are polyhedra bounded by a number of congruent polygonal faces, so that the same number of faces meet at each vertex, and in each face all the sides and angles are equal (i.e. faces are regular polygons). Only five platonic solids could be constructed. They are tetrahedron, cube, octahedron, icosahedron and dodecahedron. (fig. 4).

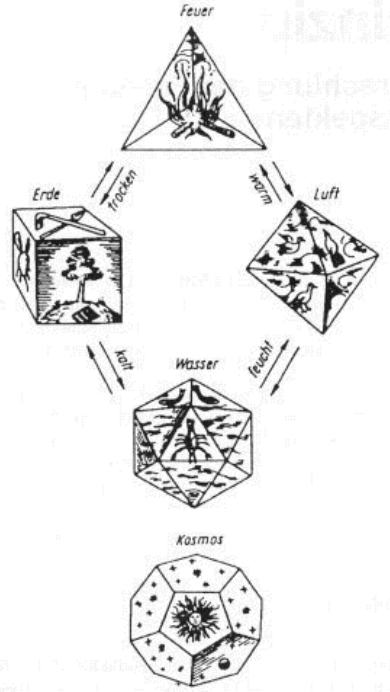

Figure 4: Icons of Platonic solids and the corresponding classical elements from Johannes Kepler "Harmonice Mundi" ("Harmony of the Worlds") (1619).

Plato, and, like him, many other philosophers, including Kepler, associated platonic solids with the classical elements. The tetrahedron, icosahedron, cube and octahedron correspond to FIRE, WATER, EARTH and AIR, respectively. The dodecahedron corresponds to the Quinta Essentia – the UNIVERSE.

Platonic Polyhedra	Four classical elements	Four states of matter (modern view)
Tetrahedron	Fire	Plasma
Cube	Earth	Solid
Icosahedron	Water	Liquid
Octahedron	Air	Gas
Dodecahedron	UNIVERSE	

Table 1: Relationship between Platonic polyhedra, classical elements and states of matter (in modern view).

[1] The 14th Archimedean polyhedron discovered just in the second part of XX century.

The most important property of Platonic polyheda is their high symmetry. These polyhedra belong to the most symmetric point groups: tetrahedral, octahedral or icosahedral.[2] They are the very Platonic solids and classical elements from which H. Kroto started the "symmetry" part of his Nobel Lecture:

"Symmetry appears to be fundamental to our perception of the physical world and it also plays a major role in our attempts to explain everything about it. As far as structural symmetry is concerned it goes back to ancient times, as indicated by the (pre-) Platonic structures exhibited in the Ashmolean Museum in Oxford. The most famous examples are of course to be found in "The Timaeus", where in the section relating to 'The Elements" Plato says: "In the first place it is clear to everyone (!) that fire, earth, water and air are bodies and all bodies are solids" (!!).Plato goes on to discuss chemistry in terms of these elements and associates them with the four Platonic... Although this may at first sight seem like a somewhat naive philosophy it indicates a very deep understanding of the way Nature actually functions".

Is it a true "deep understanding"? Table 1 alludes to a positive answer.

Nature widely uses Platonic solids for elementary forms of crystals (tetrahedron, cube and octahedron) and quasicrystals (icosahedron and dodecahedron) as well as some viruses and simplest micro-organisms (icosahedron). Below we demonstrate that the smallest fullerene, C_{20}, has a shape of dodecahedron and C_{20}, C_{60}, and other important fullerene molecules exhibit icosahedral symmetry.

Many man-made polyhedral objects in the form of Platonic solids may come easily to the mind of the reader. We can meet them in the arts and architecture across the centuries and in different cultures. In the Neolithic period some carved stones (around 2000 B. C.), discovered in Scotland, were shaped like polyhedra (including *icosahedron* and *dodecahedron*). Below we will demonstrate a number of examples of artistic depictions of polyhedra. Here we will show just two fascinating sculptural images of icosahedron: a splendid sundial in the courtyard of the Palace of Holyroodhouse in Edinburgh (fig. 5) and the monument to Baruch Spinoza in Amsterdam (Fig. 6).

Figure 5: Sundial by John Mylne (1633). Courtyard of the Palace of Holyroodhouse, Edinburgh. Photo by E.A. Katz.

Figure 6: Nicolas Dings. Monument to Baruch de Spinoza (2008). Amsterdam. Photo by E.A. Katz.

Let's now come back to truncated icosahedron (C_{60}). That is the very name "truncated icosahedron" that tells that this polyhedron can be obtained from the Platonic icosahedron by *truncation* which is a geometrical operation that consists in cutting off the vertices of a polyhedron,

[2] The Archimedean polyhedra belong to the same point groups as the Platonic solids, with which they bear close relationships.

thus generating a new polyhedron with more faces. Fig. 7 shows a particular truncation of the icosahedron, in which all the resulting edges have the same length, giving the Archimedean truncated icosahedron. We may think of truncation as the replacement of each vertex by a polygon, perpendicular to the radial direction, with the restriction that such polygons must have as many sides as the number of edges meeting at the vertex. The data from Table 2 may help us to understand this transformation. Indeed, 5 edges meet at every of 12 vertices of the icosahedron. Cutting off the vertices will generate 12 new pentagonal faces. At the same time, original 20 faces will transform to hexagons and together with 12 new pentagonal faces will constitute 32 faces of Archimedean truncated icosahedron which will also have 90 edges and 60 vertices.

Table 2: Characteristics of Platonic solids.

Polyhedron	Number of edges per each face, *m*	Number of edges that connect in each vertex, *n*	Number of faces, F	Number of edges, E	Number of vertices, V	*F-E+V*
Tetrahedron	3	3	4	6	4	2
Cube	4	3	6	12	8	2
Octahedron	3	4	8	12	6	2
Icosahedron	3	5	20	30	12	2
Dodecahedron	5	3	12	30	20	2

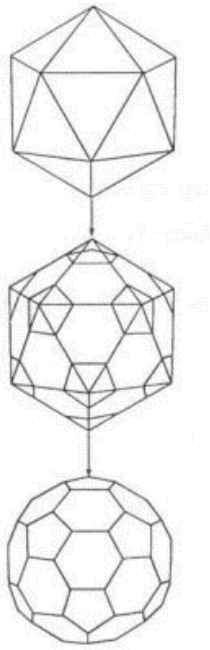

Figure 7: How to built Archimedean truncated icosahedron from Platonic icosahedron.

2.2. Mathematical Discoveries Made by Artists and Polyhedra in Art: Leonardo, Luca Pacioli, Albrecht Dürer, Piero della Francesca and Others…

> Mathematics possesses not only truth but supreme beauty,
> a beauty cold and austere, like that a sculpture,
> sublimely pure and capable of a stern perfection,
> such as only the greatest art can show.
> *Bertrand Russel*

> For me it remains an open question whether [my work]
> pertains to the realm of mathematics or to that of art.
> *M.C. Escher*

Figure 8: Leonardo's drawing of truncated icosahedron from Pacioli's book "The Divine Proportion" (1509).

In fullerene literature it is often acknowledged an original way to display a truncated icosahedron, suggested by Leonardo Da Vinci. Figure 8 shows Leonardo's drawing of truncated icosahedron from a book "De divina prportione" ("The Divine Proportion") [5] written by Franciscan friar and mathematician Luka Pacioli (1445 - 1514) and illustrated by Leonardo. The book was published in 1509. We like to believe, that Leonardo's "involvement" in the research of truncated icosahedrons (or in other words, in the prehistory of C_{60} discovery) was not accidental. This connection is deeply symbolic. The titan of Renaissance, artist, sculptor, scientist and inventor, Leonardo da Vinci (1452 – 1519) is a symbol of continuum of art and science, and, therefore, his interest in the objects like beautiful and highly symmetrical polyhedra, and particularly in truncated icosahedron is not accidental (here is the place to remind once again the title of Pacioli's book – "The Devine Proportion").

Leonardo precedes his print of a truncated icosahedron with a scripture in Latin 'Ycocehedron Abscisus Vacuus'. Term 'Vacuus' means, that all the faces of this polyhedron are shown as 'hollow'. Actually, faces are not shown at all, they exist only in our imagination. On the other hand, the edges of the polyhedron are not shown using geometrical lines, which have neither width nor thickness, but with solid segments. These two features of this print constitute a base for the representation of polyhedra, which was invented by Leonardo for illustration of Pacioli's book, and is called today '*method of solid segments*'.

Pacioli's book strongly influenced on the geometry at that time. Furthermore, Luca Pacioli is considered as one of the biggest European algebraists of the 15th century, and - not less important - inventor of the double book-keeping method, which is used by today in all the accounting systems with no exceptions. He definitely deserved a title of "Father of Modern Accounting". Even though, till now the mysterious and controversial Pacioli causes ferocious discussions among historians of science.

It is known for certain, that Luca Pacioli was born in 1445, in Italian town Borgo San Sepolero (now Sansepolcro). During his childhood, he assisted to a local merchant and also studied in a workshop and studio of the great artist and mathematician Piero della Francesca.

Some of the historians (the first was Giorgio Vasari who published a biography of Piero della Francesca in 1550) blame the author of "The Divine Proportion" in plagiarism of unpublished manuscripts, that belong to his teacher Piero della Francesca. This matter is not really clear. However, what we know exactly is that how Pacioli looked, thanks to his portraits by Jacopo de Barbari (1440 - 1515) and Piero della Francesca.

Figure 9: Jacopo de Barbari, 1495. Luca Pacioli.

In the Barbari's painting (fig. 9) Pacioli, in a robe of Franciscan monk, is shown standing in front of the table with geometrical tools and books (in a right lower corner we see a model of dodecahedron). Pacioli and a handsome young man behind him are looking at the artist (and at us, spectators). At the same time we realize, that the attention of both is focused on the polyhedron glass model. The choice of polyhedron is not random – it's a *rhombicuboctahedron*, rediscovered (after Archimedes) by Pacioli**.**

The figure of young man on the same portrait, standing by Pacioli, is still under discussion of art historians. Some of them suspect this is Barbari's self-portrait, some of them argue that this is young Albrecht Dürer (1471 - 1528). Though it is an open question, it is well known that Dürer was fascinated by the artistic style of Barbari, who created his compositions based on a mathematically defined system of proportions. After his meeting with Jacopo de Barbari in around 1500 in Nurnberg, Dürer started to study the laws of perspective. He dreamed to meet other famous Italian masters, to learn from them, to compete with them. For this purpose, in 1505-1507 Dürer took his second trip to Italy (the first one was in 1494-1495). It is not known for sure who were his teachers in this school of perspective (among others, the names of Luca Pacioli and Piero della Franchesca are considered), but Dürer continued to study in such a school till the end of his life.

Starting since 1525, i.e. in three years before he died, the Master hurried to share with next generations the secrets of perspective, that he had being acquiring all his life. He published two treatises, one of which, "Underweysung der Messung" ("Painter's Manual"), is a serious input in a theory of perspective and geometry of polyhedra. For instance, Dürer was the first to describe few archimedean solids unknown at his time. The book contains a very interesting discussion of perspective and other techniques and it typifies the renaissance idea that polyhedra are models worthy of an artist's attention. More importantly, this book presents the earliest known examples of polyhedral nets, i.e., polyheda unfolded to lie flat for printing (fig. 10). The net for truncated

icosahedron is shown in Fig. 10a. One should notice the wedge-shaped gaps between hexagons and pentagons when these faces are made to lie in a plain (the pentagons are required in the structure of truncated icosahedron to generation the curvature of the fullerene shell).

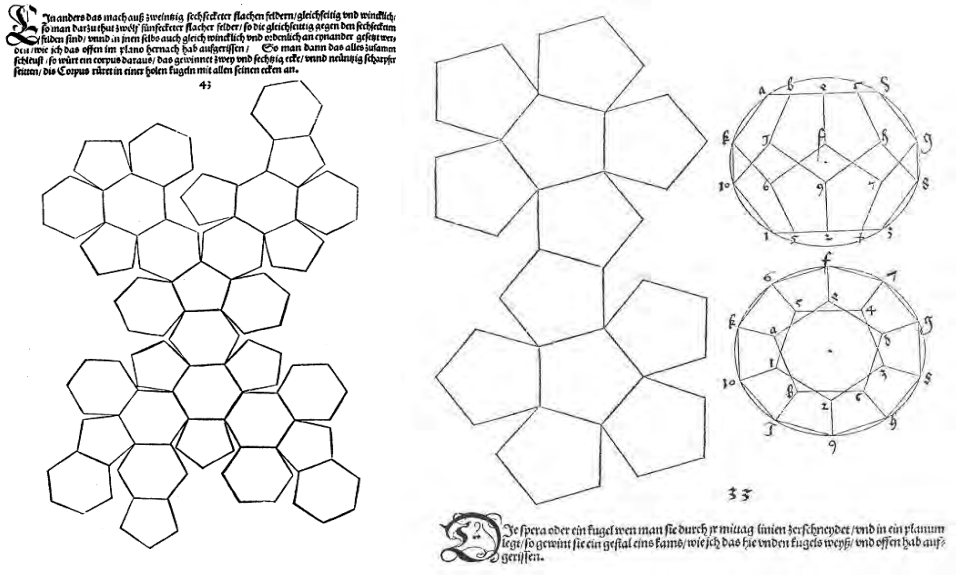

Figure 10: Net for truncated icosahedron (a) and dodecahedron (b) from Albrecht Dürer's treatise "Underweysung der Messung" ("Painter's Manual") (1525).

Nowadays such nets are widely used in studies of elementary forms of crystals, molecular structures (fullerenes, for instance), viruses, etc. We suggest a reader to make a model of C_{60} molecule using a net of truncated icosahedron shown in Fig. 11 [6].

Figure 11: Net for making truncated icosahedron [6].

It should be noted that contrary to the Dürer's net one shown in fig. 11 does not contain any pentagon. This resembles one possible mechanism by which real C_{60} molecules may form in nature using solely graphite hexagonal building blocks.

Dürer's theoretical works, as well as the art of the Renaissance in general, are filled with a thirst for a knowledge. The greatest artists of that time often became outstanding natural scientists. The idea of unity of artistic inspiration and mathematical theory is reflected in one of the most famous Dürer's masterpieces, woodcut "Melancholia 1" (fig. 12). It contains the first magic square to be seen in Europe, cleverly including the date 1514 as two entries in the middle of the bottom row. Of course, of our interest is the polyhedron in the picture. This is truncated rhombohedron that is now known as Dürer's solid. In the mathematical field of graph theory a skeleton of this polyhedron is known as the Dürer graph. S.Alavarez suggested [add15] name "*melancholyhedron"*for this polyhedron and demonstrated inorganic cluster having this shape: a shell of twelve As atoms around Ni (at a distance of 4.3 Å) in the solid state structure of $NiAs_{12}$ (fig. 12). We would suggest name "*durerene*" for such a cluster.

Not only Dürer, Leonardo and Barbari, but many other artists of different epochs and countries were interested in studying and drawing polyhedra. Peak of this interest was, of course, during the Renaissance. Studying Nature, the Renaissance artists tried to find scientific ways of drawing it. Built on geometry, optics and anatomy theories of perspective, proportions and treatment of light and shade became a base for a new art. They allowed an artist to create a three-dimensional space on a flat surface, saving an impression of relief of the objects. For some masters of Renaissance polyhedrons were just a convenient model for practicing the laws of perspective. Some of them were

fascinated by their symmetry and laconic beauty. The others, following Plato, were attracted by philosophical and mystical symbols of polyhedra. List of the greatest Renaissance artists, that often draw and seriously studied a geometry of polyhedra (beside Leonardo and Dürer mentioned above), should be started with Uccello (1397-1475) and, first of all, Piero della Francesca (~1420 - 1492).

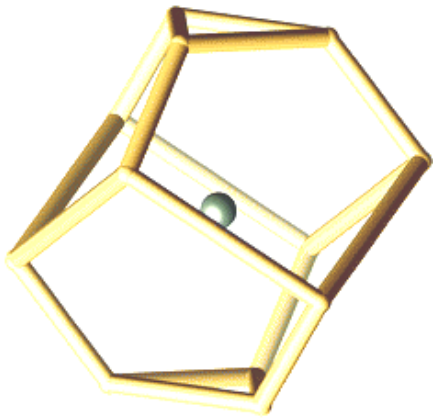

Figure 12: (a)Albrecht Dürer. “Melancholia I ” (1514); (b) structure of $NiAs_{12}$ cluster.

We have very little knowledge on life of Piero della Francesca, a genius artist, serious theorist of art and outstanding mathematician. We know that he was born in 1420 in a family of crafters in a small town of Sansepolcro in Tuscany (as well as his controversial pupil Pacioli). He studied in Florence where he showed a great interest in the art works of Masaccio, Uccello, Brunelleschi and Alberti. Afterwards, he worked in cities of Rimini, Arezzo, Urbino, Ferrara and Rome. Work of Piero della Francesca went beyond the limits of local art schools and influenced the art of the whole Italian Renaissance.

Piero della Francesca was a great mathematician, who contributed a lot to algebra, geometry, science of perspective and, in particular, theory of polyhedra. However, after his death, the name of Piero della Francesca-scientist was forgotten for a long time. It happened, probably, due to the fact, that none of Piero's mathematical work was published under his own name in the Renaissance, but it seems to have circulated quite widely in manuscript and became influential through its incorporation into the works of others. Much of Piero's algebra appears in Pacioli's “Summa”, much of his work on the archimedean solids appears in Pacioli's “The Divine Proportion” and the simpler parts of Piero's perspective treatise were incorporated into almost all subsequent treatises on perspective addressed to painters.

Luckily, in the beginning of the 20th century, the originals of three mathematical manuscripts by Piero della Francesca were found. Nowadays they are in the Vatican Library. After five centuries of oblivion, the fame of famous mathematician got back to the Master. Today we know for certain, that Piero della Francesca was the first who rediscovered and described in details 5 truncated Archimedean solids (without knowing, of course, that Archimedes already discovered them): truncated tetrahedron, truncated cube, truncated octahedron, truncated dodecahedron, and mostly important for our story, truncated icosahedron. His manuscript “Libbelus de quinque corporibus regularibus” (“Short book on the five regular solids”) written in 1480 has the oldest known image of truncated icosahedron (fig. 13).

During following years, many artists and sculptors from different countries used polyhedra as fine art objects. Fig. 14 displays two beautiful samples of *intarsia*, a special kind of mosaics made of thousands little pieces of inlaid wood. Intarsia art reached a peak in northern Italy in the late XV and early XVI centuries. Many outstanding examples of this period feature polyhedra. Both examples shown in Fig. 14 are intarsia panels by Fra Giovanni da Verona (1457 - 1525), constructed around 1520 for the church of Santa Maria in Organo, Verona. The appearance of open cupboard doors creates a strong three-dimensional effect of the masterful perspective in this flat panel which is amplified by polyhedra imaging (including icosahedron and truncated icosahedron) by Leonardo's method of solid segments.

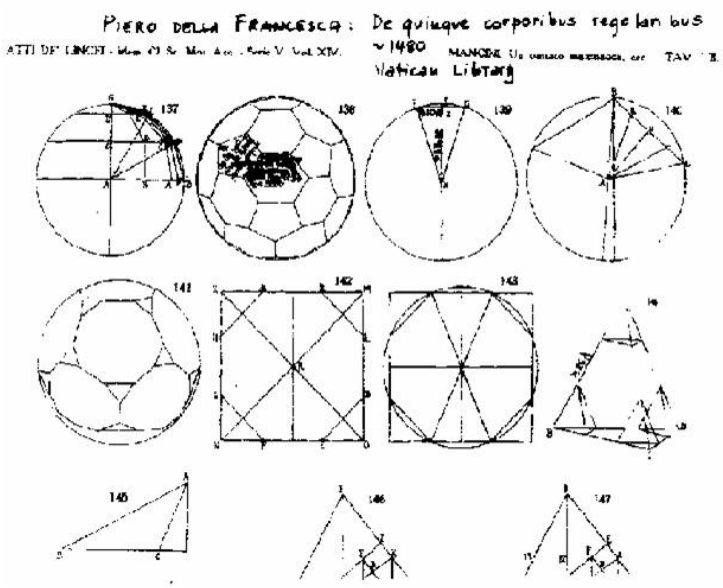

Figure 13: The oldest known picture of truncated icosahedron: drawing by Piero della Francesca from his manuscript "Libbelus de quinque corporibus regularibus" ("Short book on the five regular solids") (1480).

Figure 14: Intarsia panels by Fra Giovanni da Verona, ~ 1520, the church of Santa Maria in Organo, Verona.

2.3. Harmony of Johannes Kepler.

At ubi materia, ibi Geometria.
Where there is matter, there is geometry.
Johannes Kepler

Johannes Kepler (1571 - 1630) has a special place among those scientists, who have been exploring polyhedrons. Unlike the Renaissance artists that have discovered and even mathematically described some polyhedra, Kepler defined the entire classes of polyhedra, particularly that of Archimedean solids. In 1619, in his book "Harmony of the Worlds" Kepler derived that there are only 13 such polyhedra, fully described each of them and coined the names by which they are known today. In Kepler's drawing illustrating the Archimedean solids (fig. 3), polyhedron # 13 (icosidodecahedron) was discovered by Kepler himself.

The correspondence between the titles of Kepler's and Pacioli's books gets our attention: "Harmony of the Worlds" and "The Divine Proportion". Nevertheless, unlike the exclusively geometrical work of Pacioli, Kepler was trying to formulate the major principles of structure of the Universe, all the aspects of our world: geometrical, astronomical, astrological, metaphysical, musical (!), social (!!). Kepler understood a marvelous harmony ruling the world not just in an abstract sense. It sounded in his poetic soul as a real music. One could hear this music only by entering into a world of Kepler's ideas, feeling his powerful enthusiasm for an enchanted structure of the Universe and

Pythagorean admiration for correlation between numbers. In fact, isn't it amazing, that "beautiful" for an ear depends on a strict numeric correlation, for instance, correlation between lengths of the strings, that produce sounds, - the correlation discovered by Pythagoras? Kepler's soul, without a doubt, hosted a part of Pythagoras's soul, and naturally, he saw Pythagorean correlations in the planetary cosmos.

Another Kepler's input to polyhedra geometry is description of two of four regular stellated solids known today as Kepler- Poinsot. Kepler discovered the great stellated dodecahedron and the small stellated dodecahedron (fig. 14a). Both have regular pentagrams as their faces and the full symmetry of dodecahedron. The other two regular star polyhedra (the great dodecahedron and the great icosahedron) were described by Louis Poinsot in 1809. Stellated fullerene-like structures are shown below (Fig. 15).

Figure 14: Small stellated dodecahedron. a: Kepler's drawing from "Harmony of the Worlds" (1619); (b) Detail of a marble inlay in the floor of the Basilica of St. Mark in Venice. Attributed to Paolo Uccello (about 1420's ?); (c) Regards from Kepler to Leonardo. Monument by Mimmo Paladino near to the entrance to Leonardo da Vinci Museum in the village of Vinci (Leonardo's birthplace, Tuscany). Photo by E.A. Katz.

Fig. 14b reproduces a marble inlay which features the small stellated dodecahedron, located in the floor of the Basilica of St. Mark in Venice. Many references attribute this to the great Renaissance painter and mosaicist Paolo Uccello (1397-1475). If so, it is remarkable, for this would be two hundred years before Kepler's 1619 mathematical description of this polyhedron.

3. Euler relation for convex polyhedra helps to understand molecular structure of fullerenes

Read Euler, read Euler, he is our master in everything.
Pierre-Simon Laplace

The universe is a grand book written
in the language of mathematics.
Galileo

Leonard Euler (1707-1783), mathematician, physicist, mechanist and astronomer, author of more than 800 scientific papers is one of the most outstanding scientists in history. There was no brunch of science that would not be of some interest to this great man. Mathematical analysis, geometry, numbers theory, theory of approximation, mechanics, astronomy, optics, ballistics, ship building, music theory, graph theory or mathematical topology. The birth dates of the latter two branches of mathematics were, correspondingly, 1736 when Euler solved the problem known as "the Seven Bridges of Königsberg" and 1758 when he formulated [7] and proved [8] a theorem on correlation between the number of vertices (V), edges (E) and faces (F) of a convex polyhedron:

$$V - E + F = 2 \qquad (1)$$

This is the Euler relation which is widely and effectively used in nowadays fullerene studies.

One of the consequences from the Euler theorem dictates that a hypothetical polyhedron formed only by hexagons is not feasible. The latter means in turn that it is impossible to design a close-cage molecule using only graphite hexagonal building blocks. Therefore hexagonal and pentagonal faces in C_{60} molecule. This is true for any polyhedral molecule, cluster, living organism, architectural or any other construction. A nice application of such a principle to the analysis of the shape of radiolaria was given by D'Arcy Thompson in his classical book "On Growth and Form" [9]: "No system of hexagons can enclose space; whether the hexagons be equal or unequal, regular or irregular, it is still under all circumstances mathematically impossible. Neither our *reticulum plasmatique* nor what seems to be the very perfection of hexagonal symmetry in *Aulonia* are as we are wont to conceive them; hexagons indeed predominate in both, but a certain number of facets are and must be other than hexagonal".

Assuming an existence of the entire family of carbon molecules - *fullerenes* – in the shape of convex polyhedra consisting only of f_6 hexagonal and f_5 pentagonal faces, one gets.
For such molecules:

$$F = f_5 + f_6 \qquad (2)$$

Since all vertices of the network have degree of 3 and each edge is shared by exactly two faces, the following expressions can be derived

$$3V = 2E = 5f_5 + 6f_6 \qquad (3)$$

or
$$6(F - E + V) = 6f_5 + 6f_6 - 15f_5 - 18f_6 + 10f_5 + 12f_6 = f_5 \qquad (4)$$

Together with *Euler relation* it yields

$$f_5 = 12 \qquad (5)$$

$$3V = 60 + 6f_6 \qquad (6)$$

or

$$V = 20 + 2f_6 = 2(10 + f_6) \qquad (7)$$

Thus, there must be 12 pentagons in any of such molecules!

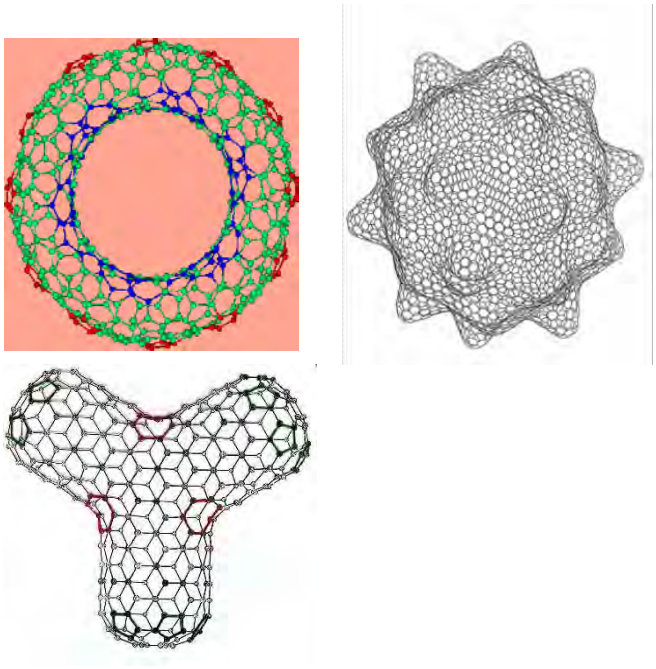

Figure 15: Fullerene-like structures with negative curvature: a – toroidal clusters, b - stellated carbon clusters, c - Y-junctions of carbon nanotubes. Pentagons and heptagons providing positive and negative curvatures, respectively, are indicated.

Number of hexagonal faces f_6 can be varied while evidently V (number of carbon atoms in the molecules) must be always even. Accordingly, the smallest fullerene has a shape of polyhedron with $f_6 = 0$, formed only by pentagons, is nothing else than the dodecahedron. The next fullerene is C_{24}, затем C_{26}, C_{28}, …, C_{60}, C_{70}, $C_{2(10+h)}$ ...

Finally, fullerene-like structures with negative curvature can be realized by implanting, heptagon disclinations into hexagon/pentagon fullerene nets.[3]

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[3] More generally, introduction of any n-gonal face (where $n \geq 7$) will result in negative curvature in fullerene-like structures.

About the aesthetics in natural sciences

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Abstract

The fact that some views, which we see with our naked eyes, seem beautiful to us, can be explained by practical needs of evolution. Others are harder to explain. The real problem starts with views that are either astronomical or microscopic, down to atomic microscopy. Why should these look so beautiful?
As a solid state physicist and an artist, who encounters atomic, scanning electron and tunneling micrographs and also metallurgical photos, I was always fascinated by the visual beauty of the natural sciences. In this article, following a short philosophical discussion about the meaning of beauty and why things look beautiful to us, I present, with short explanations, photographs, starting from dimensionless mathematics, through astrophysics and down to atomic microscopy. The common thing of all these photos is that they were taken not for the sake of their beauty, but for scientific evaluation purposes.

Introduction

Why do certain things look beautiful to us?
Are there criteria for beauty?
If yes, are they universal?

In an article by the Israeli philosopher Zvi Yanay, in the monthly magazine Galileo (Vol. 27) I found: "In nature, many animals use colors and decorations to send messages and information to their surroundings… flowers use colors and symmetrical shapes in order to attract insects, but there is no proof that there is a connection between their use of color and shape and what we see as beauty…what is this thing that we call beauty and the peacock female sees in it such a great value for evolution…?
About symmetry and health:
… genetic defects and the operation of parasites distort the symmetry of body organs and their coverage and therefore they are easy to spot.
Symmetry can, therefore, be considered as a universal grammar of the language of nature, representing genetic health and cleanliness from parasites."

Being close, genetically, to the animals, it makes sense that what attracts them for practical evolutionary reasons, may look attractive also to us. The real problem starts with views that are either astronomical or microscopic, down to atomic microscopy. Why should these look so beautiful? Maybe the answer lies in the universal denominators, listed by Yanay – shapes, colors and symmetry.

In this article, photographs, starting from dimensionless mathematics, through astrophysics and down to atomic microscopy are presented. The common thing of all these photos is that they were taken not for the sake of their beauty, but for scientific evaluation purposes. In some of them, beauty is obvious due to shapes, colors and symmetry. In others, however, some of these elements or all of them are missing and still they look beautiful only due to a nice composition.

Mathematics

Many mathematical formulas can be translated into beautiful visual views. Here are two examples:

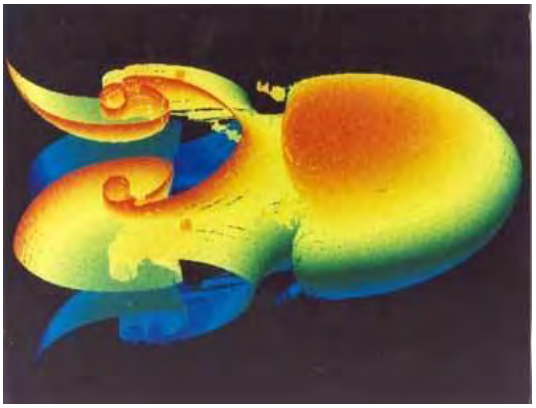

Fig. 1: Reilly-Tailor disturbance at an interface [1]

Fig. 2: a fractal [2]

Fig. 1 presents a mathematical simulation of Reilly-Tailor disturbance at an interface. It occurs when a shock wave passes through an interface between two media (gases or liquids) with an imperfection and the model depicts the occurring turbulence. Fractals are well known entities with a non integer dimension. One of them is presented in Fig.2. In both these examples, the man made colors add to the beauty that stems from the shapes and perfect symmetry.

Astrophysics

Some astrophysical entities have nice symmetry and shapes, like the rings of Saturn. In Fig. 3, green represents ice. The Whirlpool Galaxy is actually a couple of galaxies, where the left one draws mass from the right one, creating the whirlpool shape. Here, the shape as well as the composition is magnificent. Nebulas are huge gas clouds, where planets are formed. Fig. 5 displays nice colors as well as composition, while in Fig. 6, only composition contributes to the beauty of the scene.

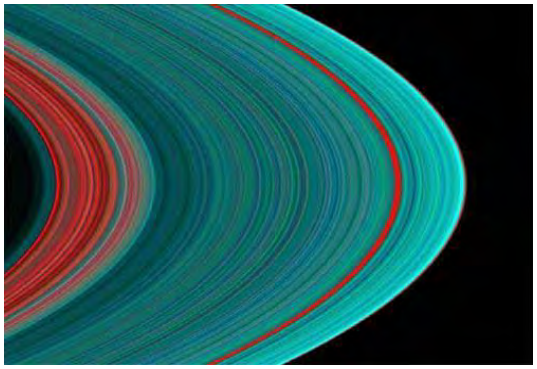

Fig. 3: Rings of Saturn ([3], ultraviolet)

Fig. 4: The Whirlpool Galaxy ([4],visible)

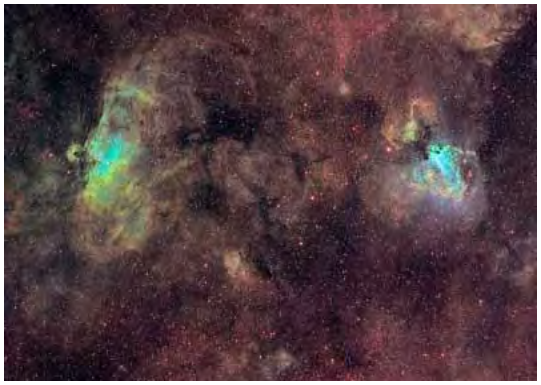

Fig. 5: The Eagle and Peacock Nebulas red) ([4], visible)

Fig. 6: The Orion Nebula([5], Infra-

The visible world

Fig. 7: Computerized tomography of a bone [5]

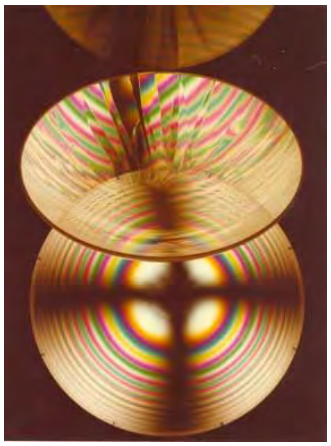

Fig. 8: Interferometry through a sapphire cape [1]

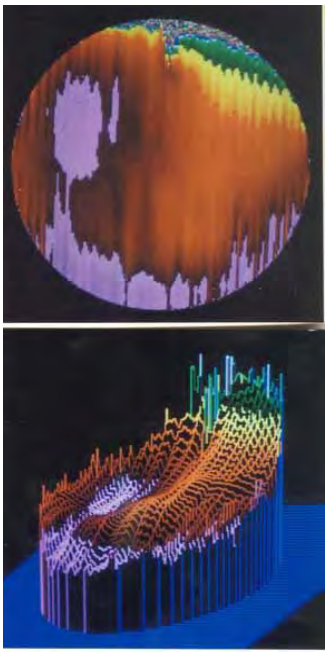

Fig. 9: Moiré display in 2 and 3 dimensions of a sapphire cape [1]

There are endless examples of beautiful scientific objects and pictures in the visible world around us and I chose randomly two examples. Had I seen a sculpture of the bone, the tomography of which is presented in Fig. 7, I would have liked it very much. Interferometry

of light through a sapphire cape of a head of a missile is intended to check the symmetry and roundness and the computerized Moiré display (photography through two grids, slightly tilted respectively) of the cape, which is intended to find small defects, make beautiful two and three dimensional shapes.

Close range microscopy

Microscopic photographs, optical (natural color) or electron microscopy (Scanning Electron Microscope – SEM, or Tunneling Electron Microscope – TEM, BW), are often very beautiful. Here are some examples.

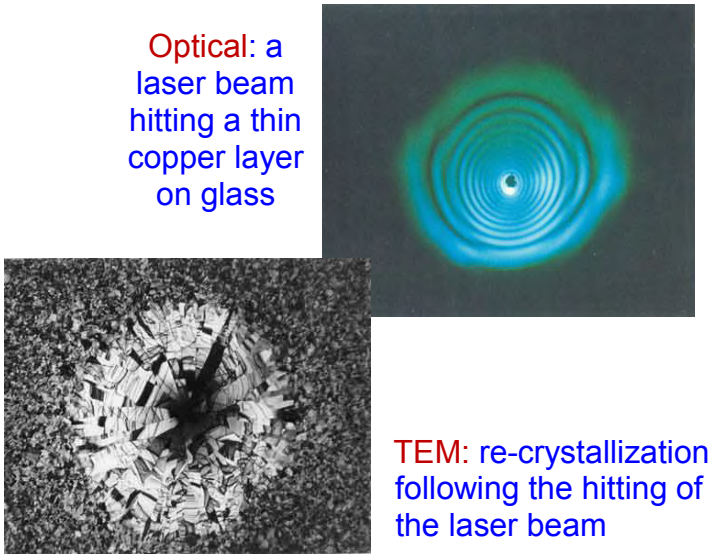

Fig.10: Laser ablation experiments [1]
Magnification ~100

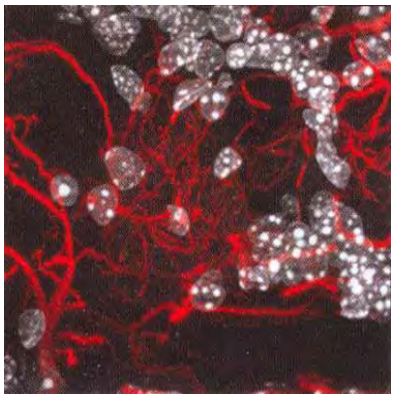

Fig. 11: A cut through a brain cell of a mouse [5]

Fig. 10, upper, presents light interferometry through a thinning copper layer due to ablation by a strong laser beam. The lower picture is a TEM realization of re-crystallization of the copper due to the heating.

Alloys form different crystalline phases, side by side, have different structures and symmetries. Two dimensional beautiful SEM presentations of such two alloys are given in Figs. 12&13 [1], while Fig. 14 [1] presents a 3 dimensional beautiful sculpture, formed by crystallization of excess of titanium at the edge of a U-Ti alloy. The magnification of the 3 micrographs is ~100.

Fig.12: SEM - a Mg-Zr alloy

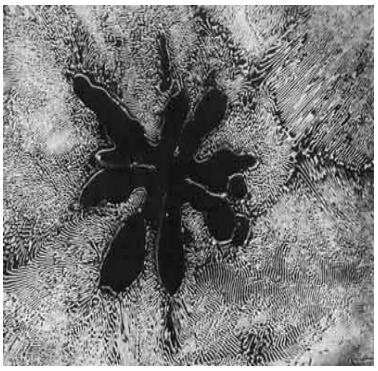

Fig.13: SEM – an Al-Nb alloy

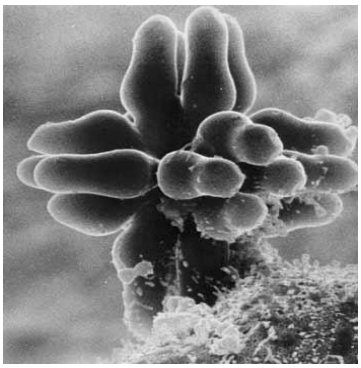

Fig.14: SEM - Ti crystallization at the edge of a U-Ti alloy

The (natural) color of the optical micro photos of alloys stems from the amount of oxidation of parts of the sample. The colors of the x-ray scanning are handmade and present different crystallographic planes. The composition of this abstract "painting" is beautiful, to my taste, at least.

Fig.15: Optical – a Cu-Bi alloy [1]

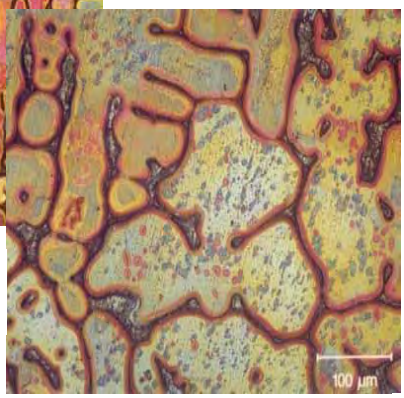

Fig.16: another Cu-Bi alloy [1]

Fig.17: X-ray scanning of uranium hydride (crystallography sensitive) [1]

Atomic microscopy (STM, AFM) [6]

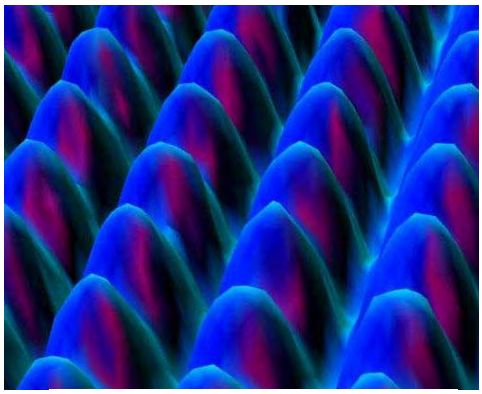

Fig. 18: An organized structure of Ni(111)

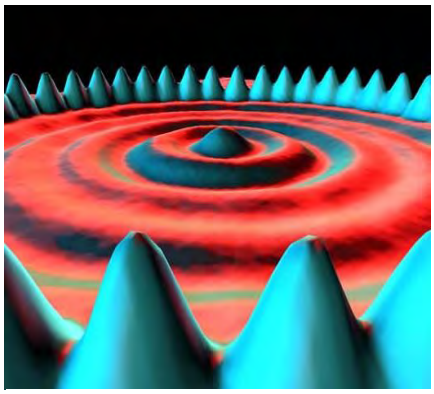

Fig. 19: Electron waves in an iron "basket" on a metallic surface

The invention of Scanning Tunneling and Atomic Force microscopies (STM &AFM respectively) in the mid 1980's opened a new field, in which atoms and electron waves can be directly observed. Two beautiful STM examples are presented here. A crystal face of Ni(111), where atoms stand in perfect rows and an experiment, by shifting iron atoms, by the STM tip, to form a closed packed "basket", in which standing electron waves can be observed. The colors are handmade.

Conclusion

The reasons why things, of all dimensions, are beautiful to us have been discussed. Examples of scientific photographs of dimensionless mathematics and from astrophysics down to atomic microscopy are presented, demonstrating how colors, shapes, symmetry and composition cause them to look beautiful.

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To see the voices: science and technology in the service of musical analysis of opera singing

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Introduction

The purpose of this presentation is, in the context of the conference theme, to demonstrate how science and technology, seemingly from the technical domain, are used in analysis of art: performance of vocal music (opera arias) and interpretation of emotional expression in singing.
Fourier's theorem, published in 1822, forms the scientific basis, digital recording, and computer technology translates this mathematical theorem to computer programs that enable very easy and rapid computation of Fast Fourier Transform (FFT) spectrograms. This allows presentation of sound as a picture, or "a look" into sound.
FFT spectrograms form the major tool that enables the author to analyze art: exploration of the human voice in artistic singing, and other sounds, in great detail, revealing many subtleties that are analyzed and interpreted.
In these studies the single, individual tone can be looked at as well as complete musical phrases.
The various forms of the evolution in time of the individual vocal tone, from beginning to termination, reveal the relation to the emotions expressed in the singing. Comparison between singing of the same operatic aria or Lied by two or more artists demonstrates the varieties in the artists' dramatic approach and musical interpretation.
This is demonstrated here in a comparative study of singing of the first four lines in the aria: "In questa Reggia" from Turandot by Puccini, sung by ten famous artists.

The Aria: – Literary and Musical Background

Puccini's last opera Turandot is based on a Chinese fairy tale about the princess Turandot. The Emperor of China, her father, issued a decree, in which young men of royal blood were invited to solve three riddles put to them by Turandot. The one that succeeds in solving the riddles will win Turandot in marriage, but those that failed will lose their heads.
The aria "In questa Reggia" tells the deep reason behind this riddle solving affair: many centuries before, the princess Lou Ling, an ancestress of Turandot, was violated and tortured to death. Because of that, Turandot, the ice princess, hates men, and thus takes revenge on men for the violation and death of Lou Ling. ("io vendico su voi, su voi quella purezza, quel grido e quella morte"). Further on in the opera Turandot is explicitely called: the princess of death ("Principessa di morte").
In this presentation, the first four lines of the aria were studied. They form an introduction, but they make a clear, definite statement, on the deep meaning of the story of the opera, and the true character of Turandot. Starting from the text and the musical aspects, the study will proceed to the vocal performance.

Text of the first four lines:

In questa Reggia or son mill'anni e mille	In this palace for thousands of years now
Un grido disperato risonò	A desperate cry resounded
E quel grido traverso stirpe e stirpe	And that cry passing many generations
Qui nell'anima mia si rifugiò	Here in my soul found refuge

The score corresponding to these lines is presented in Fig.1. The symbols will be explained later.

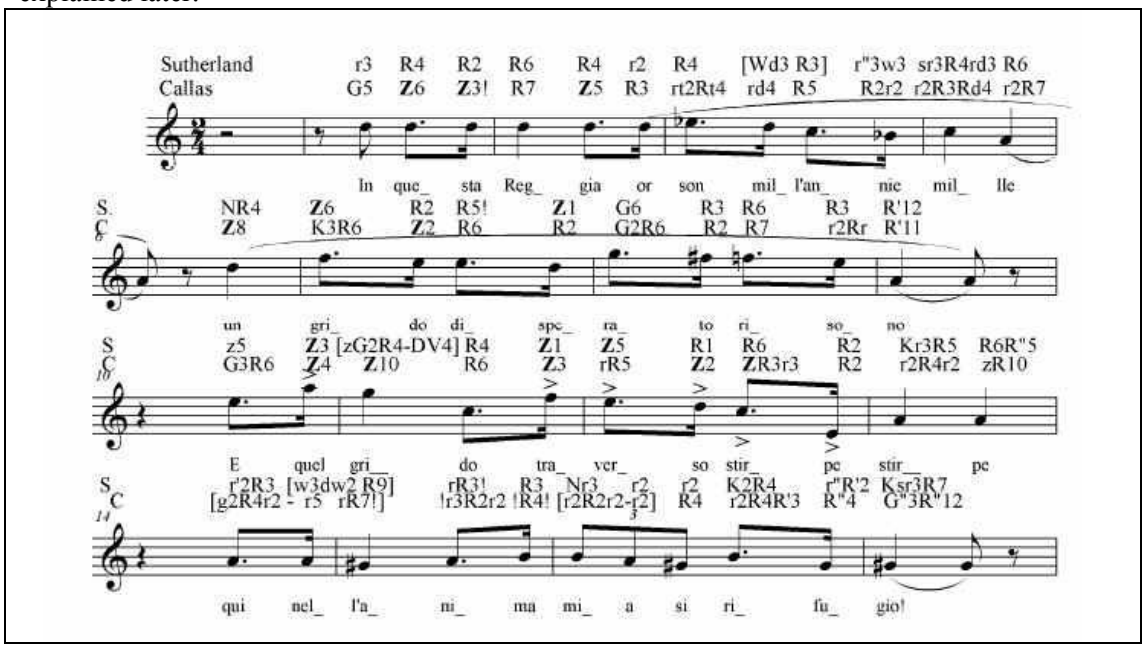

Fig.1. The first 4 lines in the score of the aria "In questa Reggia" from Turandot by Puccin

Musical Aspects, Tension-Relaxation, Dynamics

Music consists of a series of tension (or excitement) build-up and tension release (relaxation), and it is to be analyzed in those terms. The musical parameters that determine tension build-up are: Increase in pitch (tone height, tone frequency), increasing sound level (loudness, sound wave amplitude), increasing tempo (speed), abrupt change. Relaxation is the inverse process of decline (decrease) in these three parameters, and gradual as opposed to abrupt change.

The first line (in questa Reggia…- Fig.1) starts on the note D repeated six times, indicating that not much excitement is happening musically, followed by a slight, a semitone, rise to E flat, then a decline indicating relaxation.

The second line (un grido disperato....) is built of a jump (increased tension) of a third (on "Un **gri**-do", D to F) followed by relaxation of a three-note decline, then comes a second jump of a fourth (on "di-spe-**ra**-to", D to G), again indicating tension build-up, relaxing again by a four-note second decline.

Maximum tension is reached in the third line (E quel grido…) with two larger jumps of a fourth (E to G, and C to F, on the words: **quel,** and **tra**-verso), respectively. The first one relaxing in a short, two-note, steep decline, and the second relaxing in a four-note decline, finally reaching E an octave lower. Puccini marked the jumps by sforzando, as are also all the four notes in the second decline (relaxation). The fourth line is undulating, and is the final relaxation of this part of the aria.

This is demonstrated in the dynamics, Fig.2, that shows the sound wave amplitude vs. time graphs (dynamic curve) for three artists singing the four lines of the aria: Joan Sutherland, Maria Callas, and Angela Gheorghiu . For each one of the singers one observes 4 distinct groups of sound segments, corresponding to the 4 lines in the score. One also observes the differences among the three artists' which reflects their different attitude towards text and

music in their musical interpretation: Joan Sutherland sings the first line in rather low dynamic level (low sound intensity), in accord with the *p* written in the score. Increased dynamic level (tension build-up) in the 2nd and 3rd lines is also in accord with the *f* indicated in the score, but differing in detail from Puccini's intentions. The explicitly marked sforzando on climax notes in the third line, indicate that the climax (maximum excitement) is in the third line, whereas in Sutherland's singing the maximum in dynamics is in the 2nd line. Callas sings the first 3 lines in quite the same dynamic level, this is a distinct statement on the part of Callas, and it will be further discussed in the part on the FFT spectrograms.

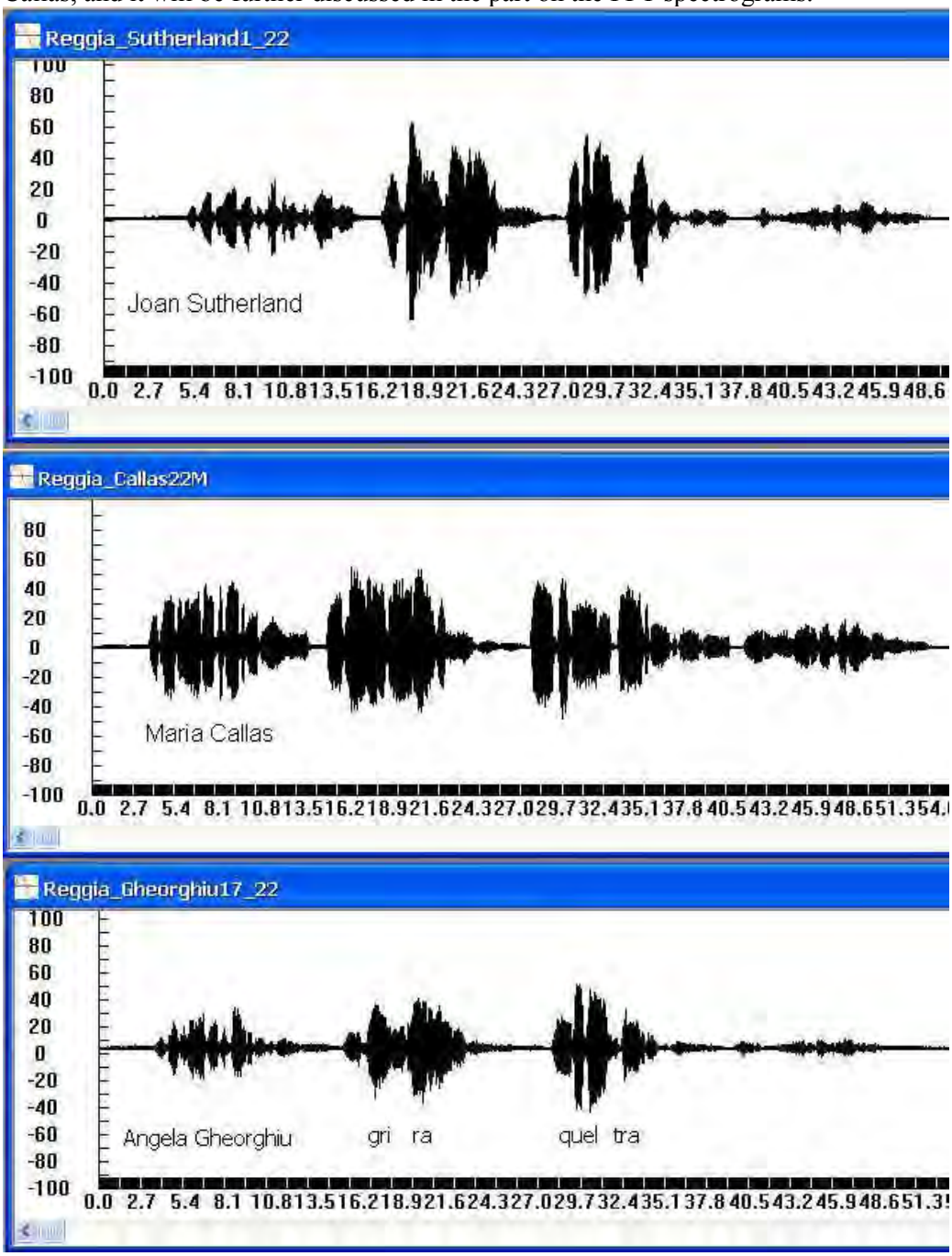

Fig.2 Dynamic curves: sound amplitude vs. time for three singers. Four distinct sound segments corresponding to the 4 lines in the score are clearly discerned. The peaks in sound amplitude for the stressed syllables: ***gr i-*** *and* ***–ra–*** *in the phrase: Un* ***gri****do disper****a****to in the 2nd line, and the syllables* ***quel*** *and* ***tra*** *– in the 3rd phrase E* ***quel*** *grido* ***tra****verso, for Angela Gheorghiu, are marked.*

Angela Gheorghiu's singing conforms exactly to Puccini's intentions indicated in the score, and the climax of maximum tension is in the third line, as is evident in the dynamics.
Tension relaxation in the 4th line is evident for each of the three artists. One can also discern patterns of tension and relaxation within each of the four groups for each singer in Fig.2. Dynamic curves, such as displayed in Fig.2, are not common in musicology. They were made possible only due to development of digital recording – another achievement of science and technology in the service of music.

Fast Fourier Transform (FFT) Spectrograms as a Tool for Investigation of Vocal Performance - Explanation of the Spectrograms

Figs.3 and 4 show two types of FFT spectrograms that will be useful in this study. Each spectrogram consists of two parts. The top part shows the sound wave amplitude (sound level) as a function of time, x-axis: time, y-axis: wave amplitude. The bottom part is the FFT spectrogram, synchronous with the sound wave amplitude curve: x-axis: time, y-axis: frequency (Hz). The following is an explanation of these spectrograms, with the symbols that serve to distinguish the various forms of vocal tones encountered in this study, and their meaning (Rapoport, 1996, 2004, 2006)
In the spectrogram, we see a series of parallel equidistant lines.
The lowest is the fundamental frequency, Fo, corresponding to the frequency of the note in the score. The higher ones are the overtones, integral multiples of the fundamental frequency: 2Fo, 3Fo……nFo, of the Fourier sine wave series.
Secondly, in these spectrograms, we see that on many of the frequency lines something that looks like a sinusoidal modulation is superimposed. This is the voice vibrato – frequency modulation - that imparts to the voice beauty, pleasantness and expressiveness.

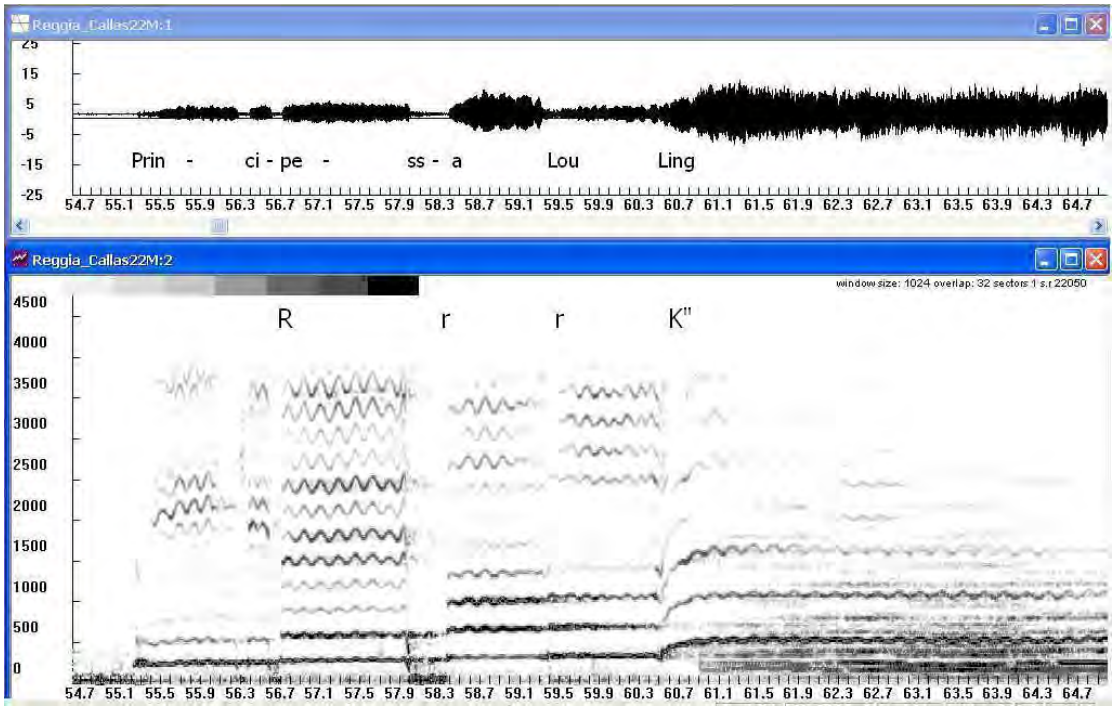

Fig.3. Demonstration of three types of tones: R, r, and K (see text)

Thirdly we see some forms of the tones that seem different from one another, and some that look similar to each other.
In Fig.3, there are tones denoted R, r, and K, respectively. R-tone is a tone with high amplitude vibrato. Small amplitude vibrato is denoted as r-tone. A tone with very small

vibrato amplitude is denoted: sr. A K-tone is a tone starting lower than the target tone (corresponding to the note in the score), rising to the target in a convex manner. In previous works (Rapoport, 1996, 2006) a K-tone meant that the convexly rising part was without vibrato, and a K-tone with vibrato was denoted G (as in Fig.1). In this presentation, for simplification purposes, both forms will be denoted as K. The K-tone in Fig.3 is denoted K". This indicates that the higher overtones above 1000-1500Hz have very low intensity, as is seen in the Fig.3. Thus K, K', and K" will indicate a K tone with overtones of full intensity, of low intensity, and of very low intensity, respectively. Similarly for R, r, and any other tone type (Rapoport, 2004).

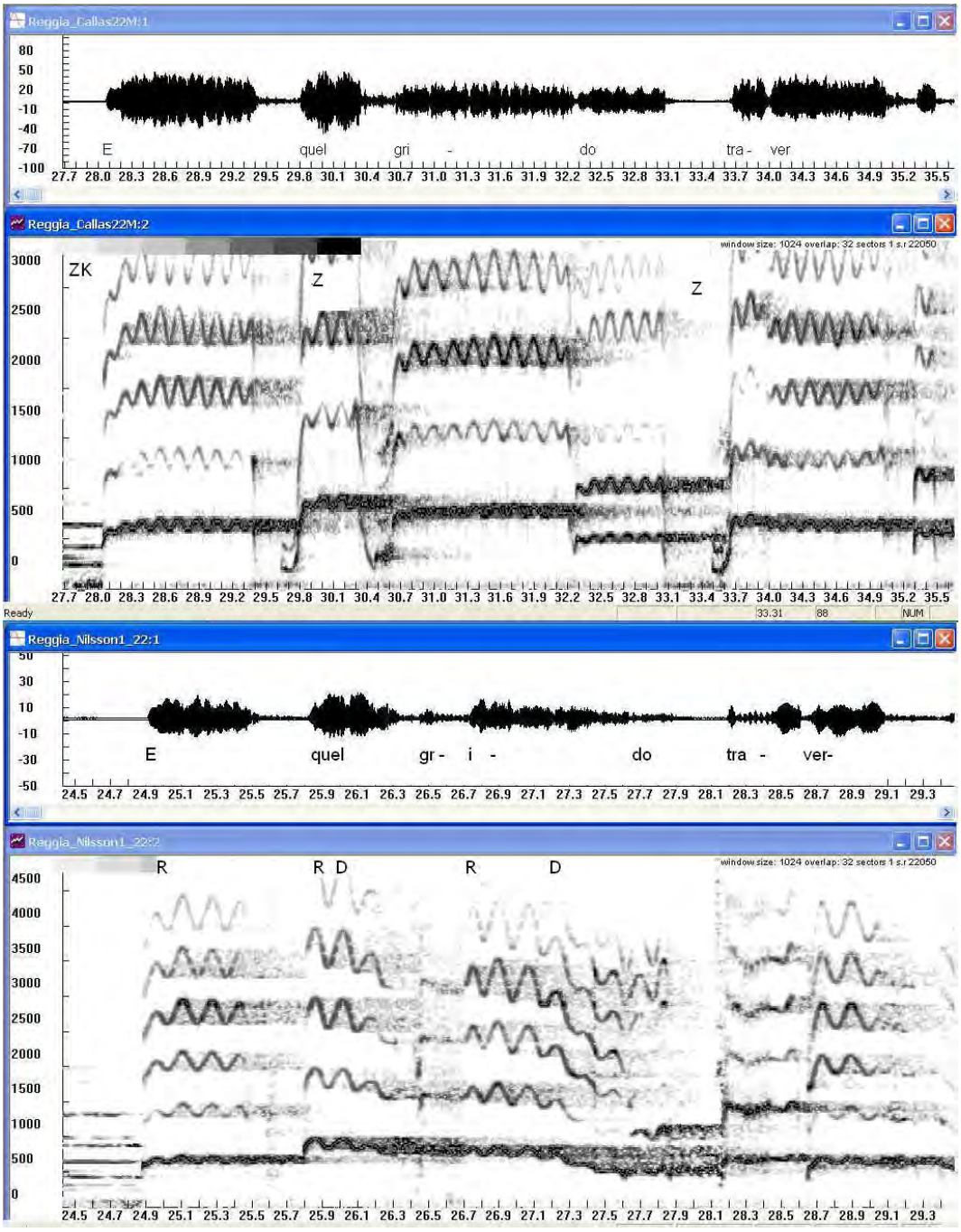

Fig.4. *Demonstration of tones of type: Z, and RD. The figure shows spectrograms of the third line in the score (Fig.1), as sung by Maria Callas (top), and by Birgit Nilsson (bottom). It will be referred to and discussed in the appropriate section.*

In Fig.4 (top) we encounter tones marked: Z, and in Fig.4 (bottom) tones marked RD.
A Z-tone is a tone starting way bellow the target frequency, rising abruptly to it. This tone indicates maximum tension (excitement) - sforzando – special emphasis or stress. A z-tone is similar to Z-tone. A Z-tone starts way below the target tone, whereas a z-tone starts below it to lesser extent. A Z-tone is characterized by its abrupt rise, it also terminates in an abrupt decline far below the target tone.

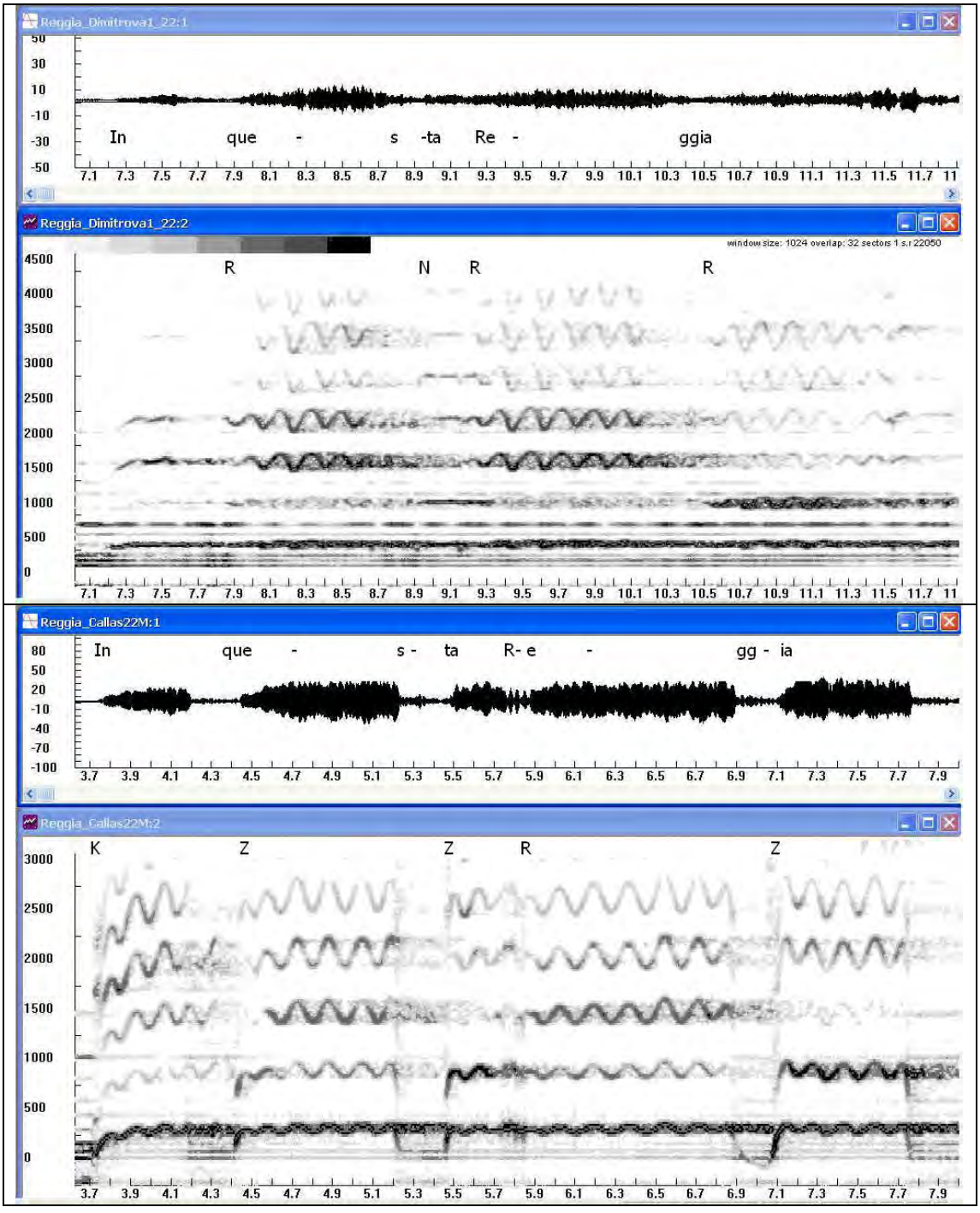

Fig.5 The first 5 tones of the phrase "In que-sta Reg-gia" (first line in the aria) - all of them are the same note D. Top: Ghena Dimitrova, Bottom: Maria Callas. Ghena Dimitrova sings this segment in R tones, whereas Maria Callas starts with a K tone, followed by Z tones.

RD-tone (Fig.4 bottom) is a tone starting as R-tone and terminating in a gradual decrease in tone height. This kind of tone is common in opera singing, it is called "portamento", and imparts an ornamentation (embellishment) to the transition from high to low tone (gradual change).The three symbols, R, K, and Z will suffice for the purpose of the present study. To these, we add the symbol CH, denoting an arch type tone, that starts as a K-tone, ascending in a convex manner towards the target tone, and at the end goes downwards also in a convex manner. For all purposes of the present work, CH-tone is equivalent to a K-tone. Other symbols that occur in the Tables further on are: M, and m, meaning R and r-tones consisting of 2 vibrato cycles, and A, and a, meaning R, and r tones consisting of 1 vibrato cycle.

N-tone denote a tone of constant frequency, devoid of vibrato.
For a complete notation scheme the reader is referred to Rapoport (2004),
There is a hierarchical order concerning these types of tones, from excitement (tension) to relaxation. Thus, in this hierarchy Z > K > R > r, and in the corresponding emotions that they represent (Rapoport, 1996, 2004): Z, corresponds to Fury > K, corresponds to grief > R, expressive operatic singing.

Detailed Analysis of the First Four Lines Opening the Aria.

Referring to the score (Fig.1), Fig.5 presents the first 5 tones (all of them are the note D) in the first line as sung by two artists: Ghena Dimitrova and Maria Callas.
As seen in Fig.5, Ghena Dimitrova sings in R-tones, corresponding to the characteristics of this first line – being an introduction, opening the story, with no particular emotion attached, and much in line with Puccini's indications in the score. Maria Callas, on the other hand, starts with a K tone, and continues with Z tones, putting a special emphasis on these tones and these words - thus making a very strong statement right at the beginning, indicating clearly the dominating emotion of rage, and the character of the cruel, ruthless princess, Turandot, the princess of ice, the princess of death (Principessa di morte).
Results for all 10 artists are presented in Table1.
Table1 presents the singing of 10 famous opera singers of the 20th century, (including Angela Gheorghiu - a contemporary leading artist).
Table1 provides a means for comparison of the various interpretations of the artists.
Three groups of singers are discerned: First group: Renata Tebaldi, Maria Callas, Joan Sutherland, Monserrat Caballe, and Ghena Dimitrova – the divas of the Italian opera repertoire in the 20th century, the second group includes the Wagnerian singers: Birgit Nilsson, Inge Borkh, and Eva Marton, and the third group includes two other singers: Eileen Farrell, and Angela Gheorghiu.
Table1 is not meant to present statistical analysis. Each artist is an individual with her own personal artistic interpretation of the role. It serves to point out specific features in the performance of each artist, and to observe differences and common features in the various performances. Looking closely at the first line of the text one can divide it into three parts: "(1) In questa Reggia (2) or son (3) mill'anni e mille". Part (1) is the opening, where Callas makes her clear statement in Z tones. Tebaldi, Sutherland, Dimitrova, Nilsson, and Farrell sing it in varieties of r and R tones. Part (2) is the part of slight tension build-up, where some Z tones appear in the singing of some of the singers (Caballe, Nilsson, Borkh, Marton, Gheorghiu). Part (3) is the relaxation stage, and various singers (Callas included) sing it in r, R, and CH tones (indicating grief) in legato, as indicated by the tones enclosed in square brackets, especially evident in the singing of Callas and Nilsson. This might indicate tenderness and compassion that Turandot feels towards the Princess Lou-Ling, as is evident in the fifth line in the text (see Fig.3 - for shortage of space the fifth line is not part of the present study). Table2 shows the second line as sung by the 10 artists. The type of tones corresponding to the jumps on the salient notes, or the emphasized words: "Un gri-do" and "di-spe-ra-to", are K, k and CH with most singers, including Callas. As pointed out previously, CH is a tone that looks like an arch, starting in a K-type convex rise, and terminating in a convex decline. Thus K and CH belong to the same family, expressing grief.

Comparing Tables 1 and 2, one observes the singers that sang the first line of the aria mostly in R-tones, underwent a transition to K, CH, and also Z-tones. Thus the predominant emotion expressed in the singing of the second line for most singers is grief, and also some rage. Maria Callas, in contrast to the others, somehow softened her emotional expression, and expressed the jumps in K tones, compared to her singing in Z-tones in the first line of the aria. Eva Marton, singing in the second line expresses almost emotional neutrality or coldness. She sings the entire line in R-tones - even the jump on "gri-do" – (except a small ch-tone on the syllable "ra" in the word "dis-pe-ra-to"). Marton thus portrays Turandot as the princess of ice, cold and devoid of any feelings. The observant reader might find some other details and nuances of interest.

	In que – sta Reg – gia or **son** mil – l'an – ni e **mil** – le
Tebaldi	R' R sm" !R R m't R' n' r'R' R' [sm" RD iR']
Callas	**K3R2** **Z6** **ZR2** R7 **Z5** **Z2** [**ch6-4** R5 Mm **Ch9** mR4]
Sutherland	R R R R R !m"! R [rD R] [d R] [sr RD R]
Caballe	sr **z**R m! !R! **Z** **Z** **Z** [smd Rw" n A'**]** !RD !R'
Dimitrova	sm" !R! [n rR!] [!R' M] rR [nD RD sm] [iRD R]
Nilsson	wt !r! m! !r iRj! **Z1!** iRj [m! d rd n w !rD !iR4!]
Borkh	rR !R! R rR! **z**R **Z1** rR [A rR] **[z**1 n] [**CHD** R5]
Marton	w A"R M R **Z** **Z** [**CH**" R R'r" AM] [**k**d' R9]
Farrell	n iR m aR [R! !m] iR m iR [R! m] **ztch**m R
Gheorghiu	[ir4r"2 rt4] M iR8 **Z8** r"3 [zch6 rd4 Rd5] [w3 **ch7**,3"] R"11

Table1.Schematic summary of the tone types in the first line of the aria, as sung by the 10 artists, The numbers following the symbols for Maria Callas and Angela Gheorghiu indicate the number of vibrato cycles for each tone – thus allowing determination of tone duration (one vibrato cycle ≈ 0.16 s, ≈6 vibrato cycles per second.)

The reader is referred now back to Fig.4, showing the spectrograms of Callas and Nilsson singing the phrase "E quel gri-do tra-ver" – the opening part of line 3 in the aria - the climax with the two jumps in this part of the aria .The difference between the two spectrograms is clear. Callas expresses fury in Z tones, and Nilsson demonstrates the beauty of the voice in opera singing, in ornamented RD-tones. As will be demonstrated in Table3, Eva Marton exhibits singing devoid of any emotion (r-tones along the entire line, the jumps included), portraying Turandot as the "Princess of ice" – a different portrayal – yet in complete accord with the spirit of the opera. Callas is Turandot in the 1st person, personifying her, expressing her emotions of fury and grief, changing to tenderness and compassion towards princess Lou-Ling in later parts of the aria. Marton is also Turandot, in 1st person, portraying another aspect of her image – coldness of ice. Nilsson, concentrating on the beauty of the voice, tells the story about Turandot, portraying her in the 3rd person.

	Un		***gri**	–	do	di	–	spe	–	***ra**	-	to	ri	-	so	-	no	
Tebaldi	R		**Z**		M	**Z**		M		**CH**		M	**ch**		sr		iR'R"	
Callas	**[Z8**		**K4**R5**]**		**Z2**	**Z6**		**[Z2**		**K2**R6**]**		**z3**	R7		[mAa		R'11]	
Sutherland	43		**115**		48	46		28		**72**		59	59		28		10	
	NR		**Z**		**Z**	R!		**z**		**K**		R	R		R		R'	
Caballe	**Z**		**Z**Rj		**Z**	!R		[**ZK**		R]		[md	R]		m		ir'	
Dimitrova	[**K**		**K**		M]	R!		[M		**CH**]		[M	R]		sr		rRr"	
Nilsson	**K**		[**zn**Rm		a	R]		M		**z** R		Md	R		m'		m'R'	
Borkh	**K!**		**k"**R		M	**Z**		**Z**		**CH**		M	R		M		R	
Marton	[R		R]		M	R		M		**ch**		M	R		R		R"	
Farrell	iR		smR		R	R!		M		**K**		M	R		R		!r	
Georghiu	21		**59**		27	27		28		**62**		55	51-36		23		9-6	
	k3R5		**zK3R7**		Md	R6		Mt		**K3R4**		R3	!R8		R5Dv3		r"11	

*Table2. Schematic summary of the tone types in the second line of the aria, as sung by the 10 artists. The numbers in the first line for Joan Sutherland and for Angela Gheorghiu denote the relative sound wave amplitude (sound level or loudness) for each tone, indicating maxima in the dynamic curve for the significant words "**gri**-do" and "dis-pe-**ra**-to", marked in astrisks in the first line of Table2, and corresponding to the jumps in the score. Again, as in Table1, the number of vibrato cycles of each tone are marked for Maria Callas and Angela Gheorghiu.*

	E		***quel**		gri	–	do	***tra**	–	ver	–	so	stir	–	pe	e	stir	–	pe	
Tebaldi	**Z**		**Z**		**z**R		**zR**	[Md		R]		sm	**k**R		w	-	R		R	
Callas	**K3r6**		**Z4**		**Z10**		**z**R5	[**Z3**		R7]		**Z2**	**Z8**		Mt		**Z8**		**Z11**	
Sutherland	50		**91**		72		20	**34**		**57**		17	18		3		10		5	
	z		**Z**		**ZK**RD		R	**Z1**		**z**R		R"	R		R		**K**r		r	
Caballe	**Z**		R		**KR**		r"	**Z1**		R		**Z1**	**Z**D"		w		**K'**R'		R'	
Nilsson	R		RD!		aRD		MT	w		**Z**		!M!	iR		!M!	M!	**K**		iR!	
Borkh	**K**		**K**		**Z**		R	**Z1**		**z**R		A	RD"		A		R		**z**R	
Marton	[R		R]		R		R'	R		R		m"	R		-		Rr		R	
Dimitrova	**Z**		**Zch**		**Zch**		R'	**Z**		R		w"	**zR**		A	-	**KR**		**zR**	
Farrell	R		**Z**		R		R	**Z**		R		**Z**	**zR**		M		**zK**		R	
Gheorghiu	40		89		**78**		16-9	**51**		36		23	19		6		11		5	
	k3R6		**K3**R3		**Z**R8		Rt5	**Z3**		R6		m'	R5		R'3		**k3**r5r"3		r"9	

Table3. Schematic summary of the tone types in the third line of the aria, as sung by the 10 artists. As in Tables1 and 2, the numbers in the first line for Joan Sutherland and for Angela Gheorghiu denote the relative sound wave amplitude for each tone.
Again, as in Tables1 and 2, the number of vibrato cycles of each tone are marked for Maria Callas and Angela Gheorghiu.

The fourth line is the relaxation part of the 4-line introductory part of the aria. For shortage of space it is not included here.

Conclusions

Science (Mathematical Fourier theorem) and technology (Digital recording, FFT - Fast Fourier Transform computer program) combine to provide a tool and a method for analysis of singing in general, and opera singing in particular. A comparative study of singing of the first four lines in the aria "In questa Reggia" from Turandot by Puccini, by 10 world leading opera singers was performed by use of FFT spectrograms. This demonstrates the power of this method. The spectrograms show that there are various types of vocal tones. They were classified in six families (previous studies by the author). They convey various emotions, and encompass the full range of emotions from very calm to utmost excitement and tension. In the present study, three of the six tone families were encountered. A special notation scheme, developed by the author, enables the vocal performance in this aria to be described by three letters and the corresponding emotions associated with them: K, indicating grief; Z, indicating rage; and R, indicating expressive, relatively relaxed mood of singing. Thus the character of the first four lines of the aria studied here is established as expressing grief and fury. In addition, patterns of tension-relaxation can be followed along the progression of the aria, and were demonstrated in the dynamic curves and in the spectrograms.

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Rapoport E. (2004) Schoenberg-Hartleben's Pierrot Lunaire: Speech – Poem – Vocal Performance, J. New Music Research, Vol. 33, No.1, pp. 71-111 Routledge, Taylor & Francis Croup Ltd, UK

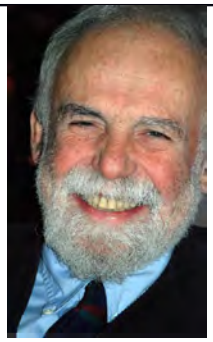
Rapoport E. (2006) The Marvels of the Human Voice: Poem - Melody – Vocal Performance http://www.tau.ac.il/arts/music/hebrew/Publications/download/Rapoport.pdf

Sources

Recordings of the aria used in the present study were taken from commercially available CD's, either full operas, or highlights from recorded recitals. A partial list:

- Maria Callas: Turandot, EMI, rec. ~1958, Teatro alla Scala, conductor Tulio Serafin.
- Joan Sutherland: Turandot, Decca, rec.1972, London Philharmonic Orch., conductor Zubin Mehta
- Monserrat Caballe: Turandot, Highlights, EMI, rec. 1977, Orch. Philharmonique de Strasburg, conductor Alain Lombard
- Birgit Nilsson: Turandot, EMI, rec. 1965, Teatro dell'opera di Roma, conductor Francesco Molinari-Pradelli
- Eva Marton: Turandot, Sony, rec.~ 1984, Wiener Staatsoper, conductor Lorin Maazel
- Angela Gheorghiu: Puccini Opera Arias, EMI, rec. 2004, Orch. Sinfonica di Milano Giuseppe Verdi, conductor Anton Coppola.

Immanent codes of cities identity



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Abstract

Following Piero della Francesca and Florenskji it is possible to perform immanent codes only if we define infinite in our vision. This process is always dynamic and it can perform endless variations, as in the organic world. Increasing process of our subsequent results, following also inter-subjective visions, can identify an ideal. This is possible when we focus a frame of our own poetics as a starting point of view.

For a vision of future, we can represent the unique identity of each city and of each object by following a process of identification, by designing with algorithms not-linear structures as artificial-DNA.

So it's possible to support, design and manage the progressive identity of each city, that could be identified as Ideal City by its inhabitants. This is a process that works by interpreting the immanent codes and their increasing results in endless variations. Identities are nested one over the other, they are never in contrast one each other, and they could be interpreted and designed as an homothetic system of rules able to fit multiplicity and complexity.

The experiences in Generative Art made by the author in the last 25 years are focused on the construction of Ideal Cities as artificial DNA of existing cities and on species of industrial objects and their practical feasibility in intelligent industrial production. In this paper will be shown the experimented generative approach able to design peculiar artificial immanent codes following subjective-intersubjective visions. The pictures of this paper belong to experiments made in the field of identity until those made in May 2011 for identifying a possible interpretation of Jerusalem identity mirroring a vision of incoming Ideal City.

Identity.

The concept of identity is fundamental in each cul-

Figure 1: Jerusalem, Listening God, generative architecture for Jerusalem

Figure 2: Ideal City, Piero della Francesca

Figure 3: Ideal City, variation C.Soddu 2001

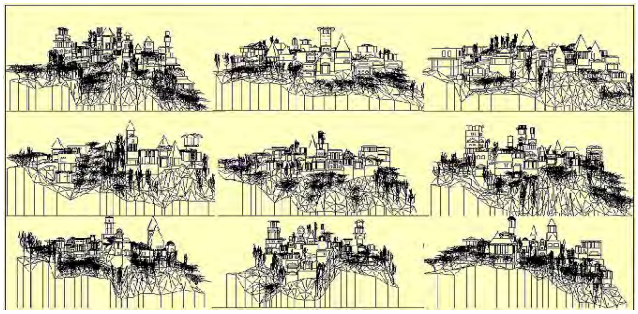

Figure 4: 1988, 9 variations of Italian Medieval Towns generated with Basilica software by the author .

tural and creative approach.
Identities of our being an artist, an architect, a designer as the identity of our cultural references, until the uniqueness identity of each country, of each city, of each district and of each architecture are stratified. All these identities strongly define the qualitative aspects of our way of living and our ability to build the environment in which we like to live. Differences among Identities build the substratum for the progression of the culture.
But, obviously, identity exists only when it is possible to recognize it. If we succeed in identifying an unknown artwork as belonging to an artist that we know, as normally happens for instance for Caravaggio, for van Gogh or for Kandinskji, it means that the identity of the artist exists going beyond his single artworks. This recognizability happens in the architectures too, from Giotto to the baroc of Borromini, from Palladio to Gaudì. And in "historical" cities where it's possible to recognize which city is, also by a simple image of a common street without "monuments".
This recognizability comes from a logical approach that is innate in us. It belongs to the abilities that we naturally developed since we were children. This process of identification, that we naturally develop, allows us to enter in deep in the subtended logics and suggests us how to define logical fields for designing the identity.
Since childhood we learned how to recognize the identity of the things surrounding us. We for instance recognize a chair as different from other objects of the furniture. We identify it different from tables, from stools, from armchairs, from sofas and from whatever surrounds us. And we recognize an object as a chair even if we didn't see this particular chair before, even if it has an unusual and "new" form, even if it doesn't fully answer to presumed

Figure 5. Simone Martini, a representation of medieval town

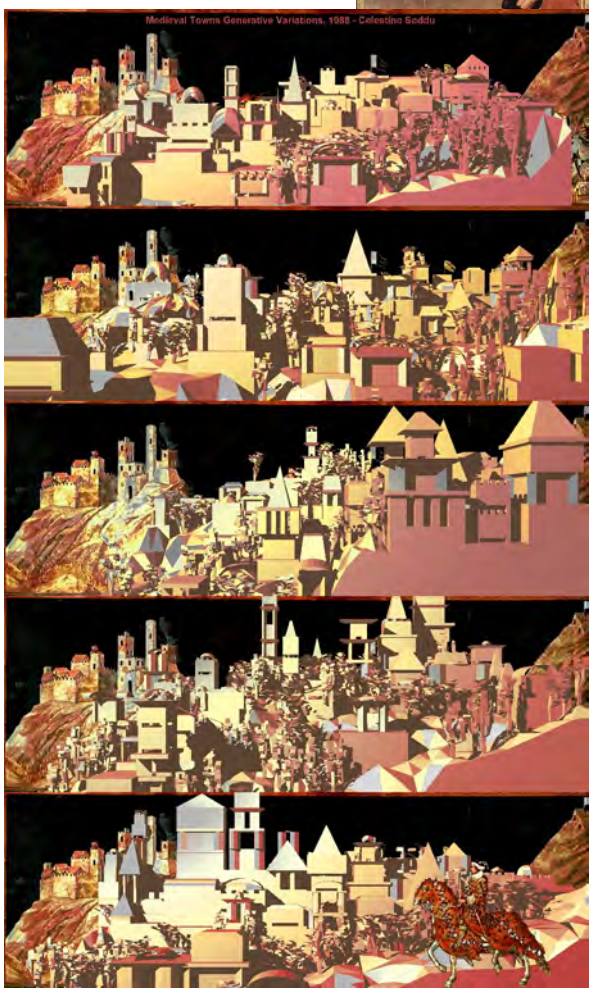

Figure 6: 5 generated variations of medieval cities inserted into a fresco of Simone Marini.

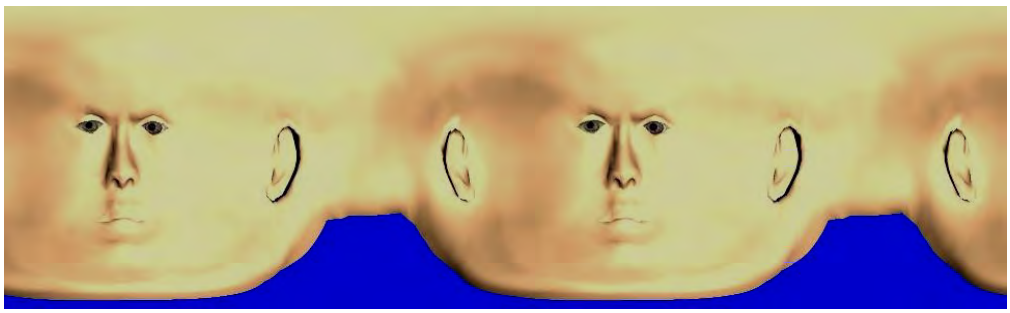

Figure 7: Russian icon with Christ represented in "reverse" perspective indicated by Florenskji. A human head represented in "reverse" perspective. The image is repeated two times (360+360 degrees) for better understanding the external representation of all the head. It is made by swapping the 360 degree interior total perspective, made with the point of view inside the head, into an exterior representation. This swap interchanges the point of view with the target of sight. At the end we have endless points of view and only one sight target. The head is the center of endless subjective points of view. The image is clearly similar to the Russian icons.

functional criteria.
It is also possible that this recognition of an object as belonging to a species is not completely shared with all people.
A borderline field exists in which the recognition is vanishing for some people, absolutely clear for others. Better, the existence of a recognizable identity is tied up to possible interpretations, infinite subjective visions of the same event. Each of these visions, also being unique, subjective and obviously partial, contributes a conclusive way to the "ideal" identity of the event. This happens too for the concept of "ideal city". The "ideal" chair or city are concepts in progress. They increase their identity with each "new" created event, with each “new” interpretation. Each new interpretation of a city done through new architectures, a new romance, a new song keeps alive the identity increasing process.
It is possible to identify an immanent ideal code through the concept of the infinity.
In my approach I referred to the representation of the infinite following how it's performed in the reverse perspective of Florenskji.
While in the perspective of Brunelleschi the relationship is between one observer and one target object, in the reverse perspective of the Russian icons, identified by Florenskji, the relationship is between endless observers and an unique observed event, that normally is the face of the Saint. Florenskji, with his reverse perspective, performs at the best a representation able to fit a common ideal identity built

Figure 8: Delhi, generative architecture for Indian Identity in progress, C.Soddu, 2006


Figure 9: Chicago, finding the Identity of the beginning of last century. 2003

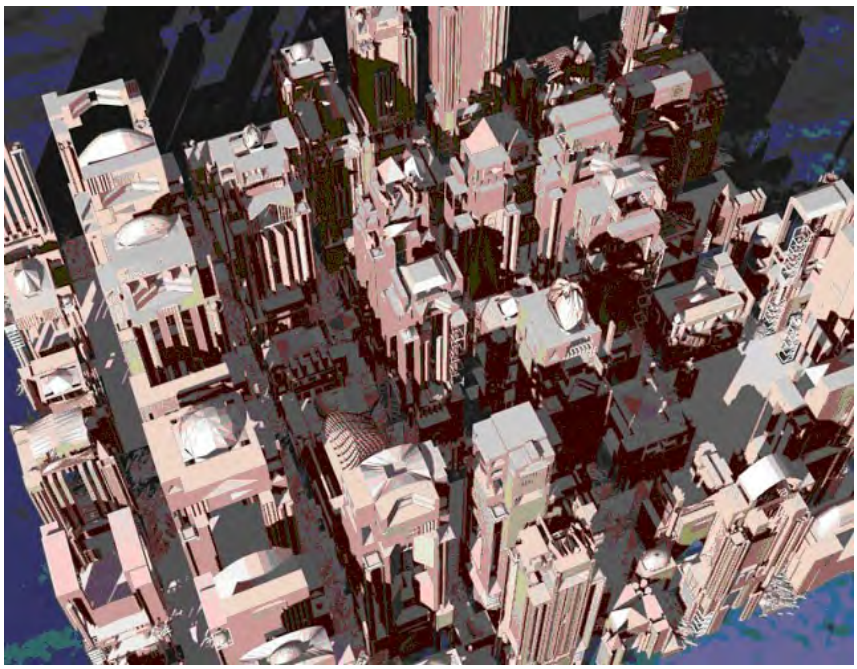
Figure 10: NYC identity, generating a block of Manhattan, C.Soddu 2003. No architectural generated form are really in Manhattan but, all together, the generated block looks like a part of Manhattan

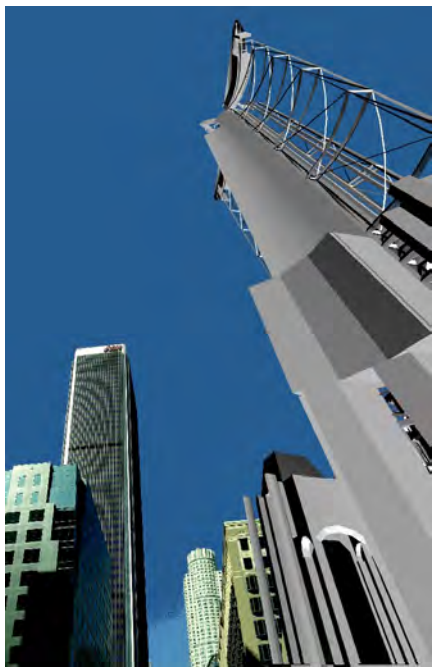
Figure 11: Los Angeles Identity, Generation 2001.

through endless possible different views and interpretations. In my work I have reconstructed the algorithms of this particular but essential perspective representation and I have realized that they are the same, but symmetrically capsized, of a not-Euclidean 360 degree perspective (refer to my book "Not Euclidean Image", Gangemi Pub. 1986). The reverse perspective could be interpreted, and constructed, as a not-Euclidean perspective representation of the face of the observer when the observer looks at his own face from the inside of his own head. This follows what Florenskji assumes: the perspective represents only the bidimensional skin of the object and not the its inside, sliding to a lower dimension. (see my article "Perspective, a Visionary process: The Main Road for Crossing Dimensions, NNJ v.12, n.1, Springer)

Figure 12-13: Hong Kong Identity, generative architectures. C.Soddu 2001-2008

Figure 14-15: Nagoya, Japan. Two variations for Nagoya Identity in progress, C.Soddu 2004

Transformations through different perspective modes performed through repeated passages among different dimensions have been at the base of the construction of my generative algorithms. The reason is that they are able to manage formal transformations keeping alive the similarity of the represented event both in topological and in morphogenetical characters, but operating through progressions that make explicit that all variations belong to a species as a shared ideal identity.

Where can we find the characters of the identity, of the immanent codes a city?

If functions are the same, if the used forms are the same, which reference can define the identity of an object?

If we consider the nature, and if we have in mind the book "On growth and Form" by D'Arcy Thompson, we can appreciate the power of the formal symmetries. We distinguish a crocodile from other animals not because he walks, eats, swims, has a mouth with teeths or has the legs. In fact these functional elements are common to the most disparate species. Neither we recognize him because it has leaning eyes or sharp teeth, because also these formal elements are common. We recognize him because we identify the animal as a possible representation of a dynamic paradigm able to define the structure of the proportions among the parts together with its topological structure. In other terms we recognize the event as one of

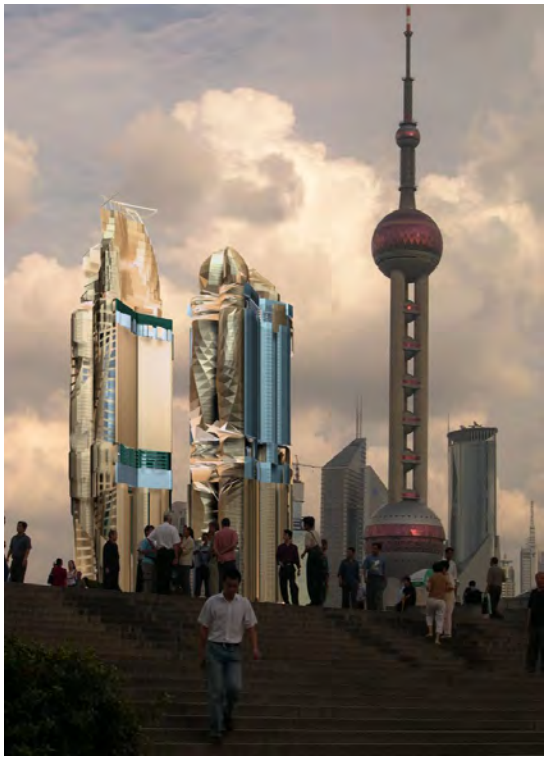

Figure 16: Shanghai Identity in progress, C,Soddu 2003

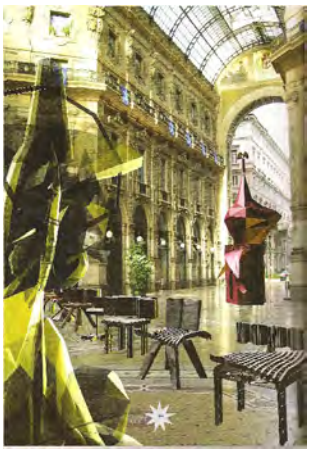

Figure 17-18-19: Generated variations of chairs inside the Gallery of Milan and two variations of the museum of Futurism in Milan. C.Soddu 2004

the possible variations inside a progressive line that brings to an "ideal crocodile", that each one of us has in mind, even if with a different tone.

The identity is the affiliation to an "ideal" dynamic concept that we built with our experience, and therefore it doesn't coincide with the ideal concept of others but whose existence, together with all different concepts, is essential for constructing a common "ideal" reference as inter-subjective dynamic concept.

Identity is the reconstruction of a logic belonging to multiple and similar events. It is a concept that refers to a progression toward something and not only to the analysis of the present objective data, functional or formal data.

If we experiment this approach in our creativeness, we find the possibility to build the logic of ideal events by meta-designing them through paradigms that dynamically characterize them before their construction. It is possible, as well we know, to have an idea, a vision that we are going to perform and to communicate through manifold results, all different but all belonging of this ideal vision. Only these manifold variations can build, in progress, a deep communication of an idea.

What interests us is that, when an idea starts to be identifiable, every following variation is not only recognizable as belonging to a specific vision, but it is able to increase the identity of the vision, the identity of the subjective creative concept and the "identity" of the common "ideal" concept that we share with other people. It performs really an increasing complexity of an immanent code.

All this always happens in the experiences of art, but also in science, being art and scientific "discoveries" indissolubly connected to a subjective vision. This

Figure 20-21: Lecco and Como lake, Italy. identity and culture Italian references, C.Soddu, 2009

Figure 22: Sardinia, Italy, new nuraghe for identity in progress. C.Soddu, E.Colabella. 2008

structure of construction of a paradigmatic idea is the peculiar structure of the generative approach, of the Generative Art. This because it is able to perform the generation of manifold, endless possible results, variations, each one recognizable and capable to increase the clarity of the idea.

From 1988, when I performed my first generative project trying to design and communicate the identity of typical Italian medieval towns, my activity has always been directed toward the design of the identity and recognizability of a species. In that first project the generative vision of the species of Italian medieval towns was not born only analyzing the existing medieval towns but from my interpretative and subjective approach to artistic representations of these towns: the frescoes by Giotto and the tables by Simone Martini. I have realized that, as it happens in the processes of identification performed in the infancy, the subjective interpretations are essential in the construction of a recognizable identity. In identifying the recognizability of a species, for instance the shoes, can incredibly be useful to have appreciated the shoes painted by Van Gogh.

My generative projects have been therefore made by building dynamic logics, algorithms that turn the existing events into something more closed to the idea. The aim of my identity design is to write the rules for transforming a city and its events, architectures, doors, windows, bridges, streets, in a way that the city will be closer to its own ideal concept than before. And to define a progressive transforming path where the increasing complexity runs in parallel with the increasing identity in every possible variation and result.

Building my generative processes I have realized therefore that I was building something like a subjective DNA of artificial events. As the natural DNA, these generative projects are constructed with

Figure 23: Tel Aviv, increasing identity with generated architecture, C.Soddu 2004

Figure 24: Jerusalem, increasing variation #2, C.Soddu 2011

Figure 25: Jerusalem, increasing variation #4

Figure 26: Jerusalem, increasing variation #3, 2011

Figure 27: Jerusalem, identity and increasing complexity, variation #1

algorithms, partial engines of transformation as the genes are, and with a paradigm that defines the harmonic rules of each single process of transformation inside the whole system. During these last 25 years, my experience has been the experimentation in the construction of several possible rules of identity of artificial species and in increasing their recognizability. Together with the possibility to increase the feasibility of each possible and unpredictable result by using the advanced devices of intelligent industrial production.

These experiences involved environmental identity of city as Chicago, New York, Los Angeles, Washington D.C., Hong Kong, Shanghai, Milan, Rome, Delhi, Tel Aviv and, on the occasion of this meeting, Jerusalem. My aim was to trace the identity of these un-repeatable cities through the insertion of architectures that could be capable of increasing the recognizability of the identity increasing with a further interpretation the immanent ideal codes.

Conclusion

The base concept is that the identity is never static. If not, it would inexorably decay only in a museum. Identity is a dynamically generative concept. It follows the common "ideal city" that every inhabitant has of the city in which he lives. The immanent codes of every city, lived and interpreted by every inhabitant, and mainly from each single architect, contribute to the organic life, and therefore to the growth of its identity. Jerusalem, in the aim of my architectural experimentations, should become "more Jerusalem then before", because of the increasing of subjective interpretations of immanent codes, as happened in the past.

An aspect incredibly emerged from these experimentations on different cities, sometimes deeply different in their identity: a small, infinitesimal transformation of a parameter inside the generative algorithms in the "artificial DNA of city" has been enough to move from the possibility to represent an environmental identity to another strongly recognizable identity. As happened, for instance, in a generation of architectures that I have performed in Delhi, after having visited the city for the first time. I modified only the parameters that checked the progressive iteration inside each event, increasing what we can call the "fractal symmetry" and the produced architectures acquired characters able to reflect the Indian identity of the city. Confirming therefore the idea of D'Arcy Tompson that each species in Nature is transformable in another only acting on some parameters of geometric transformation.

Figure 28: Flying ipercube castle in the Jerusalem sky, C.Soddu 2011

In the images 24-28 are presented some examples of generations of environmental identities, from the medieval cities until Jerusalem, performed with the generative software of the author, Argenia, able to directly generate 3D models.

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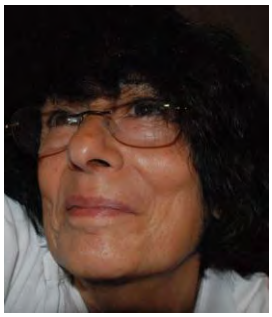
The equality ambiguity



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In a lucent bottle on the sea of art, Uranus shouts to the moonlight, endless.
*Enrica Colabell*a [A*]

Abstract

Investigation about **time** in the site of the equality ambiguity. Hypothesis: time is the time of a process between remembering and imaging. Memory is *magistra ludi* (*the teacher of the game*) in this generative art process. On the traces of the ancient Art of Memory, that is mainly a visual art, it has defined a double system performed by memory schemes as a dynamic equality (Betti) connected to **a direction in double verses**. Inside this direction it is individualized a first point of view, that is able, also if the first is random, to perform a new interpretation, as **an abduction act** (Pierce) in a generative process. The performed fragment of ambiguity is able to generate **endless variations**, by connecting the past remember to the new imaginary. This process is similar to *colores* (*colors*) performed firstly in Micrologus by Guido D'Arezzo, using *moto obliguo* (*oblique movement*) a polyphonic process from dissonance to harmony. **Exempla** (exemples).

This is an investigation about two categories: equality and ambiguity. ***How*** they can stay together is the main aim. The hypothesis is that they connect autonomously, each one emphasizes in connecting its own autonomy . If we identify the equality as a line and the ambiguity as a double verses and if we put them together, we can have a direction with a double verses (i.e. up/down). The direction can be horizontal or vertical, or diagonal inside a geometrical figure. The main historical structure of how this 2 tools are connected is the Brunelleschi perspective, defined from a line of ground, its mirrored line as horizon and one point of view reflecting its double on the ground line. But if we fold the direction, we can cross the space from Euclidian to not Euclidean representation. The art and science research of the last thirty years is mainly about the process of folding. The built results in architecture and design are only about the folding of the 2D surface, losing 2 very important dimensions, especially in architecture, that are space and time.
So as just performed in a precedent investigation about a generative process in Art (1), we can discover 2 main basic elements in *the equality ambiguity*

1- A *folded* direction
2- A *double reflecting* verses, as ***acting*** of a visionary infinite mirroring.

Acting needs a ***time***.

The hypothesis is that the acting time works between a remembering/imagining in endless variations. A mirroring of the past and a vision of an imaginary future, connected together as an *instant* of time.

Memory, imagination and time

"Opposes itself to the fate
one hand of yours,
But immediately the other
one, you see, assures
yourself,
That only you can affirm
Crumbs of memories."
Giuseppe Ungaretti, Chorus 7

About time

"Nature makes to quickly flow the time of our existence, but reason can prolong it: it is inevitable that life slips away fast to whom doesn't try to catch it, to hold back it or at least to make to proceed more slowly it, but he lets pass so it, the more rapids of all the things, as a superfluous and recoverable good." Seneca, Epistulae morales ad Lucilium

"The life of the wise man, therefore, is devoid of time, it is not limited: he escapes the laws of the human genre and he dominates, likewise to God, all the epochs, the past because he remembers it, the present because he alive it and the future because he foresees it". [2]

The Art of Memory, *magistra ludi. Ancient tools for imagination.* [3]
Publicius underscores the value of etymology, onomatopoeia and other forms of wordplay for the selection of memory images.

Wind folds my words of stranger
Around the corners of the small streets.
I lost the map direction, it is panic.
Looking up toward the sky,
Remembering a jingle of my infancy
Suddenly I discover the mirror of beauty,
The ancient site of harmony:
It is silence in my art, just for an instant.
*Enrica Colabell*a [B*]

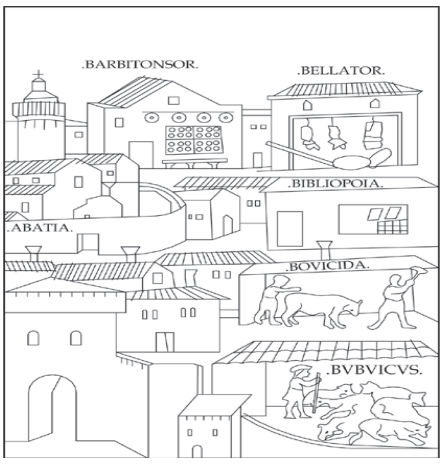
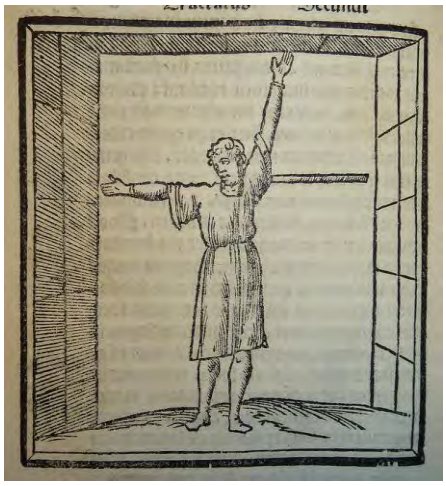


Fig. 1 Jerusalem as a tool for memory – Architecture and memory-

Arca is a term Isidore of Seville links with arx, "one of the family of storage-room metaphors for memory" that represents, according to Carruthers, a visual pun "on the Temple citadel of Ezekiel, the 'city on a hill' in Matthew, and the Johannine 'Heavenly Jerusalem'" (Isidore,Etymologiae, 15.2; also Carruthers, Craft of Thought, 19, 281 n. 31). The first image in Publicius' Art of Memory, illustrating rules for places, depicts a fortified city on a hill. Romberch included such an image in his 1533 treatise. [4]



Linnaeus lost beyond Mute
Small live on the tree in a cold wind, I folded my skin
Following the wind, a worrying wind, a hide shaving wind.
Your least promise is folded in my elbow, folded forever.
Dark window without snow, take me care this night.
Just for a moment: the passage of the blackbird.
He will sing for me a song on his lost whiteness,
A tender song for sleeping, the song for the alone children.
Be quiet, just for a moment: a moment of beauty in your eyes.
The unnamed alive ware is folded wherever , no conscience:
Only a site of a nomad performed hybridization of our time.
No words, no names, no imagination, no pietas: we lost.
The voice of life becomes Mute, a fatal error of random;
But I am still waiting for the last song of this night,
A prayer of love over the hard cold darkness.
Just a frame of lucent light, in a total mirrored whiteness.
*Enrica Colabell*a [C*]

Figure 2 *Woodcut illustration from Johann Horst von Romberch's work on memory, Congestorium artificiose memorie (Venice: Melchiorre Sessa, 1533). "A memory locus which is to contain a memory image must not be larger than a man can reach; this is illustrated by a cut of a human image on a locus, reaching upwards and sideways to demonstrate the right proportions of the locus in relation to the image."*[5]

Figure 3 - Woodcut diagram of a portion of a visual alphabet and its application from Johann Horst von Romberch's work on memory, *Congestorium artificiose memorie* (Venice: Melchiorre Sessa, 1533). "*Visual alphabets are ways of representing letters of the alphabet by images. These are formed in various ways; for example here it is through pictures of animals or birds arranged in the order of the first letter of their names, as A for Anser, goose, B for Bubo, owl.".* Figure 4 – Simulacra – Random. Number: *individual; plural* . Figure 5 - *Woodcut diagram of a memory system ("Hortus Philosophiae" [i.e. the garden of philosophy])* . [Idem5]

Betti reciprocal theorem

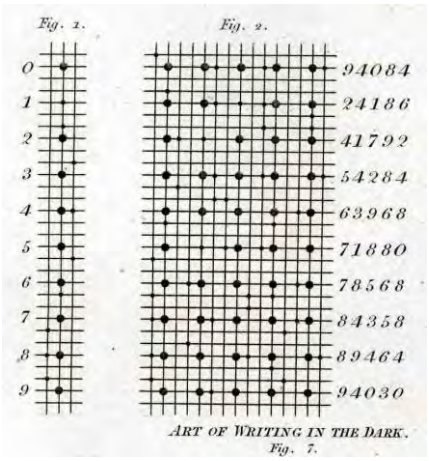
This is a theorem in the mathematical theory of elasticity which states that if an elastic body is subjected to two systems of surface and body forces, then the work that would be done by the first system acting through the displacements resulting from the second system ***equals*** *the*

work that would be done by the second system ***acting*** *through the displacements resulting from the first system.*

Pierce abduction

In trying to clarify *the process of abduction* we can use, following the concepts by Focillon, [6],the touch as a starting point of a knowledge process. If we write in the dark as blind, we can imagine our representation as a connection of parts in a direction. *An interesting and very large philosophical issue that comes up is the concept of image formation and its dependence upon sight for intuition, as with geometry or topology. Plato determined that image formation issues were* ***precognate*** *and the same in sight and non sighted people.*

Abduction is the passage from intuition to the representation of the ***idea***.[7]



Folding a direction in 18th century calculator for blind people

In ***"Palpable arithmetic:*** *feeling and seeing representations of numbers", we have a specialized meaning in places as a calculating device in which the numbers are recognized by touch and used by blind mathematicians ; i.e..Leonard Euler,* ***Nicholas Saunderson*** *(the inventor of Art of writing in the dark), Louis Antoine , Lev Pontryagin*.[8]

La Gioconda , one direction in the 3 double verses between:
the left eye, the left angle of the mouth and the forefinger of the right hand

" Doesn't read me who is not mathematical in my principles" Leonardo

In smiling, your left angle of mouth
Folds vertically for brightening the ambiguity
Of your face as equality of your heart.
You can discover the same in the bridge overshadowed.
*Enrica Colabell*a [D*]; [XY,1]

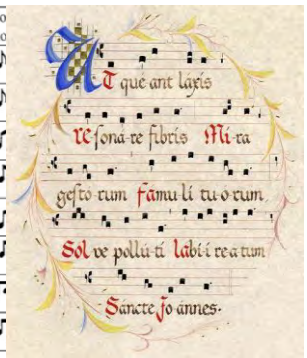
"…The child said:" I am real very curious, Maestro Leonardo, to know the reason why you wrote every script of yours in reverted way".
"Oh, a good question. So you give me the opportunity to talk about the veiled mirror in my death bed room. So if you see in a mirror my written words you can discover the good side of their significance. They are the results of the same generative process of La Gioconda. She is the other side, the good one, of my soul. My reverted scripts represent the process that reader must active for reading them. After the process, you became the raider of a noble investigation street, following the enchanted discovering words sound. I can give you a very simple example. You learnt numbering on the fingers of your hands, you can use the right or the left one, naturaliter. But if you start in numbering until ten starting for example from the left hand and you restart for twenty starting by the right hand, in your mind you will see the numbering until twenty as a mirror of the precedent ten. Following nature, that is figurative and also abstract, you can write also in reverted way ,with the illusion of time" [9]

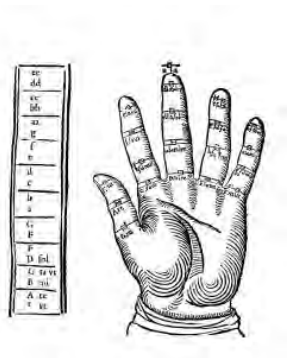
Tools for voice - Guido D'Arezzo, *the musical line.*

S. Martini, Fresco *Musici*, Assisi [X1]

The musical writing used in the Medieval time was *neumatica* (from the Greek neuma = sign). The neuma don't usually represent a single sound but a group of sounds. The origin of the neuma must be sought in certain signs that it is accustomed to set on the sacred or poetic texts, and whose performs it was to suggest an expressive recitation. It dealt with points and lines, now *ascendancies*, now *descending*, now *undulated*. It was a kind of memo. With the time however it was begun to feel the demand of a more precise writing. The solution that found more fortune was that to set not the neuma *on the same line,* but to different heights. Guido of Arezzo reached *the musical line* in the 11th century. He performed firstly a so called *Guidonian hand*, a mnemonic system that assigns each note a physical place on the left hand. In teaching, an instructor would indicate a series of notes by pointing to them on their hand, and the students would sing them. It was written on the *Guidonian hand* this sentence: *"Learn to read your hand, if you want to learn the beautiful song. Without this system, you will study for a lot of five-years periods without any result".*

Nome	Neumi di S. Gallo	Neumi aquitani	Neumi beneventani	Neumi gotici	Notazione quadrata	No mo
Virga						
Punctum						
Pes o Podatus						
Clivis						
Scandicus						
Climacus						
Torculus						
Porrectus						





Neumata –The Chant of St. John – The Guidonian hand – [X2]; [X3], [X4]

Guido proposed a system composed of four lines: preparing the neuma on the lines and in the spaces between a line and the other, so it was possible to fix with precision the height of

every sound. The *tetragramma* will remain in use up to the century XVI, when it will be replaced by the rule of five lines. The name of Guido of Arezzo is also tied up to the denomination of the notes: ut, re, me, fa, sol, la, they were abducted by the initial syllables of a hymn to St. John. So he defined an important system of *solmization*. His system revolutionized well soon the musical didactics of the time favoring the passage from the mnemonic learning to that for reading, allowing in this way to fix in writing clearly the sounds.

Musical structure for Architecture, *folding the direction in a perfect able circle*

If we fix the 2 verses in 2 points A, A' we can generate a circle , moving A' in the static A, running A' in double verses left and right.

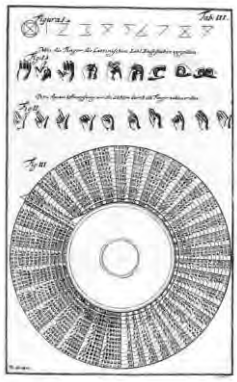


Fig.1-The Guidean hand.[Y1] – Fig. 2- A work from 1587 entitled *Musique* and attributed to John Cousin the Younger (1522-1597); the basic premise for this device was to be able to order the different chords of 20 different instruments [Y2]. Fig.3- The rosone of the Abbazia of Pomposa, where Guido D'Arezzo wrote ***Micrologus***, one of the principal sources of our knowledge of organum, an early form of polyphony [Y3].

...sì come rota ch'igualmente è mossa,
l'amor che move il sole e l'altre stelle.
/...like a wheel that equally is moved
by the love that moves the sun and the other stars.
Dante, Paradiso,XXXIII,133-135

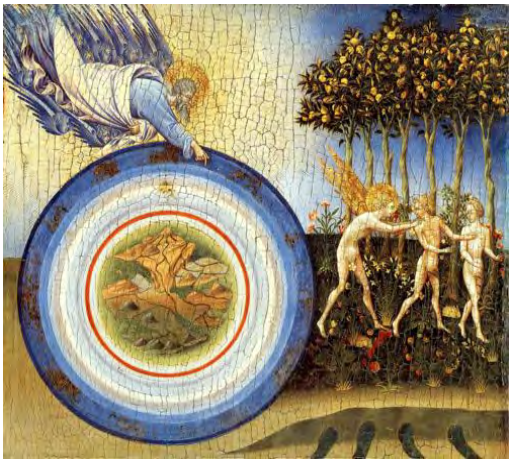


Fig. 1- A Miniature illustration
Fig. 2- *Creation of the World and Expulsion from Paradise* by Giovanni di Paolo, 1445 [Y4]

On this *Canto of Paradise* Poincaré defined in1905 his mathematical conjecture, solved in 2002 by Gregory Perelman, refusing medals and money.

Quater quartinae (four quatrains) around the equality ambiguity

To God I will sing a new song with all my love,
In resonance with the hearts of all children in the world,
Black and white, red and yellow smiling faces:
Unique points of view, as ambiguity in the equality is.
My right hand strings my left hand, in the voice color;
My fingers talk the ancient tools for brightness in the shadow,
My eyes follow an imaginary horizon, performed by the chorus lines:
The istina flies toward the white and blue of the sky, over the vagrant dark.
It's now our time, now in the ambiguity of a past future, now forever.
You recline your lovely face on my right shoulder, the Angel shoulder.
So my vision performs an equality vision in your little heart,
Singing piano piano for you, my sweet heart, my lovely baby*.*
One point, one line, one circle, one sphere, in sequence;
Time performs from sphere an helical space, following Orion.
You come from the Beauty silence, in the ambiguous space of life.
White mirror as snow in aurora, with the first blue song of a robin.
*Enrica Colabell*a [E*]

Chopin: *" Tempo rubato"* Double equality in ambiguity [10]

Chopin was a great performer in his art of tempo rubato, as a blue tone of the night able to hold every different interpretation."Tempo Rubato" is the freedom of movement tuned to the performer in certain passages for emphasizing the expression. Without any doubt the rubato is born from "Il canto Gregoriano". Cantors had some notes following their will, crossing suddenly on others, certainly for preserving the tradition of declamation used by the Greek rhapsodes. It is met in Italian ***recitativo*** *and later in Frescobaldi, Bach (Fantasia cromatica), Mozart and Beethoven. This, in Chopin, is considered as a sign of Italianism. There is inside most of all the direct influence of the folkloristic Slavic folklore music, where the rubato exists in a natural status. Liszt called it "the rule of the irregularity". It belongs to the peculiar movement of the* ***fraseggio*** *and to its* ***tonality****. The rubato is a flexible measure able to give to the melodic phrase a characteristic tone of each mother tongue. Chopin asked always that the song part, often that on the right hand, had freedom of expression, involving the alteration of tempo. Chopin used to say: "That your left hand be your Maestro and preserve always the measure" And still: "There are done some balances for restoring the whole".*
The rubato is one of the topic mysteries of the Chopin opera.
Liszt tried to explain it with a verbal simile: "Just suppose a tree that the wind makes fold. Among its leaves cross the sun rays and the flickered generated light is the rubato".
To the art of suggestion Chopin adds an indefinable nuance that expresses together an interior tension and a species of anxious aspiration.

The voice of heart
Raffaello, Saint Cecilia
A vertical direction folded in the book of the Angels chorus

Imagining the music, *a true tale happened in Rome during the second world war:*
Two little girls spent their after
lunch time in learning to play piano
at four hands, simulating it on the
board of a table. The sequence of
time was one day on the table of
the first girl, the day after on the
table of the second girl.
After a week, they decided in total accord
that the second table generates
a more harmonic sound.
*Enrica Colabell*a [F*]; [XY,2]

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[Y2] longstreet.typepad.com
[Y3] stpauls.it
[Y4] sacred-circle.tumblr.com
[A* ; B*; C*; D*; E*; F*] These are all original poetic texts written by the author for the topics of this paper.
[XY,1]; [XY,2] The frames of the pictures " *La Gioconda" by Leonardo* and *"St. Cecilia" by Raffaello* are elaborated by the author.

Art, science and technology in Calatrava's bridges

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Abstract

The oldest structures built by human beings are dwellings as shelters and bridges for crossing rivers and deep valleys. Bridges are an index of civilization, an expression of architectural art, in which strength, utility and beauty are combined. Often architects and their associated engineers integrate their respective knowledge and experience in order to create bridges from different materials, such as stone, wood, masonry, ropes, iron, steel and reinforced concrete.

When it comes to architectural practice two ways of thinking converge: rational thinking, an objective process which provides an analytic approach to problem solving, and abstract thinking; intuition, sensation and feeling. Both tendencies are necessary in the process of design, they supplement each other in both: architecture as an art, and as a science of construction. Santiago Calatrava is one of the most evident fulfillments of this convergence of thought.

Fig. 1. Dr. Santiago Calatrava

Santiago Calatrava: artist, architect, engineer

He was born in Benimamet, an old municipality now forming part of the city of Valencia, Spain, where he studied arts since nine years old, and attended the *Escuela Tecnica Superior de Arquitectura de Valencia*, which gave him his title as an architect in 1974. Later he enrolled in the *Eidgenössische Technische Hochschule* (ETH) in Zurich, Switzerland, where he completed graduate work in civil engineering with the doctoral thesis ‹‹On the Foldability of Space Frames››. By the year 1981 he opened his studio in Zurich, focusing on both architecture and

civil engineering. From that point on his projects, works, publications and awards began to increase notably [1].

To envision him as an architect, engineer and artist, specifically a sculptor, provides an explanation to the characteristics of his work, but to separate each trade is to misunderstand the role of an architect, on that matter he explains ‹‹I prefer, then, simply to say I'm an architect››. (Fig.1)

The most characteristic of his works is the cultural complex City of Arts and Sciences, in his hometown, Valencia, one of the most iconic landmarks of contemporary architecture worldwide.

Calatrava- Technion Cooperation

Fig .2. Obelisk at the Technion

Dr. Calatrava has a long standing cooperation with the Technion-Israel Institute of Technology. Recently he received an honorary doctorate of science from the Technion; also holds the appointment of Technion Distinguished Visiting Professor. He frequently teaches in the Faculty of Architecture and has presented plenary lectures in science and technology for students of different faculties. On June 2009 he unveiled his latest creation; the obelisk at the Technion, Haifa, (Fig. 2). The towering kinetic structure, located at the very heart of the Technion, will serve as a modern symbol for the Russell Berrie Nanotechnology Institute. Calatrava said the obelisk ‹‹celebrates the very technical and very mechanical as things of beauty››. The tower houses an external skin of 224 moving stainless steel ribs, permitting a wave-like motion generated by an electric motor. This movement is more akin to our ribcage, moving in and out during the process of human respiration. Again, Calatrava uses the human body forms and functions as an inspiration for his ideas and creations, including his bridges [2].

Bridges

Calatrava's work excites and arouses, often resembling aspects of the natural world, ships, and bows in a sculptural building. Much of his career has been dedicated to bridges, elements of cities which he has turned into landmarks. Four of his most characteristic bridges are Puente de la Mujer (Woman Bridge) in Buenos Aires, The Alamillo in Seville, Petah Tikva pedestrian bridge and the Jerusalem Chords Bridge, [3], [4].

a. Puente de la Mujer

Fig. 3. Puente de la Mujer

Puente de la Mujer (Bridge of the Woman) is a movable and rotating bridge, built of reinforced concrete and steel, in Puerto Madero, Buenos Aires. (Fig. 3) To present date it is the only of Calatrava's projects in Latin America.

The bridge is meant to be an abstraction of a couple dancing tango, its thirty-nine degree inclined mast, standing gravity defiant to hold the cables to the deck, represents the man holding the woman, who is leaning over horizontally. The project was donated to the city by Argentinean business man, Alberto Gonzalez, and inaugurated in 2001, it is strongly related to the Alamillo Bridge in Seville.

b. Alamillo

The Alamillo was one of the four bridges constructed for Seville's Expo '92, its purpose was creating access to La Cartuja, a nearly deserted island in the west bank of the Guadalquivir River, and it also linked the historic part of the city to the modern part. (Fig. 4)

Its asymmetric design and monumentality soon made it the most outstanding bridge in Seville, and an adopted landmark by the residents of the city, characterized by its dramatic structure.

Fig. 4. The Alamillo Bridge at night

c. Petah Tikva pedestrian bridge

Calatrava's first bridge in Israel was said, by the architect himself, to have been built because of the request of Azorim Properties developer, after seeing an exhibition of his work at the Technion Museum. The Y-shaped cable-stayed glass and steel bridge spans 50 meters, and connects pedestrian traffic over the Jabotinsky Road, connecting the Rabin Memorial Hospital and the Ovnat Shopping Mall. (Fig. 5)

Fig. 5. Petah Tikva pedestrian bridge

d. Jerusalem Chords Bridge.

A famous meeting between Calatrava and E. Holmert, Jerusalem's Mayor, was held on the idea of a special bridge for Jerusalem, E. Holmet said to Calatrava ‹‹This is the oldest city in the world›› and Calatrava answered ‹‹I will build the most beautiful bridge ever, and it will be a bridge promoting peace, as the city name implies››. In the list of Calatrava's unique white cantilever spar cable-stayed bridges the most sculptural yet is the Jerusalem Chords Bridge. (Fig.6)

Fig. 6. Jerusalem Chords Bridge

Said to be similar to the Alamillo Bridge, its design was made to add a visual element to the Jerusalem's skyline and it constitutes the tallest structure in the city. Although its construction has been controversial, the physical aspects of the bridge are remarkable, without a doubt with time it will become a valued icon of the city.

Closure

Global climate change is the most critical, actual concern of world governments and human society. Related extreme climate events such as torrential rains and consequent flooding, devastating storms and winds, periodical wet/dry cycles, airborne pollutants, saline aerosols in coastal areas, have a detrimental effect on infrastructure through problems of corrosion, wear, deterioration. The combination of the natural actions will increase the potential for damage for both metallic and non metallic materials used in the infrastructure construction. It might be rightly assumed that Calatrava's knowledge and experience will assure, without a shadow of doubt, the correct selection of engineering materials for his bridges, which will withstand the forces of nature for prolonged times.

A landmark becomes a part of social identity; with time a historical value, impacting in various aspects of city life, like economy, tourism and capital gain. Accordingly, these bridges go beyond their basic function of connecting spaces; they become a sculptural symbol that artfully

modifies the cityscape. Because of Santiago Calatrava's knowledge of science and technology he has been able to create and suggest structures that have changed the way bridges nowadays are constructed, materializing an art concept and transforming it into a stunning element of urban infrastructure [5].

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Reflection lines and highlight lines

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Abstract

Human made objects (e.g. cars, household appliances, jewellery) are frequently bounded by high quality surfaces of complex shapes that are highly reflective. The appearance of these objects can be best investigated – both experimentally and theoretically – by evaluating the structure and distribution of reflection lines. Because of the difficulties in analytical computing of reflection line patterns, a simplification, the highlight lines, were introduced for surface interrogation. Although highlight lines provide limited overview on the reflective features and the possible deficiencies of the surfaces, they are widely used in practice. Subsequently, we point out that a common mathematical basis can be developed for computing the two patterns, and through efficient computer implementations a powerful and sensitive tool of surface evaluation can be created for designers and stylists.

1. Introduction

The term “high quality surfaces” is attributed to their smoothness, evenness and aesthetic appeal. The most important high quality surfaces are those representing cars, airplanes and ship hulls, household appliances, jewelleries etc. Their design involves not only functional criteria but also requirements related to style and appearance. Creating methods and tools that support the work of a designer or a stylist is a challenging task.

Various visual display methods are available for the quality evaluation of surfaces. The most sensitive indicator of surface quality is the reflection line display method which consists of evaluating the shape, density and distribution of reflections of a set of linear parallel light sources (Patrikalakis, Maekawa [3]). The method is well applicable for disclosing minor errors and for fine-tuning the surface shape, which other methods fail to achieve. Reflection line patterns depend on the viewer location, which provides a sensitive way of detecting surface shape and irregularities from different directions.

Unfortunately, analytic computation of reflection lights is very complicated and requires solution of nonlinear differential equations. Furthermore, real time solution would be needed while the surface is moved in space, to efficiently support the work of a stylist. This is the reason why a simplification of

reflection lines is applied in the engineering practice. These are highlight lines (Beier K. P., Chen Y. [1]), which are an "imprint" of a linear light source; a set of points on the surface where the surface normal intersects the light source line. Highlight line patterns are independent of the viewer position. Although the mathematical machinery is considerably simpler for highlight lines, the sensitivity of detecting small irregularities is strongly reduced compared to the reflection lines.

In the paper we develop a common mathematical framework for computing reflection lines and highlight lines. Instead of solving differential equations we derive distance functions characterizing reflection lines and highlight line points, and evaluate them by fast computer algorithms. In this way detailed interrogation of surfaces can be achieved in real time. We compare the power of detecting surface errors of the two methods by an example.

2. Geometry of reflection and highlight lines

Parametric representations of free-form surfaces in Bézier, B-spline or NURBS form, are widely used in computer graphics and CAD applications. These kinds of representations define the shape of the surface **S**(u,v) by an array of control points $\mathbf{P}_{i,j}$ and the Bézier, B-spline or NURBS basis functions of order k and l:

$$\mathbf{S}(u,v)=\sum_{i=0}^{m}\sum_{j=0}^{n}\mathbf{P}_{ij}N_{ik}(u)N_{jl}(v) \qquad (1)$$

The shape of the surface is mainly defined by the control points; degrees, knots and weights of the basis functions provide additional degrees of freedom in design.

Reflection lines are images of a linear light source on a reflective surface. The line of the light source can be described as $\mathbf{L}(\lambda) = \mathbf{A}+\mathbf{B}\lambda$ where **A** is a point on **L**(λ), and **B** is a vector defining the direction of the line. Let **v** denote the unit vector from the surface to the direction of the viewer. Then the reflection direction **r,** which is the reflection of **v** on the surface, can be calculated as

$$\mathbf{r} = 2\,(\mathbf{vN})\mathbf{N} - \mathbf{v} \qquad (2)$$

where **N** is the unit normal vector of the surface (see Figure 1).

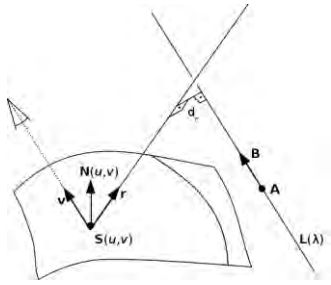

Figure 1: Reflection on the surface

A point on the surface belongs to a reflection line (image of a point of the light line) if the line in the reflection direction intersects the light line, that is, the perpendicular distance between them:

$$d(u,v)=\frac{\left|\left[\mathbf{B}\times r\right]\cdot\left[\mathbf{A}-\mathbf{S}(u,v)\right]\right|}{\left\|\mathbf{B}\times r\right\|} \qquad (3)$$

is zero. As can be seen, computation of a reflection point depends on the viewing direction, consequently the reflection line is determined not only by the surface shape and the lighting conditions, but the viewpoint as well, making computation and evaluation of reflection lines more involved.

Highlight lines – simplification of reflection lines – are defined as a set of surface points where the surface normal and the light source line intersect. The distance of these two lines can be obtained if we write **N**(u,v) instead of r in Eqn. 3:

$$d(u,v) = \frac{\left| \left[\mathbf{B} \times \mathbf{N}(u,v)\right] \cdot \left[\mathbf{A} - \mathbf{S}(u,v)\right] \right|}{\left\| \mathbf{B} \times \mathbf{N}(u,v) \right\|} \qquad (4)$$

and d(u,v)=0 defines the highlight line.

3. Comparison of reflection and highlight lines

To study the reflective properties of surfaces a set of parallel light sources is used. Their reflection on the surface forms a pattern consisting of the reflection curves. The shape and continuity of the curves, their density and distribution are sensitive indicator for the surface quality. The shaded image (photorealistic picture) of a car body panel (Figure 2) would not disclose any deficiency of the surface. The highlight line pattern in Figure 3 already shows some irregularity in the middle, but this is much more evident in the reflection line pattern (Figure 4). Figure 5 shows that reflection light patterns strongly depend on the viewer position, which provides an efficient tool for extensive studying of surface features. Figure 6 shows the corrected surface (see Gyurecz, Renner [2]), the regular structure of highlight lines and reflection lines.

Figure 2: Shaded image of a car-body surface

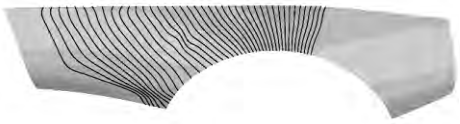

Figure 3: Highlight lines

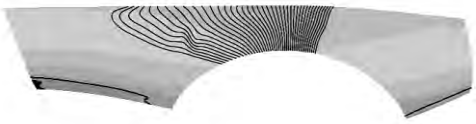

Figure 4: Reflection lines

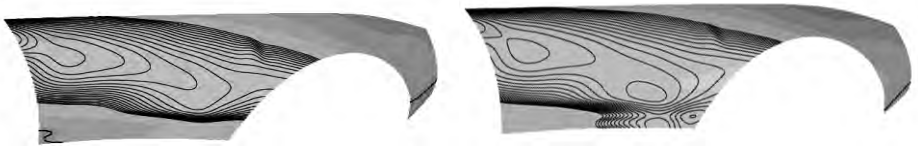

Figure 5: Reflection lines with different viewpoints

Figure 6: Highlight lines and reflection lines of the corrected surface

4. Conclusions

Highlight lines and especially reflection lines are perfectly suited for examining delicate details of a surface. Although their analytical management differs significantly, they can be handled using unified mathematical tools as long as the aim is to display and examine their form and distribution. This gives a tool to a creative designer or stylist to find and correct small but aesthetically significant irregularities of functional and artistic surfaces.

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The history of photography from Aristotle to the digital Bayer process

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I shall be discussing some of the people involved in the progress of the development of the photograph, as well as the processes themselves. The object of the presentation was to throw some light on the development of the photographic process from the time of Aristotle to the development of the digital process by Bayer in 1976. The definition of photography that I shall use, is the joining of two Greek words, photo meaning light, and graph, to draw. We shall see how this process of drawing with light, has developed over the centuries. I shall pay special attention to the development of photography in the Middle East.

You may say what has Aristotle to do with photography? He was a thinker-yes- but also a scientific experimenter. In 384 BCE, he invented the Camera Obscura. This was a box with a small hole that allowed light to enter and form an image on the opposing wall. His objective was to view the sun indirectly, but so doing he formed the first image using natural light. At about the same time, a Chinese inventor, Mo Di (470BCE-390BCE), used a pinhole camera and referred to this camera as a "collecting plate" or "locked treasure room".

The Camera Obscura was known by the Muslim experimenter Hassan Ibn Hassam born in Basra (965-1039 CE) as well Leonardo de Vinci (1452-1519). Giovanni Battista Porta (1538-1615) used it to throw light onto a piece of paper which moved forwards and backwards until he had a clear image. He drew the resulting image on the paper. On one occasion, he seated an audience inside the Camera Obscura, and placed actors outside the camera. When the image of moving actors appeared on the screen, the audience panicked. He was then accused of sorcery!! Canaletto, Vermeer, and other famous painters in the eighteenth century, also used the Camera Obscura as a basis for their paintings. The reversed image of the Camera Obscura was rectified by the use of a mirror. By this time, the hole in the Camera Obscura had been improved by the use of a glass lens. The word, lens comes for the word lentil, since the glass is shaped like a lentil used in making soup. The Camera Obscura was made on a larger scale at the beginning of the nineteenth century and was called a Camera Lucida, also used for drawing. Some of the larger examples of the Camera Obscura still exist in England as heritage sites.

Concurrently with the Camera Lucida, a number of rich alchemists were experimenting with what they called silver salts. They found that silver salts, when exposed to light, turned black. Among these experimenters, was the British scientist Sir Humphrey Davy. In 1801, he used electrolysis to find magnesium and sodium. Together with Tom Wedgewood, he managed to produce an image using leather but this turned black when exposed to external light. In his many experiments with heat and light – and possibly with advice on silver nitrate from his tutor Alexander Chisholm and from members of the Lunar Society – Wedgwood, who was a British pottery magnate, first used ceramic pots coated with silver nitrate as well as treated paper and white leather as media of print, and had the most success with the white leather. Although he originally tried to create images with a "Camera Obscura", his attempts were unsuccessful. His major achievements were the printing of an object's profile through direct contact with the treated paper, thus creating an image's shape on paper, and, by a similar method, copying transparent paintings-on-glass through direct contact and exposure to sunlight.

There were three main founders of modern photography, Fox Talbot, Niepce and Daguerre. In England, Henry Fox Talbot produced an image at his home in Laycock Abbey. He produced the first photogram, an image made by placing a leaf on photo sensitized paper and in 1825 the famous view through a window of Laycock Abbey where he lived. In France, in May 1816, Joseph Niepce and his brother Claude succeeded also in producing an image, but again this turned black when exposed to external light. These were called retinas. Niepce succeeded in creating images on bitumen in 1822, and after his death, in 1877, bitumen was again used.

Joseph Niepce in 1827, succeeded in fixing an image on pewter. Niepce collaborated with Dageurre, who was a scene painter for the theatre and painted huge images called dioramas. He was the originator of what is known as trompe d`oeuil, images which deceived the human eye such as can be seen in Mahane Yehuda in Jerusalem. Niepce and Daguerre continued their co-operation until the death of Niepce in 1833.

The nature of true photography today starts with Daguerre`s patent of 1839 known as the Daguerreotype. It was an amalgam or an alloy of silver and mercury highly polished-originally sensitized with iodine vapor or later with silver bromide or silver chloride. This produced a clear reversed image on a copper plate. The disadvantages were that it could not be reproduced and could not be properly viewed at an angle. Sodium thiosulphate was used to fix the image. Its fragility meant that it had to be enclosed in glass. The sizes of the plates were from a whole plate 16.5 by 5cm by 21.6 cm, to a sixteenth plate 3.4 by 2.15cm. The patent for the Daguerreotype was registered in the same year in England. Later the Daguerreotype spread like wildfire through Europe and America for a period of some ten years. In England, William Henry Fox Talbot, succeeded in producing, what he called the calotype in 1841. This was paper brushed with a silver emulsion but gave a negative from which prints were taken but not as clear as the daguerreotype. Gallic acid was one of the means of fixing the image so that it would not turn black. The calotype was used by a Scottish Christian doctor by the name of Keith Alexander, who attempted to photograph the Holy Land in 1841. He arrived in Syria on a mission for the Scottish Church only to find that the calotypes had turned black during transportation. He returned with his son in 1844, and finally published eighteen out of thirty dageurreotypes as engravings. This was the only method by which photographs could be printed until the invention of the Woodbury printing process some years later.

Just after the dageurreotype patent of 1839, a Monsieur Lerebours of Paris, sent a well known artist by the name of Groupil- Fresque and his nephew Vernier to the hostile Middle East to photograph the Holy Land. Girault de Frangey published a book of colored lithographs, based on photography in the Middle East. Photography was coming of age. In about 1850, Scott Archer, simultaneously with Gustave de Gray in France, invented the collodion process. Collodion was a cotton wool dipped in a mixture of ether and alcohol. A glass plate was covered with chemicals, processed, and resulted in a negative which could produce an unlimited number of positives. The speed of the operation was much faster than the dagueurreotype or the calotype, which required exposures of up to ten minutes thus limiting photography to everything except portraits. The collodion process reduced the time of the exposure to three seconds and the prints were made on egg albumen treated paper or glass. It cost one tenth of the price of a daguerreotype but was more complex to produce.

By 1857 Dr. Richard Hill Norris had opened the Birmingham Dry Collodion Company, and in 1871, Richard Leach Maddox suggested that silver bromide held in a layer of gelatine, could be used instead of dry plates. There was no need to polish the copper plate as in the daguerreotype but it was a messy process and could leave stains anywhere. The dry collodion process, which was used at about the same time, took longer to process and so the wet collodion process continued in parallel for another twenty years. Around this time, ambrotype, the tintype or ferrotype were developed. The ambrotype had a negative, unlike the dageurre process, also gave a result which could be seen from all angles. It was similar in many ways to the wet collodion process.

The tintype or ferrotype, introduced in 1853, gave a positive image and was used by street photographers until the 1950`s owing to its cheapness. It was produced on metallic sheet coated with collodion and processed in a similar way. It was very popular in the US and more robust than other processes which made it popular for sending by post during the American Civil War. Some Victorians had a weird taste in photography as illustrated by a tintype of a dead baby. Dry plates, where the silver medium was held in place by gelatine eventually took the place of tintypes.

Carbon prints were used from 1864, following the patent of John Wilson Swan. A sheet of paper was coated with light sensitive gelatine which contained a pigment, usually carbon. They were used in the 1880`s for book printing owing to resistance to fading which was one of the problems with albumen prints. They could be printed in various shades, e.g. blue, gray or sepia. The requirement of a long exposure time was the reason that Roger Fenton could not photograph battle scenes in the Crimean War of 1853-1855. The amount of equipment required was the reason for the use of a large wagon. He photographed the officers and soldiers who were able to sit for long periods. After the failed attack on Sevastopol, he sold his equipment and returned to England, where he became one of the founders of the Royal Photographic Society.

The cyanotype was invented by Sir John Herschel in 1842. It used a combination of potassium ferricyanide and ferric ammonium citrate mixed separately with water. The recipient medium was an absorbent material such as cardboard or paper and this was coated with the mixture and dried in the dark. Objects were placed on the material to make a print using a UV source (sun, sunlamp). After rinsing in water, a white print emerges on a blue background. This process is very useful in producing photograms like those originally produced by Talbot in the early nineteenth century i.e. by direct contact with the photographic emulsion.

Creating a gum (or gum bichromate) print involves applying an emulsion of watercolor and gum Arabic, combined with an ammonium or a potassium dichromate sensitizer onto sized paper. After drying, the emulsion is exposed by contact with a UV light source. Available sources include; sunlamps, UV BL fluorescent tubes, Mercury vapor lamps, or sunlight. Development of the image is achieved by floating the print on water. The water penetrates the gum and permits the un-hardened gum to dissolve. Development takes around 30 minutes. After one layer has dried the paper may be re-coated and exposed again. Anything from three to sixteen printings are possible, depending on the extent of staining of the paper with pigment. Paper choice, intensity of pigment and other factors all affect the number of coats possible. Around 1860, the first stereo images were on the market. They proved to be very popular but required a small collapsible viewer to obtain a stereo effect. They retained popularity well into the 20th century.

The photographer, William Muybridge was faced with the problem of photographing a horse in motion to prove or disprove that all its hooves were off the ground during a gallop. His solution was to set up a battery of twelve cameras to photograph the motion of the horse.

What is the connection between a grocer and photography? The answer lies in the Englishman, Frances Frith. He was born in Liverpool in 1822. He had a wholesale grocery which he sold in 1855 to take up photography. His first visit to the Middle East was in 1856 with two large cameras and an enclosed tent which he used for developing his images. He described in his diary using "buzzing collodion" in dusty temperatures of up to 40C. When asked about his doings in the tent, he said that it was his harem. He made two more visits to the Holy Land and opened a photographic shop in Reigate in England.

Gustave Flaubert and Maxime de Camp were sent by the French Ministry of Education to the Middle East in 1851. Maxime de Camp had learned the gold salt process from Blanquand –Everad in France, which involved the use of gold chloride. This considerably enhanced the final product. He learned photography from Gustave Le Gray, and his calotypes started appearing from 1851. His book, "Le Nil, Egypte et Nubie", containing 220 calotypes, was one of the first to be illustrated with original photographs.

The invention of the steam ship, meant that the Middle East was far more accessible to Europeans than previously, and was the foundation of the tourist industry in the Middle East. The French artist Auguste Salzman arrived in 1855 and took views of Jerusalem, one of many visiting photographers of this period.

Robertson and Beato were the first news photographers to pass through the Holy Land, Robertson after the Crimean War and Beato was on his way to the Indian Mutiny- remember there was no Suez Canal. From Robertson, Beato learned the albumen glass-plate negative process, noteworthy for the sharpness of its images. In 1856 he assisted Robertson in covering the final days of the Crimean War, a three-year conflict in which Britain and France joined the Ottoman sultan to oppose Russian strategic interests in the region.

Mendel Diness, a watchmaker and a converted Jew under the protection of the British Consul, worked in Jerusalem. He was despised by the Jewish population of Jerusalem for his conversion and

divorced his Jewish wife. He ran into severe competition in photography and after ten years as a professional photographer, he moved to America.

The invention of the Woodbury process in 1874, which I mentioned earlier, allowed the grandsons of the Duc de Lunes to publish his photographs in book form. Photography was helped in America by George Eastman`s Kodak company which produced the first portable camera on a mass produced basis in 1888. He used celluloid as a backing to the emulsion. This increased the popularity of photography enormously. For a fee of $1, the photographer sent the camera to the factory in Harrow England or Rochester in the United States, and received the camera back with the images through the post. "You push the button-we do the rest." was the advertising motto.

Photography was used in surveying the Holy Land by the British in 1865 on the Palestine Exploration Society expedition backed by a Lady Coutts and the British Royal family. Photographic inventions in the mid-nineteenth century were plentiful and while most of the work was done in black and white, a Swiss company had invented a color process known as the Photoglob or Photochrome process. Lithography was a popular means of reproduction in the nineteenth century using limestone. The Photoglob or Photochrome process used a coating of bitumen and a photosensitive layer on the limestone to reproduce a repeatable negative. This process was complex and expensive but was still in use until 1970.

By this time, even though photography was comparatively new, it had gained considerable popularity. This popularity was one of the factors which encouraged Felix Bonfils to establish a studio in Beirut in 1867 together with his wife and young son, Adrienne. This was another stage in the development of photography – its development into a commercial venture. The Bonfils Studio was prolific and had agents placed all over Europe, who received the rolled canistered photographs of the Middle East

Around the year 1880, the idea of a visiting card with the visitors photograph imprinted on it, became very popular and formed a large part of a professional photographer`s portfolio.

The increase in tourism in the Middle East, prompted the Stafford Family in the 1880`s to open a tourist shop in Jerusalem under the name of the American Colony. In addition to other wares, they sold photographic postcards of the Holy sites and this trade rapidly improved with the arrival of the Kaiser Wilhelm in Jerusalem in 1898.

All these processes, in their early stages, required long exposure times. William Henry Talbot had experimented with magnesium in a bottle to obtain a flash but the late nineteenth century saw the introduction of magnesium powder for use as flash material. This sometimes had the effect of burning the photographer as well as his studio. The shutter of the camera was left open and quickly closed after the flash. The flash tube as we know it today, appeared on the market only in the 1920`s and was made by Philips.

Up to the present, we have talked mostly about black and white photographs. In 1909, Sergei Mikhailovitch Prokudin-Gorsky was sent by the Tsar of Russia to survey Russia in color. He used a black and white camera fitted with alternate red green and blue filters to produce some amazing color photographs. He used a camera which had three parallel lenses His collection of photographs was bought by the library of Congress in 1948.

Also in this period, the Lumiere Brothers in France had invented the cinematograph, the first moving film. They both had played with light since childhood, and had produced a number of patents. It was the Lumiere Brothers who invented a color process called the Autochrome in 1904 and commercialized in 1907. One does not normally associate potatoes with photography, but this process was an exception.

What they did was to take potato starch and color it with the basic colors of red, orange green and blue-violet on to a glass plate. Lampblack was used to fill the gaps on the plate. Over this was a layer of silver bromide emulsion and varnish. This was compressed under a pressure of some five thousand pounds per square inch onto the glass plate. The resulting matrix was placed in the camera as a plate and a yellow filter added to reduce the tendency to blue. The final effect is rather like the pointisme of some of the Impressionists such as Seurat since the final image is a series of dots.

The plate was replaced by celluloid in the early 1930`s and the emulsion was improved to twelve times the speed of the original emulsion and by 1933, it was sold as a roll film. In spite of these improvements, the Autochrome could not withstand the competition from Kodak and Agfa who introduced their version of the color film in 1935 and 1936. These were 3 layers of film, each one

photo sensitive to red green or blue. The manufacture of the lightweight Leica 35mm camera in the early 1920`s caused a revolution in photography for those who could afford it, and the advent of color film in 35mm sizes was an additional boost.

To go back in time, to 1910, Professor R. W. Wood discovered the use of infra-red photography and ultraviolet photography. There were a number of infra-red films produced in the 1930`s, and infra red is still in use today. A special infra-red filter is used to block the greater part of the spectrum and allow the infra-red light to enter the camera. By using infra-red film in aerial photography, archeological details can be picked out, which are not viewable to the human eye. A more common use of infra-red is for artistic photographic results. Black and white infrared film is used with an infra-red filter, and leaves green foliage looking white in the print.

Infrared photography is also used today in medical, military, and thermal applications. Cameras, film and filters are available on the internet. Ultraviolet photography has its uses today in police forensics and stress analysis amongst many scientific applications.

In the years after WW2, there was a proliferation of systems on the market for reproducing images in color. In this period, Kodak expanded laboratories into Europe. Dufay, Agfa and Gaevert arose from the ashes of war, as did Fuji in Japan. All invested in R&D and the competition gave rise to continual improvements in the film emulsions. Movie films in 8mm and 16mm were available to the general public and 1964 saw the first super 8 films on the market with the side sprocket in a vertical position. Sound could be added by applying a strip of magnetic tape to the side of the film. Sakura in Japan and Ilford in England both produced films in color. The Ilford film emulsion gave a soft dreamy look and was used in the film "Les Parapluies de Cherbourg." in 1964.
Kodak was a major player in the production of film emulsions and their C41 process was a leader in the market. Their films were processed in central laboratories but eventually there was a demand for home processing, which had been available in black and white for some time. Their E6 process was used for developing transparencies which could be shown through a projector and screen.
All the other manufacturers produced their own versions of transparency films and emulsions both negative and positive.

Fuji in Japan developed the Velvia emulsion, which became the professional standard for many years. The professional film makers in Hollywood produced photography systems such as Cinerama and Vistavision for use in such epics as Ben Hur and Cleopatra.

Digital photography was first introduced in the 1950`s for use with television.The improvements in use allowed it to be incorporated into the first space programs, sending images from space back to earth. A camera used in 1973 weighed over eight pounds and gave images of 0.1 pixels. In 1976, a scientist by the name of Bayer, working for Kodak, invented an electronic method of capturing red green and blue light which paved the way for the modern electronic camera. The first digital camera was the Mavica, made by Sony, which was brought onto the market in 1981. It stored images on a 1.44 MB disc which could be erased when full. Improvements of the Bayer filter were made by the Sigma company and now the company is calling its processor the Foveon (US) with three layers, red green and blue. The main companies using a digital processor are Nikon, Canon, Pentax, Sigma, Sony and Panasonic each with its own variations.

So we have travelled from the era of the wooden box of Aristotle to the modern digital camera. Technological and chemical knowledge were essential to the development of the photographic medium and every day brings new products to the market. Today, with digital photography, there are no dangerous chemicals, no mess – Just smile and push the button.

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The importance of music in the lives of individuals with Rett syndrome

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Abstract

Rett syndrome is a genetic disorder affecting mainly females. Music is a motivating medium for individuals with Rett syndrome (RTT) and was recommended by Andreas Rett. Music therapy evokes positive responses in girls and adults with RS. It promotes and motivates their desire to interact and communicate with their surroundings as well as develops their cognitive, affective, sensori-motor and physical skills. Since most individuals with RTT do not have verbal communication, music can function as a mean for self expression and as a form of communication with their surrounding.

The article will describe four areas where music is relevant for the emotional expression and communication, enjoyment, cooperation, function and learning for this group of clients.

The value of the following working areas will be discussed in this article:

- Evaluation –the value of music and music therapy as a central part of the Israeli RTT evaluation/support team.
- Communication & learning – the importance of music therapy as a motivating factor that enhances communication and promotes learning process in individuals with RTT.
- Physical therapy – the importance of music in achieving cooperation and enjoyment in individuals with RTT despite their obvious dislike of movement by an external facilitator (A physical therapist)
- Dual-therapeutic intervention – the value of the dual intervention approach (Music and physical therapy) with individuals with RS, which was initiated as a result of the complexity and challenging features of this disorder.

The article is an amalgamation of existing literature on music and music therapy for individuals with RTT, shared with over 20 years of clinical experience of both writers with this population.

Introduction

Rett syndrome (RTT) was first described as a clinical entity in the German literature by Andreas Rett in 1966 (1). During the period 1966-69, Rett (1924-1997) reported on further 22 cases of females with this disorder and regularly lectured on this topic throughout Austria and Germany [1]. Bengt Hagberg

and his associates from Sweden were responsible for bringing awareness of this disorder to the English speaking medical community in 1983 with a description of 35 individuals with strikingly similar clinical features of: "progressive autism, loss of purposeful hand movements, ataxia, and acquired microcephaly" [2]. Since then it has been observed that RTT affects mainly females and is found in a variety of racial and ethnic groups worldwide with a variable clinical phenotype [3]. The estimated incidence of RS is 10-15 per 100,000 females [4], although a higher incidence rate has been reported by some researchers [5, 6, 7]. It is considered to be the second most common cause of multiple disabilities in females resulting from a genetic disorder, after Down's syndrome [8, 9]. Most have a normal emotional, communicative, cognitive and motor development at first [10, 11, 12] with the appearance of abnormality between 6 months and up to two years of age [13]. RTT is a severe neuro-developmental disorder characterized by losses in the areas of intellectual functioning, fine and gross motor skills and communicative ability. Other features include deceleration of head growth and the development of stereotypic hand movements, occurring after a period of apparently normal development. Individuals with RS often develop seizures, disturbed breathing patterns, characterized by hyperventilation and periodic apnoea, (among other abnormalities), scoliosis, growth retardation, and gait apraxia [14].

To the untrained eye RTT seems as a constellation of complex difficulties; yet despite their severe developmental disability, The external observer can easily focus on the extremely severe 'lost skills', and these may be perceived as not retrievable and even worse; at a constant regression. Surely, the losses are brutal; however this type of assumption can be deceptive and easily mislead the caregivers in handling and relating to the girls with a pessimistic view. This in turn can affect the girls to fall into hopelessness and apathy, and is a sure way for an ominous future. Yet, due to their emotional capabilities individuals with RTT sthrive when the the appropriate motivational factors are presented to them. One such highly efective elemnt is music.

Music is a motivating medium for individuals with RTT and was recommended by Andreas Rett in 1982 when he published a second article on the effectiveness of music in the management of individuals with this disorder [15]. Over the years music has been continuously reported as a medium that can promote and motivate the desire of these individuals to interact and communicate with their surroundings as well as to overcome their difficulties and develop their cognitive, affective, sensori-motor and physical skills. Since most individuals with RTT do not have verbal communication, music can function as a mean for self expression and as a form of communication with their surrounding [15, 16, 17, 18].

Music therapy is a particular motivating medium in developing social relatedness, emotional expressions, cognitive, communication, stimulates movement, functional hand use and learning and it evokes positive responses in these individuals [16, 18, 19, 20].

The following section will describe four areas where music is relevant for the enjoyment, cooperation, function and learning for this group of clients.

Evaluation - Before appropriate intervention can be carried out, proper evaluation is warranted [21]. This statement is especially true when the clinician is working with a continually changing client such as individuals with RTT. In this part of the article the Israeli RTT centre will be described as a model for a holistic assessment and evaluation for individuals with RTT.

The Israeli Rett Centre consists of two assessment teams – a medical and an educational/therapeutic team [22]. The educational/therapeutic team performs assessment to establish suitable intervention program for the person with RTT shortly after she had been seen by the medical assessment team.

A team of specialists, including a special education teacher, speech and language therapist, occupational therapist, physiotherapist and a music therapist undertake multi-disciplinary assessment for the purpose of advising at tertiary level on the therapeutic management of RTT. The educational/therapeutic team meets 3-5 individuals with RTT per month. The model of the Israeli evaluation team was described elsewhere [22], and the present article will focus on music therapy and the music therapist who functions as the team's moderator.

The process of assessment is not the same as the process of therapy [21]. During the assessment, the team gather information and gain as broad impression as possible of the clients, not only their functional and physical disabilities, but also their resources, motivation, attention, interest

in their environment, and readiness and abilities in communication. This will help making educated decisions about future therapeutic and educational interventions for the client.

Individuals with RTT tend to be anxious in unfamiliar places, and with unknown people and events. Therefore, the evaluation team tries to perform the evaluation within her most natural environment such as her home, kindergarten or school environment. Still, she could naturally feel "on display", the centre of attention, while many adults observe her.

The multi-disciplinary team agreed that it is best for the client and for the therapeutic team if the assessment starts with music therapy. The music therapist begins the assessment by singing a greeting song accompanied by the guitar and invites the client to respond. During the greeting song the therapist introduces the client to other of the team who would engage with her during the assessment. Through the music and personal bonding the music therapist is able to form a 'private' interactive space separating the child and therapist apart from the observing professionals. After the greeting song the therapist prepares by explaining to the client (through vocal improvisation) what will happen during our shared assessment time. This approach through musical communication usually helps the client to overcome her anxiety to the unfamiliar people and the situation, prepares her for what will happen, and gives the team a picture of her as a functional, communicative individual. The music therapist stays throughout the assessment, especially in transitions between one form of therapy medium to the other, as well as aiding other therapists when needed.

The aim of music therapy during the assessment is to build a musical and a personal relationship with the client in order to benefit most possible information in a very short time. When a relationship has been formed, the assessment through the music can help the client to respond to music and musical expression. As an evaluator the music therapist is able to find out which instruments or vocal sounds they are most responsive to, how they react to changes in melody, rhythm, tempo and volume. The music therapist observes how the individual reacts to familiar songs, to the therapists mirroring or reflecting to various musical sounds the client makes, to turn taking, and imitation within the frame of musical improvisation. During the assessments the individual is given many opportunities to direct and interact with the music therapist. This intense short term evaluation also enables an evaluation of her emotional state, as well assisting her in expressing her likes and dislikes, her wants and needs.

Communication & learning - Individuals with Rett syndrome have special educational needs, and experience profound and extreme learning disability [23]. Despite the fact that they are usually characterized as severely developmentally disabled, it is difficult to assess their intellectual potentials, thus leaving teachers and therapists working in special education teams with doubts about their educational potential. Sigafoos et al. 2000 found in their study for assessing behaviors in three girls with Rett syndrome, that some of the girls' motor movements and other idiosyncratic behaviors might have been conditioned as unconventional forms of communication [24]. They called these behaviors 'potential communicative acts'. It is reported that some girls are able to make choices [25, 26].

As Rett syndrome is considered a neuro-developmental disorder, it is believed that this population, if given the opportunity, may have the capacity to learn new skills [27, 28, 29] even after reaching adult life [27, 30]. Individuals with RTT can identify symbols when taught in a motivating form. This was demonstrated by a study that examined the effectiveness of computer-based interactive language development system [31].

The lack of clear accepted forms of teaching for this population, and the ambiguous knowledge regarding learning ability of individuals with RTT urged us to look for alternative ways of learning for this population [27, 32].

The capacity to learn new skills when provided with opportunities has been postulated by a few professionals and scientists in the field of Rett syndrome [28, 29, 30]. There are several types of learning and some authors have postulated that the population with RTT might have the ability to learn through "basic forms of learning" such as conditioning [27].

In a study performed by the first author seven girls with RTT, between the ages of four to ten were evaluated for their learning ability. A single case, multiple probe design was used during 30-minute trials, three times per week, lasting for up to eight months. During the trials the participants were asked to choose from a selection of 18 familiar and unfamiliar songs while their ability to learn and respond consistently was observed and measured.

In this study learning took place despite the fact that the participants had to learn a new form of choosing procedure and despite a constant change in the position of the symbols which reduced the potential effects of conditioning learning.
An important basis in the learning process was the fact that the participants established a relationship with the therapist as other clinicians/researchers have previously suggested to be important [33, 34]. The participants were comfortable with the researcher, her style of interacting and singing, and as a result were available to participate in a new experience and at the same time learn.
The success in learning through songs in music therapy may have been a strong motivating force, caused change to occur, and provided a strong foundation for learning [35].

Physical therapy -

The acceptance of physical therapy intervention by setting a musical environment

Since physiotherapy is suggested as an important treatment against scoliosis [36, 37, 38] and since positional transfer abilities (are usually the first functional capabilities to be lost in RTT [39], physiotherapy is of extreme importance and even a vital treatment for individuals with RTT.
In spite of its importance, physiotherapy can be unpleasant, and even penetrating. These facts may induce unpleasant feelings, which the girls are incapable of expressing. Individuals with RTT function according to their emotional state, and when they dislike physical treatment (as in the case example), they might react by falling asleep and even by evoking a seizure. In this special case example I (The second author) found it necessary to intervene by providing a positive milieu for treatment and by helping to increase her motivation to participate and reduce her fear of movement.

Noa *– A case study.*

Noa is a 10 years old child, diagnosed with RTT. *In the beginning of the intervention program she could sit unsupported and was able to walk only with support (she would freeze up if she was left without the support and would shout in fright), she was able to perform transitions from prone lying to a standing position with substantial assistance. When being asked and helped to change position from standing to laying prone she would freeze up and would not perform the task. When ascending/descending stairs she would vigorously cry and refuse to cooperate. Her secondary diagnosis includes right sided C scoliosis with a Cobb angle of* 20^0*, osteoporosis (expressed in three pathological fractures in the past four years). At the beginning of the intervention she was showing significant fear of movement (when in transition, when her body or limbed were moved by an external facilitator) displayed in facial expressions and screams of fright.*

Noa showed rejection of the physical therapy program right from the beginning. She was crying, felt unpleasantness with movement, and therefore there was no progress in her abilities. As a result, the therapeutic program plateaued.
It was necessary to introduce a new element that would enhance Noa's cooperation with the intervention program. Therefore, her favorite DVD music programs were suggested to her during therapy and she could choose a DVD between two of them. During therapy the DVD was played and Noa moved to the rhythm of the music. She was happily cooperating and she was now able to walk independently (indoor) with supervision. She was now able to go up and down stairs with moderate assistance, walk independently with supervision, she became unafraid of external facilitation including vigorous dancing. Her scoliosis became stable and she needed much less support to perform transitions including going from a standing position to prone position.

Individuals with RTT are usually extremely disabled. Most are slow to react to external stimuli and dread movement by external facilitators. When physical therapy intervention is applied without attuning to the child's emotional state she might react with lack of cooperation and or she might totally reject the treatment by falling asleep or by provoking a seizure. Such reactions can be avoided by introducing additional motivational factors such as: verbally preparing the child to the up-coming movement, music video films, food, animals and the assistance of the child's family members. While all such additions might help, music is surly the most motivational of all, as was evident in the described case. Thus, on occasions when the physical progress of a therapeutic intervention comes to halt, music should be considered.

We believe that the short case described in this article can open up a window for opportunity to advance treatment possibilities for children with RTT exhibiting multiple disabilities. We also believe that this treatment approach can be implemented with other children exhibiting a combination of movement, sensory, speech and motivation difficulties. By implementing this approach the results will reward the child and the therapists as one. This approach shows that even in a severe neurological disabling disorder, such as RTT, there is always a possibility of excelling treatments and achieving additional functioning and less disability.

Dual-therapeutic intervention - Earlier in this review we saw that during assessment and evaluation music therapy can work in conjunction with other professionals. The music can motivate the client to bring forth resources that otherwise may be difficult to detect. Her communicative, cognitive, learning and motor abilities can be brought to higher levels through the accompaniment and the support of the music therapist. In different settings it could be advised to work in co-therapy for the same reason as mentioned earlier but in a more focused way. This means that the music therapist can work together with the physical therapist, occupational therapist or speech and language therapist. The purpose of these types of settings will typically be to promote work in different skills in addition to emotional/expressive musical skills. In order to work in co-therapy it is recommended that both therapists are established therapists with ample clinical experience.

In an earlier paper [40] the authors; a music therapist and a physical therapist, described work principles in a longitudinal case study with one girl with RTT. Both therapists had worked separately with the girl previous to their joint work. The music therapist found it challenging to work alone with the girl due to her physical limitations. It was difficult for the music therapist to support her physically while playing instruments. The physical therapist found the girl uncooperative, which resulted in gradual lowering the physical demands and shortening session's duration. Both therapists had separate and mutual goals in which they attended to and adjusted according to the girl's physical and emotional needs every session. The result of this therapy was that the girl improved in all areas (communicative, emotionally and physically) while fully participating in long and intensive sessions.

This example shows the benefit of co-therapy for some individuals with RTT. Working in co-therapy is not an easy task for the therapists who arrive to the session from different backgrounds. It is therefore necessary that the therapists meet to discuss before and after each session to improve their co-work with each other so that the client can benefit from the merging of the therapists. A video recording of the mutual sessions is recommended as tutorial material for the therapists to observe and improve.

Conclusions

Music and Music therapy is recommended for individuals with RTT. They respond emotionally to musical interactions, share these emotions and expressivity with the therapist and as a result expand and open up new venues for communication and learning.

This article attempted to convey possibilities in how to engage in music and music therapy with individuals with RTT in different settings and situations and how the therapist can use this medium to enhance cooperation and willingness to participate in various and sometimes difficult challanges. It is of outmost important that a healthy mutual relationship will be established between the client and the therapist as the music can serve as a bridge into new venues for emotional, communicative, social, functional, or educational development.

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The effect of music training and production on functional brain organization and cerebral asymmetry

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Introduction

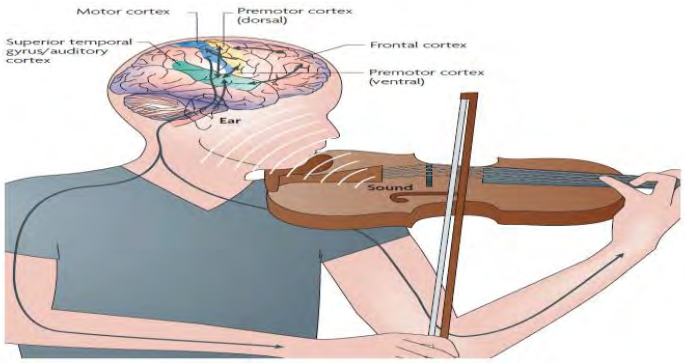
Symmetry is an everyday concept that we use when talking about patterns. For example, the human body has approximate left-right symmetry. We recognize other types of symmetry in shapes such as rectangles, squares and circles, and we recognize repetitive types of symmetry such as found in wallpaper patterns and music. Informally we can explain that a pattern is symmetric if the pattern is equal to itself when it is moved in some way. For example, a square is equal to itself if it is rotated 90 degrees. A circle is equal to itself if it is rotated any number of degrees. Both shapes are equal to themselves if they are picked up and turned over (in the case of a square it must be turned over around one of 4 axes that go through the centre, in the case of the circle we can turn it over around any axis that goes through the centre). The wallpaper is equal to itself if it is shifted by the distance between repetitions of the pattern (in the direction that the pattern repeats itself).

We can extend this informal intuition about what symmetry is to give a more formal mathematical definition of symmetry:

Symmetry is a set of transformations applied to a structure, such that the transformations preserve the properties of the structure.

Music performance requires precise control of timing over extended periods to follow a hierarchical rhythmic structure. Music performance also requires control of pitch to produce specific musical intervals (frequency ratios) that are not relevant in speech (even tonal languages do not rely on specific intervals, but on pitch contours) and music makes unique demands on the nervous system. The auditory–motor interaction during musical performance illustrates feedback-feed forward interactions occurring in music performance and is exemplified in Fig. 1. The motor system controls fine movements that are needed for sound production and are described in more detailed below. Sound processed by auditory circuitry is then used to adjust motor output. Output signals from the premotor cortices influence responses within the auditory cortex, even in the absence of or prior to sound. Motor representations are active even in the absence of movement upon hearing sound. Therefore there exists a tight linkage between sensation and music production.

Figure 1. Auditory–Motor Interactions During Musical Performance (after [1])



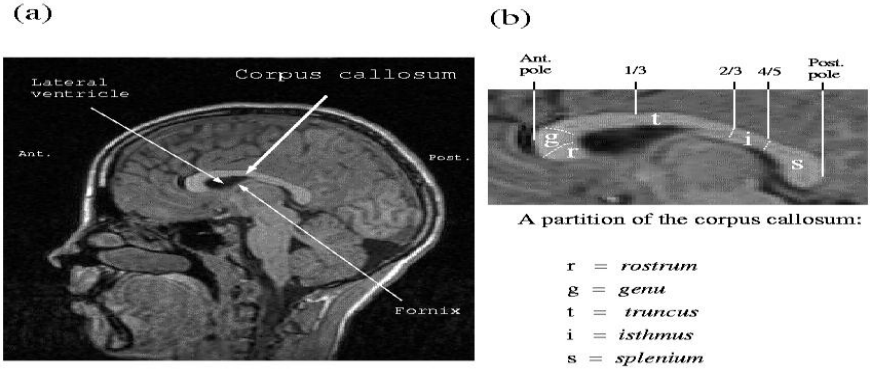
Traditional patterns of education and training have largely been inadequate since they concentrate almost exclusively on the left hemisphere (e.g. developing powers of linguistic and numerical reasoning), and neglect the right hemisphere which controls perceptual, sensory, musical and intuitive abilities and therefore do no address issues and processes of functional physiological and anatomical asymmetries. All education and training should develop procedures employing the paradigm of neurological asymmetry. Training of the whole brain is not only important for rehabilitation but also for education and the study of music and musicians in hearing and performance in ways that clearly illustrate that point .

BRAIN ASYMMETRY AS A NECEESARY INGREDIANT IN MUSIC PRODUCTION

The Corpus Callosum

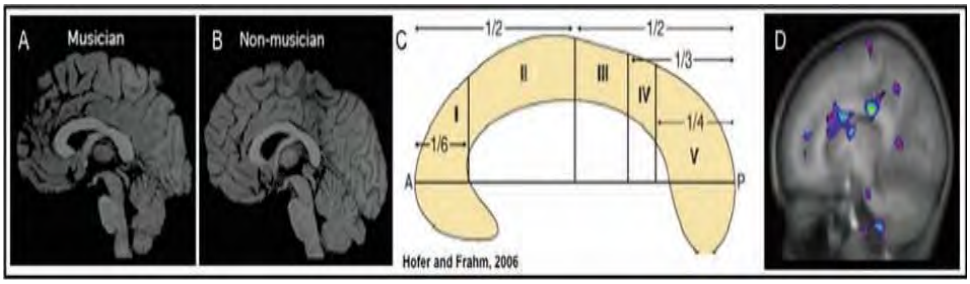
The morphometry of the corpus callosum (see Fig. 2) is of particular interest for studies examining brain asymmetry and interhemispheric exchange for several reasons. First, the corpus callosum is the main interhemispheric fiber tract and plays an important role in interhemispheric integration and communication and therefore symmetry. Morphometric studies that have revealed group differences in the size or shape of the corpus callosum are generally are viewed as based on differences in cerebral asymmetry and interhemispheric connectivity. [2-4]. We know also that callosum development is associated with the cycle of myelination and that its functional development extends into late childhood and early adolescence. [5]. *In vivo* imaging reveals that increases in the mid-sagittal callosal size can be seen even beyond the first decade with a maximum change in size during the first decade of human life (see Table I). [6,7]. Further, for a long while, consensus has existed that the control of movement and coordination as well as inter-manual transfer of sensorimotor information improves gradually from ages 4 to 11 years, an age span coinciding with callosal maturation [8-11].

Figure 2: The corpus callosum and its partitions



Early and intensive training in keyboard and string players and the requirement for increased and faster interhemispheric exchange in order to perform bimanual complex motor sequences might lead to structural changes in the callosal anatomy. We know that there exist differences in the brains of musicians and non-musicians [12-14]. The examination of the differences in the brains of musicians and non-musicians provides an ideal model to compare and examine functional and structural brain plasticity as musicians continuously practice complex motor, auditory, and multimodal skills. We also know that music training in children results in long-term enhancement of visual-spatial, verbal, and mathematical performance [15,16].

Figure 3: Corpus callosal differences in the brains of adult musicians and non-musicians. (A) Brains of adult musicians and (B) non-musicians demonstrate differences in the size of the anterior and mid-body of the corpus callosum, (C) demonstrates callosal subdivisions and locations of interhemispheric fibers that connect motor and hand regions of the right and left hemispheres and (D) represents areas of significant difference in voxel size over 15 months comparing instrumental and non-instrumental control children that are superimposed on an average image of all children. The changes found in the mid-body portion of the corpus callosum of parts that contain primary sensorimotor and premotor fibers.



We have found that the brains of adult musician and non-musician (Fig. 3) show differences in the size of the anterior and mid-body of the corpus callosum. In particular, as exemplified in Fig. 1(D), areas of significant difference are noted in voxel size over a fifteen month period when comparing instrumental against non-instrumental control children. The changes are mostly noted in the mid-body portion of the corpus callosum of parts that contain primary sensorimotor and premotor fibers. Fig. 1(C) demonstrates the subdivisions and locations of interhemispheric fibers that connect motor and hand regions located in both the right and left hemispheres.

Schlaug [17](2001) compared thirty professional musicians and matched non-musician controls and found that the anterior half of the corpus callosum was significantly larger in musicians as represented in Table I below. He noted that musicians possessed a significantly larger anterior corpus callosum with early musical training as compared to musicians who started their training later and both compared to controls.

Table I. Mid-sagittal area measurements of the corpus callosum (CC) in mm^2 (mean ± SD) [*after* 17]

	Total CC Area	Anterior CC Area[a]	Posterior CC Area
All musicians (n = 30)	687 ± 85	371 ± 46	314 ± 43
Musicians with commencement of musical training ≤7 years of age	709 ± 81	384 ± 42	321 ± 44
Musicians with commencement of musical training >7 years of age	637 ± 77	340 ± 43	297 ± 38
Nonmusician controls (n = 30)	649 ± 88	344 ± 48	305 ± 43

[a]Significant differences are those between controls and all musicians, between controls and musicians with early commencement of musical training, and between the two subgroups of musicians with or without early commencement of musical training.

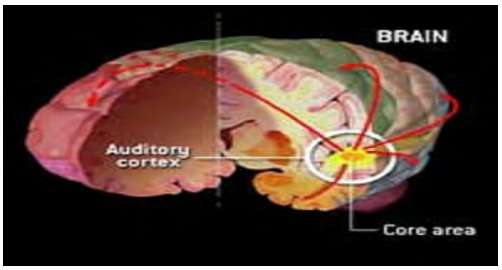
Previous anatomical studies found a positive correlation between mid-sagittal callosal size and the number of fibers crossing through the corpus callosum. The anterior part of the corpus callosum contains mainly fibers from frontal motor-related regions and prefrontal regions, [18] and the anterior corpus callosum matures the latest of all callosal sub-regions. Therefore, this anatomical difference in the mid-sagittal area of the corpus callosum has to be seen in the context for a requirement for increased interhemispheric communication subserving complex bimanual motor sequences in musicians. These reported brain changes clearly exemplify environmental influences on brain development and should be viewed in the context of both human development and rehabilitation.

The Motor Cortex

As reviewed above, there is much evidence supporting the notion that plastic changes can be induced in the functional organization of the human sensorimotor cortex following sensory stimulation or following the acquisition of new motor skills. These functional changes after skill acquisition may be related to microstructural changes such as increased numbers of synapses per neuron [19], increased numbers of glial cells per neuron (Stefan et al. 2000), and/or more capillaries (Stefan et al. 2000) as has been shown in animal experiments.

Many parts of the brain participate in music making (Fig. 4). Musical sounds are processed in the auditory cortex. Pathways then carry music to areas of the brain that perform and anticipate harmonic and melodic changes, as well as feel, remember and read.

Figure 4: Many parts of the brain participate in music making. Musical sounds are processed in the auditory cortex (●). Pathways then carry music to areas of the brain that perform (●), anticipate harmonic and melodic changes (●), feel and remember (●), and read (●).



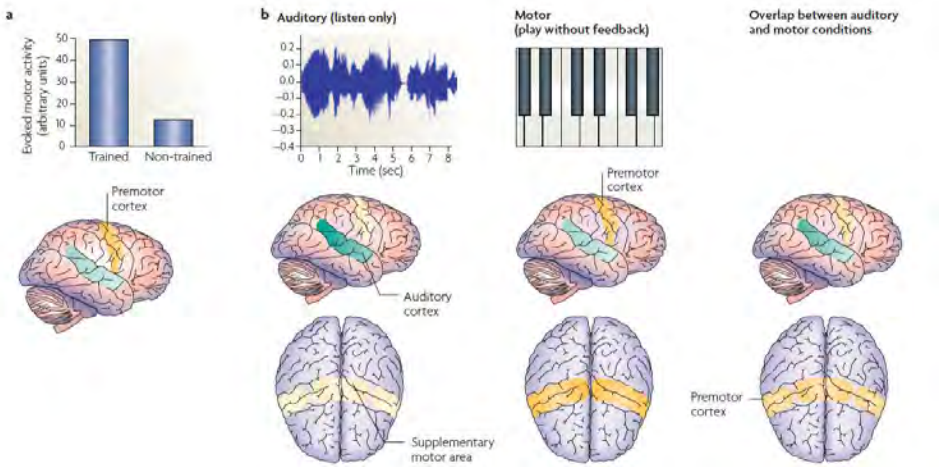
Music production motor control systems requires abilities in timing which is related to the organization of musical rhythm, sequencing, related to playing individual notes on musical instruments and the spatial organization of movement that results in sensory-motor integration. Reviewed in greater detail by Melillo and Leisman [16], we know that cerebellar, basal ganglia, and pre-motor cortex involved patients have impaired ability on perceptual-motor timing tasks, as well as in the computation of movement prediction, in the control of movement trajectories.

We know that motor timing not controlled by single region of the brain but by regional networks that control movement. The high-level control of sequence execution at the least involves the basal ganglia and the pre-motor cortex, whereas fine-grain correction of individual movement is controlled by the cerebellum.

Motor sequencing, on the other hand, according to Melillo and Leisman [16] implicates the supplementary and pre-supplementary motor areas, cerebellum, parietal, and pre-frontal cortical areas. The cerebellum integrates individual movements into unified sequences. The pre-motor cortex is involved in tasks requiring the production of complex sequences contributing to motor prediction.

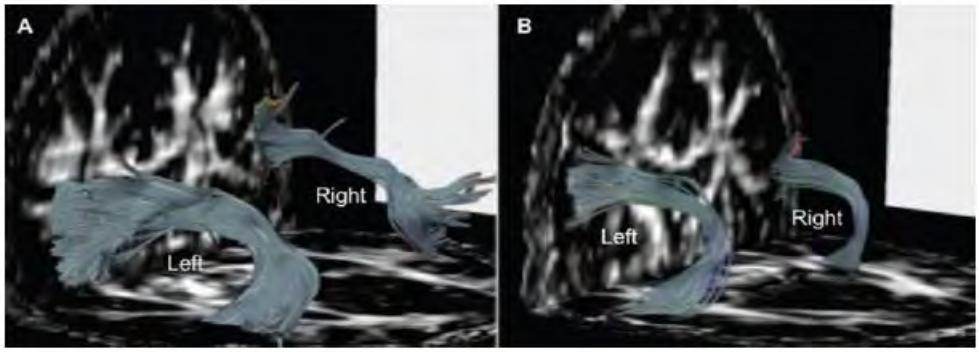
Finally, spatial organization involves the parietal sensorimotor and pre-motor cortices that control movements when the integration of spatial, sensory & motor information is required. Fig. 5 indicates that when individuals with no musical training learn melody on keyboard, upon hearing a learned piece, exhibit expected activity in auditory cortex and premotor areas. On the other hand, no effect is noted when individuals listen to a melody in which there has been no training. When examining brain activity in musicians while listening to a piece that they could play, we can note a significant overlap of activity in auditory and premotor regions. The auditory and motor systems interact during music perception and production.

Figure 5. a) People with no music training learn melody on a keyboard after hearing the learned piece, exhibit expected activity in auditory cortex, and premotor areas. No effect is noted when listening to untrained melody (bar graph). b) Brain activity in musicians while listening to piece they could play (l. column) with activity playing same piece with no auditory feedback (Mid. column). Significant overlap is noted in auditory and premotor regions in each condition (r. column). Auditory and motor systems interact during perception & production (after [1]).



We know [20] that musical training is supported by brain plasticity. We can see, for example, that in Fig. 6 that training affects the *arcuate fasciculus*, and auditory-motor tract, enhanced by music training.

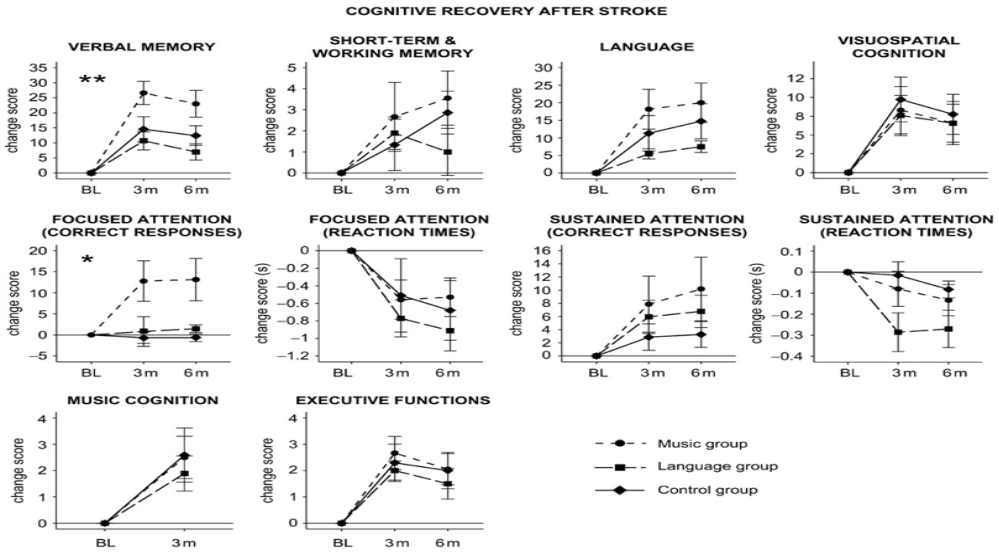
Figure 6. The (A) arcuate fasciculus [AF] of healthy 65-year old musician and (B) AF of a 63-year-old non-musician, matched for handedness, gender, and IQ. The musician has a larger AF on the left as well as on the right hemisphere than the non-musician. The data supports the notion of plasticity of the AF in those undergoing instrumental training or therapy using tasks that involve auditory-motor mapping, a task that musicians do throughout life (see [20]).



Conclusions

The result of this plasticity evidenced in musical training is that a rational basis is provided for the employment of music therapy for cognitive growth and rehabilitation of cognitive skills in individuals with brain impairment (see Fig. 7)

Figure 7. Effects of music training on cognitive performance post-stroke.



Acquired brain injury can result in problems with movement, language, sensation, thinking or emotion. Any of these may severely reduce a survivor's quality of life. The use of rhythmic stimulation to aid movement and walking, singing to address speaking and voice quality, listening to music to reduce pain and the use of music improvisations to address emotional needs and enhance a sense of wellbeing. Shlaug's group [17] has indicated that musical ability has been associated with left-right differences in brain structure and function. In vivo magnetic resonance morphometry of musician's brains was shown to reveal atypical anatomical asymmetry of the planum temporale, a brain area containing auditory association cortex and previously shown to be a marker of structural and functional asymmetry. Musicians with perfect pitch revealed stronger leftward planum temporale asymmetry than non-musicians or musicians without perfect pitch. The results indicate that outstanding musical ability is associated with increased leftward asymmetry of cortex subserving music-related functions. That asymmetry is clearly associated with music production demonstrates it power in the rehabilitation of those with both acquired and non acquired brain injury. The basis for the potential therapeutic effect of music resides in its power to effect neuroplasticity.

Neuroplasticity allows the brain to adapt to the individual's external environment. Experience-driven neuroplasticity of the kind resulting from musical training and production has been explained by growth and improvement of new dendrites, synapses and neuron [21,22], and the disinhibition or inhibition of pre-existing lateral connections between neurons by sensory input. What we have seen is that anything from several minutes of training to life-long music production can induce changes in the recruitment of areas of the motor cortex or establish auditory–sensorimotor coupling understood in part on the basis of neural plasticity as well on the asymmetric function of the brain. This then serves an effective basis of rehabilitation.

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Cezanne and the Mont Sainte-Victoire: a neuroesthetic approach

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Abstract

Among the pictorial themes dear to Paul Cezanne, the depiction of the Mont Sainte-Victoire throughout the years is the one that most eloquently shows the evolution of the artist's technique. Through fifty-five oil paintings and sixty watercolors directly or indirectly dedicated to the famous

Aix-en-Provence mountain, we discover the evolution of a style which would later grant him the title of father of modern painting. In trying to guide the reader through this evolution, we chose four key paintings that, in our opinion, reflect four key moments in the evolution of Cezanne's technique.
1. Around 1870, Trench at the foot of Mont Sainte-Victoire (La tranchée avec la montagne Sainte-Victoire) – Neue Pinakothek, Munich (figure 1).
2. 1882-1885, Mont Sainte-Victoire (La montagne Sainte-Victoire) – Courtault Institute, London (figure 2).
3. Around 1890, Mont Sainte-Victoire (La montagne Sainte-Victoire) – Musée D'Orsay, Paris (figure 3).
4. Between 1904 and 1906, *Mont Sainte-Victoire Seen from Les Lauves*
(La montagne Sainte-Victoire vue des Lauves) – Kunstmuseum, Bale (figure 4).

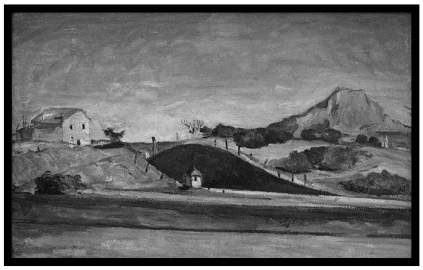

Figure 1: *Trench at the foot of Mont Sainte-Victoire,* Neue Pinakothek Munich.

Figure 2: Mont Sainte-Victoire. Courtault Institute, London

Figure 3: The Mont Sainte-Victoire, Musée d'Orsay, Paris.

Figure 4: *Mont Sainte-Victoire Seen from Les Lauves*, Private Collection, Bale.

I/ Significance of the Mont Sainte-Victoire in Cezanne's life

The meaning of the Mont Sainte-Victoire to Cezanne is first and foremost emotional. The Sainte-Victoire represents his childhood, his walks with friends Emile Zola and Jean-Baptiste Baille, and his native and very dear region of Provence. Despite his moving to Paris, Cezanne would frequently come back to Aix-en-Provence. On July 23rd 1896, he would admit to Philippe Solari, the Aix-en-Provence sculptor, "It's not worth our country. When one is born there, that's it, one cannot be tempted by anything else" [1].
The Mont Sainte-Victoire also has a symbolic meaning in the life of the artist. Just as nature is free and triumphant, Paul Cezanne would terminate with aplomb his long-standing friendship with Zola in 1886, after the latter published L'œuvre, a novel where Cezanne recognized a disguised description of himself in the portrayal of the failed artist, Claude Lantier. Cezanne would also free himself from his father's authority, who had protested against his marriage to Hortense Fiquet.
Technically too, the pyramidal shape of the Sainte-Victoire would serve the artist’s quest for simplification in the technique of painting -- which would later be regarded as the prelude to cubism. To this end, Cezanne would be working on his landscape with the meticulousness of a geologist,

analyzing textures and volumes. He would concede in a letter to Joachim Gasquet, "I need to know about geology, about how the Sainte-Victoire takes its roots" [2]. But beyond his scrupulous study of volumes, Cezanne would also concentrate on how chromatic variations determine the drawing and the perspective. He would focus on the contrasts between colors, plays on colors, plays on light, and variations in the textures. "Will I ever succeed in my long sought goal?" he would doubtfully ask Emile Bernard in 1906 [3].
Finally, like a researcher in his laboratory, Paul Cezanne would wonder about the scientific aspects to his quest of simplification. His concerns would be geologic first. "He was learning about the geological structure of the landscapes. These abstract relations had to work in the act of painting, but had to be adapted to the world of the visible" [4]. They would also be physiologic: "One has to create a view for himself, one has to see nature like no one else had seen it before them [...] I conceive of art as a personal perception. I associate this perception with sensation, and I ask intelligence to organize it in a piece" [5]. What could be a more obvious proof of his visionary theories, on how vision operates, than his famous saying "to paint is to contrast" [6] when, studying the ocular movements, we have come to the conclusion that the eye is indeed attracted by contrasts?
Defining the art movement to which Cezanne belongs is a difficult task. Inspired by the classic Nicolas Poussin, the romantic Eugene Delacroix and the realist Gustave Courbet, Cezanne never really fitted into one particular movement. At times impressionist, at times post-impressionist, he is also considered the founder of cubism and the father of modern painting. Of great influence on the work of Cezanne would be the introduction of photography in 1839 which liberated the artists from the constraint of rendering a precise, "photographic" account of reality, thereby making room for creativity. If light were the sum of dots and haziness, the impressionists would decide to represent the "haziness", and leave the "dots" to the care of the photographers. By allowing artists to leave their workshop and go paint on site, the invention of the tube of paint in 1840 would also revolutionize the world of painting. Limited by time in their completion of their work outside, the artists – and Cezanne in particular – would resort to frank oblique brushstrokes replacing the classic time-consuming solid color paint. Cezanne would eventually grow out of impressionism. Where impressionists regard vision as the sum of all lights, Cezanne considers that this process is not complete until the brain comes into play. "You must think. The eye is not enough. One needs thinking" [5].

II/ The evolution of Cezanne’s technique

The four main modifications to Cezanne’s technique are the loss of visual strategy, the loss of drawing, and the mixture of colors, which all point to a taste for the unfinished.
The retina consists of two types of photoreceptors, namely the cones and the rods. Cones account for sharp vision. They are concentrated at the fovea (a region of the retina). At the periphery, a much lower density of cones only allows for blurry vision. This aspect of the eye’s physiology explains why moving the ocular globe is required to observe an object or a specific detail.
The number of fixations and saccades – defined as rapid eye movements from one point to the other - may be recorded by an eye tracker [7]. Such a method allows for an understanding of the information collected by the eye and transmitted to the brain. Since Yarbus’ primary works in 1967 [8], this technique has been applied to several fields ranging from neurosciences to driving exercises. In our hospital, we studied the visual strategy of 30 subjects observing Cezanne's four paintings (the ones mentioned in the introduction). The profile of the subjects varied in age from 15 to 60, gender, and social background. The mean time of observation for each painting was 15 seconds. The eye tracker recorded the number and mean duration of the fixations, the number, mean amplitude, frequency and direction of the saccades for the four paintings.
Three parameters were analyzed: Number of fixations, duration of each fixation, and number of saccades. We observed an even spread of fixations in the first three paintings, depending on the zones of interest created by the artist. Looking at the selected parameters, we observed a clear pattern; looking successively at the four paintings in a chronological sequence, we could clearly see that the number of fixation was increasing and the duration of each fixation decreased. Looking at saccades, it was evident that the number saccades increased from the first to the fourth painting (Table 1). However, it needs to be noted that no significant differences were observed when comparing the second and third painting (The Mont Sainte-Victoire from Bellevue and The Mont Sainte-Victoire). Still, the evolution of fixations (number and duration) and saccades was significant when comparing

painting one, two and three combined and four. The number of fixations increased greatly with the last painting, as the subjects were probably looking for an anchor point in the midst of this confusing color patchwork, which could be interpreted as Cezanne's way of forcing the spectator to collect all the different colors and recreate a "colored sensations" [9].

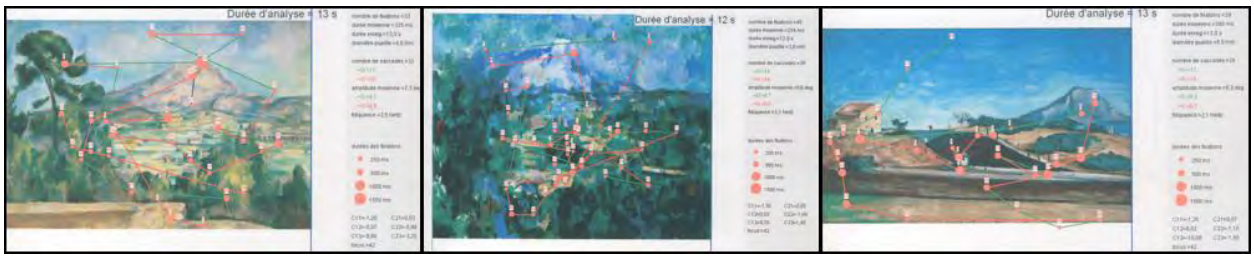

Figure 5: Eye tracking recording (of random subject) on three of four paintings

Painting	Number of Fixation		Fixation Length		Number of Saccades	
	Average	Standard Deviation	Average	Standard Deviation	Average	Standard Deviation
#1	30.0	1.7	379.1	18.7	27.8	2.1
#2	34.8	2.4	306.5	11.7	31.6	1.3
#3	34.7	1.8	305.0	11.4	31.5	1.5
#4	39.7	1.4	268.8	11.1	38.5	1.7

Table 1: Data from eye tracking recordings.

As one proceeds chronologically from one painting to the other, one cannot help but notice the vanishing of the brushstroke. This is especially true of the drawing of the pine tree. From painting to painting, the contours of the tree are more and more fuzzy to the point of becoming a simple accumulation of different shades of green. This simplification is even more obvious in the depiction of the top of the Mont, which, in the Bale painting, is only defined by the color of the sky – the artist having decided to leave the canvas blank at this precise spot. Likewise, in that same painting, the valleys at the bottom of the mountains are represented by completely unstructured colors. The vanishing of the brushstroke results in color imposing shapes. The tension between color and shape is one of Cezanne's most important preoccupations. "When the color achieves richness, the form achieves fullness" Cezanne liked to say [9].

From one painting to the other, the colors also progressively lose their borders. The green of the thorns has left the branches to become an integrant part of the sky. This is especially true of the Bale painting. Some of the colors are even reversed, with the blue of the sky in the foreground among the trees, and the green of the trees in the sky. Henri Matisse used to say: "*When I put a green, it is not grass. When I put a blue, it is not the sky*" [9a]. By that, he was probably referring to the work of his teacher, Cezanne, on colors.

Already in many still lives, landscapes from Gardanne (1886), and even more so in watercolors, Cézanne exposes his taste for the unfinished -- The oven for plaster, 1890-1894; Black castle in front of Mont St. Victoire, 1890-95 and St-Victoire seen from the Lauves, 1902 -1906 are two illustrations of this concept. Once again, in the Bale painting, the top of the mountain is left blank. The canvas is left immaculate, and the observer fills in. This collaboration between the painter and the observer arouses some neurosensorial phenomenon.

This is precisely the effect used by Cezanne in his watercolors: a non-finished picture, with just a few brushstrokes at the edge of an empty zone, and the observer's eye will fill in the blanks. One hundred years later, Lothar Spillmann would publish in the journal of vision about what he would call the watercolor effect: "The watercolor effect (WCE) is a phenomenon of long-range color assimilation occurring when a dark chromatic contour delineating a figure is flanked on the inside by a brighter chromatic contour; the brighter color spreads into the entire enclosed area" [10].

The fact that we find tolerable that the reality is represented by lines while in the nature these lines do not exist means that our visual system extracts outlines. So too, in front of the Sainte-Victoire vue des

Lauves (Bale, Kunstmuseum) our brain extracts the shape of the valleys from the bottom and fills the empty zone by itself.

III/ Discussion with the brain

One of the specificities of Cezanne's painting lies in the presence of lines, and vertical or horizontal brushstrokes. Even though painting in the nature requires the "alla prima" technique, i.e. "first shot" technique which is to paint "humid on humid" in order to complete a work in one setting, Paul Cezanne would, at the end of his life, resort to this same technique in his workshop, making hatched paintings at thus leaving the interpretation to the care of the viewer.

Where the pointillist Seurat was dissecting every detail of his painting into points of light, Cezanne on the contrary was interested in the simplification of natural shapes into geometrical ones. Cezanne is the one who simplified nature into cones, spheres and cylinders. He loved to say: "Treat Nature by the sphere, the cylinder and the cone, etc." [9]. At the end of his life, Cezanne would go so far as to paint only lines. With a prominence of lines, as opposed to well-defined shapes, Cezanne's paintings stimulate the reactivity of brain cells.

In 1981, the Nobel Prize in Physiology or Medicine rewarded the work of David Hubel and Torsten Wiesel who, in 1959, studied the cerebral cells' response to light. Having inserted a microelectrode into the primary visual cortex of an anesthetized cat, they projected patterns of light and dark on a screen in front of the cat [11]. They found that some neurons fired rapidly when they were exposed to lines at a given angle, while others responded best to another angle. In other words, cerebral cells do not respond to points of light, but rather to angles and lines.

By trying to stimulate the brain, Cezanne distances himself from the impressionists. While the latter regard vision as being the sum of all lights, Cezanne refuses this simplistic "retinal vision." Light is only the beginning of the process; the brain is the tool that completes it. Without knowing about the neurophysiological mechanisms of vision as we know them today, Cezanne found a way to stimulate our neurons. The visual information, coming from the retina via the optic nerves, reaches the pre-striate cortex and is then distributed to the visual areas. Those areas are themselves largely interconnected in a complex network, from which one can extract the two main vision pathways: the ventral pathway and the dorsal pathway. The ventral pathway, or occipito-temporal pathway (area V1), connects the striate cortex to the pre-striate areas (V2 and V3) and is implicated in the knowledge of an object, the recognition of its attributes (shape, color, texture) and its conscious representation -- it is the "what is it" pathway. The dorsal pathway, or occipito-parietal pathway, connects the striate cortex to the posterior part of the parietal lobe and focuses on the movements and localization of an object, while also guiding one's actions towards this object, by a largely unconscious process. It is the "where is it?" pathway. The cerebral processing of the visual information is complex. It occurs in several steps. Step number one is the targeting and decomposition of the picture into its shape, color, contrast and movement. Step number two is the reconstruction of the image from its different properties. What happens is basically "an extraction of form from essence." The last step compares and cross-references the image seen with previous images stored in our brains, and will be classified accordingly as belonging to a certain category. The basic principle is that the brain dismantles before rebuilding a reality of its own. The reality is built in our brain.

It would seem that, even without knowing human physiology, Cezanne was trying to accomplish the first step in the processing of an image: its targeting and decomposition. The painter was indeed trying to simplify his work to the extent that our brain would.

The concept of "neuronal recycling" defined by Stanislas Dehaene [12] takes into consideration the capacity of neurons to adapt. Our natural environment has taught our neurons to "acclimate" by creating an "elementary alphabet of shapes" [12] grouping images into categories, depending on the shape they adopt - lines, intersection of lines, curves, angles being the main repertoire entries. The works of Marc Changizi [13] confront this recycling concept by showing that a n actual correlation exists between the written symbols and the images fragments from nature or from urban life that surround us, and that they were not a mere invention of our neurons. Changizi argues that when several objects meet, superimpose or hide one another, their contours form specific configurations where simple shapes like those of the letter T or the letter L dominate. We can likewise imagine that Cezanne's technique of painting evolved in a way that would fit our brain: singling out primary elements of a complex image in a way that would easily be picked up by our neurons. It is indeed the

simplification of Cezanne's technique that would grant him the title of "father of modern painting." From Cubism to Abstract Art, painters would indeed, following Cezanne's lead, simplify their technique even further. While George Braque would be a loyal heir to Cezanne's geometrical representation of nature, Picasso and Mondrian would mostly use lines and angles, Juan Gris would focus on perspective and the power of background color, and Fernand Leger would resort to the fragmentation of shapes.

IV/ Conclusion

During Paul Cezanne's life, the representation of the Mont Sainte-Victoire would become more and more simplified. Through four main transformations that are the disturbance of the visual strategy, the disappearance of the drawing, the mixing of colors and the tendency for the un-finished, Cezanne finds a way to converse directly with our brain. In his neuroesthetic approach of painting, he decided to replace his flat areas by colored lines oriented in a way that would stimulate certain neurons, to displace colors from where they belonged logically, to force the viewer to collect visual information from all over the painting, and finally to resort to the brain in order to make sense of his un-finished work.

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Narcissus and atlas: using scalometers to reveal distortion while considering multiple orders of magnitude


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Abstract

Today many scales or magnitudes are accessed via relatively new instrumentation, and data from all known scales are often rendered side by side in continuous graphical form, invoking visual continuity to imply a conformance between macro- and micro-scales. The usefulness of such continuous rendering is counteracted by operational and dimensional discontinuities intrinsic to the scales portrayed. A set of graphical solutions called scalometers, is proposed, resembling the cartographic scales used in atlas-making. Mapmakers, who deal with distortion between two scales, cite the mythological Atlas; for multiple scales we cite Narcissus as well, since users need to be wary of projecting their everyday expectations into these foreign scales.

Paper

Vast and tiny scales have been considered throughout recorded history, back to the ancient religions that contrasted man with God, and quantitative speculations are at least as ancient as Archimedes' Sand Reckoner who estimated the number of grains of sand that would fill the universe [1]. Mercator, an influential Renaissance cartographer, innovated quantitative methods to accurately project one scale onto another. He famously invoked the mythological figure Atlas to connote the feat he had achieved: just as Atlas held the world in his hands, just so a map-reader at scale A can consider a much larger scale B. We use "scale" to refer to the differences between realms, each scale being a category or set of general ranks of extent, measurement or size. To assist the reader the map bears a graphical gauge to correct distortions, such as that reproduced below.

Researchers have more recently charted ever vaster scales, as part of a technologically-enabled trend broadening the scope and impact of human activity. Today's governments are routinely called upon to regulate macroscopic activities such as global warming and gigawatt power plants along with microscopic activities such as carcinogen monitoring and gene splicing. Yet common citizens have little experience or knowledge of such disparate realms, and tools are needed to help inform our thinking across scales and avoid any errors that might creep into our decision-making process.

"Powers of Ten," a film by Eames, was an influential attempt to clarify the issues [2]. The film opens on two actors having a picnic, and renders a continuous zoomed sequence out from two human actors to the limits of the observable universe. The zoom then reverses, returning to the blanket and magnifying a picnicker's hand repeatedly until microscopic limits are reached. The smooth, unified experience is a cinematic fiction that obscures two critical discontinuities: zoom-in vs. zoom-out, and physical distortions.

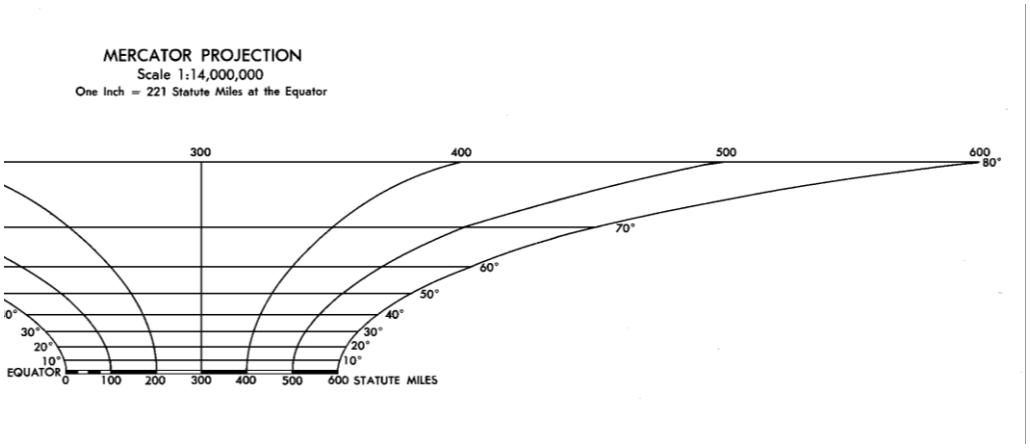

Figure 1 An atlas graphical gauge documents distortions introduced by projecting one scale onto another. Mercator varying linear proportional scale, detail. From Defense Mapping Agency World Map, series 1150.

First, radically different realms seem to be made equivalent. Given two scales A and B, the parthood relations of A to B are complex: B is unrelated to A in that it inhabits a separate, unequal rank that describes B and not A. This dichotomy of connected-yet-separate is called variously sequence vs. rank, dependent vs. independent, equal vs. unequal, or continuous vs. discrete, and is tidily expressed as an "order," e.g. "order of magnitude." No indication is given of the radically different realities present in each order, discussed further below. Second, zoom-in and zoom-out are similar only in their repetition. Zoom-out is an act of construction , aggregation or multiplication, while zoom-in is an act of explosion, disaggregation or division. These two dichotomies lie at the heart of the issues discussed here. Atlas held the world in his hands, contrasting two scales rendered with a single projection: what about Eames and his film's viewers, who behold forty scales, rendered with many different projective methods? What gauge can help their viewers?

To solve the problem we first render the numbers involved. Below, decimal numerical values are rendered in a circular scalometer. The number one is at bottom, center. The values aggregate to the right and disaggregate to the left. Each number is positioned at a "stop" that specifies its exponent: stop "2" is at the value "100" and so on. Note the co-joining of the stops "23" and "-23" across a gap, an issue discussed below. Using this gauge, with its seeming smooth continuity, let's consider a familiar and intimate experience: our own human life.

Every child without exception—you included—began life as a fertilized egg (stop "-4") and became in turn a blastocyst, embryo, and fetus, doubling in size over and over again. Your biological form changed radically at each stop. You live your mature life at stop "0" and may not remember life at those other scales, but facts indicate that you needed no heart or circulatory system when you inhabited stop "-3" since each of your cells directly accessed the nutrients it needed. When you were an infant at stop "-1" you could stumble without getting hurt—an ability you needed in order to learn to walk. Once you reached stop "0" a stumble could hurt and even shatter bone. These changes are not theoretical, and remain a common theme of children's literature. The characters of Alice in Wonderland, Tom Thumb and Gulliver's Travels visit realms one or two stops removed from our everyday world (scalometer stop "0"). Gulliver, for example, visits Lilliput (stop "-3") and Brobdignan (stop "1"). Children relate to these stories since they are living through such changes. Consider that this is life across a mere 4 orders of magnitude: imagine the further discontinuities of forty.

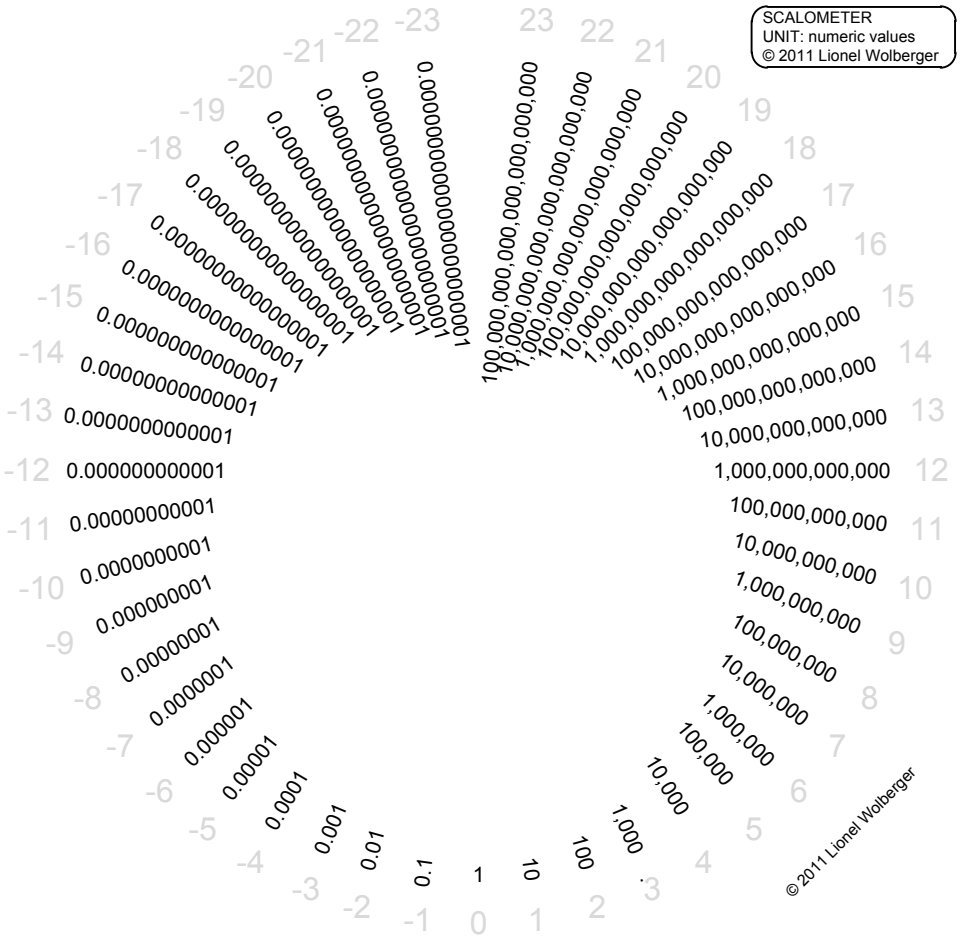

Figure 2 Rendering the powers of ten in a circular format serves as simple method for quantifying changes in scale, and renders a single gap joining the extremely large and the exceedingly tiny.

The changing physical imperatives of each scale are ascribed to the changing nature of physical fields. While electromagnetism (EM) dominates the world at stop "-4", gravitation dominates the "0" stop, and so on. In the cartoon below Glashow [3] assigns a physical force to each scale range. He also bridges the gap between stops "25" and "-30" with a snake's head, showing that the gap itself is not what it seems, but is an artifact of our exponential mathematics, a subject I return to below.

Dimensional analysis is the art of codifying the physical changes associated with changing force ratios [4]. One example is the Reynolds number, a ratio of inertial forces to viscous forces. Videos of microscopic activity, such as bacteria flagella movement, give an illusion of speedy movement. Yet visually rapid movement is a profoundly misleading illusion. The Reynolds number dictates that bacteria (stop "-6") move slowly and thickly: for a person it would be like "swimming in thick molasses in which one was not allowed to move one's arms or legs faster than the hands of a clock." [5]

Scale discontinuities are also inherent in the varying quantitative operational methods required to measure events, with intense discontinuities resulting in the meaning of the metrological units invoked. While the same unit is invoked across the survey such as length, time or energy, the meaning of the term may change so drastically as to make comparison in many ways, absurd. Bridgman, a leading physicist, cautioned students of relativity to keep these differences in mind when studying Einstein's theories. In a classic thought experiment, relativity students compare the length of a train car with a light wave—a leap of 8 stops on a scalometer. Bridgman warned: "his 'length' does not mean the same as our 'length.'" [6]

Bridgman's warning is relegated to the study of the philosophy of measurement (metrology) or the philosophy of science—yet it is germane to correcting distortions encountered every day when dealing with phenomena from disparate scales. To convey the changing nature of reality at these scales, a scalometer may be rendered in a sigmoid fashion as below. At the sigmoid's center the numbers "0.01, " "1" and "10" visually group in a roughly linear continuity. As the values continue to be generated they peel away from this visual line. The further one goes from "1" the more radically the numbers depart from the linear norm, graphically depicting the departure of behavior everyday human expectations.

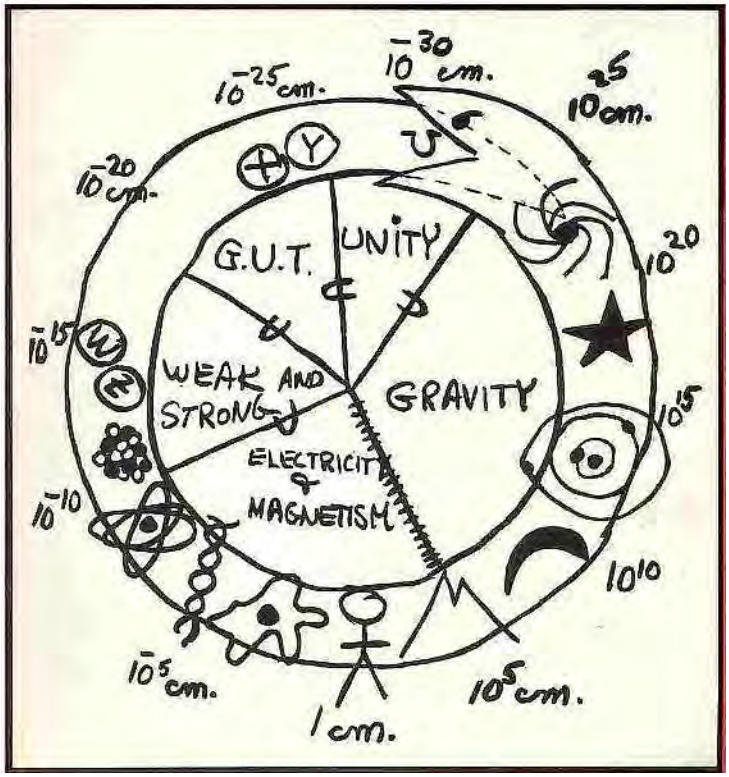

Figure 3 Cartoons and values of length are rendered in a circle with the Uroborus, a snake swallowing its own tail, superimposed across the gap between the large and the tiny. L. Sulak, based on Glashow. [3].

Operational methods must vary, as the more scales we attempt to comprehend, the more we are forced to technologically enable our biological sensory organs. The retina, for example, aggregates and processes light before forwarding a pulse along the optic nerve. In that operation it resembles our other sense organs that host receptors in "fabrics" and perform significant pre-processing of signals before forwarding to our brain. This act of aggregation permeates the experience of vision itself, and visual aggregation and disaggregation—the zoom-in and zoom-out of film—is understood even by a child. Our sense of time is similarly amenable to aggregation, and children intuitively grasp fast forward and slow motion film. But other senses forbid aggregation: imagine an Eames-type zoomed experience comparing the taste of a galaxy, the smell of a quark, or the innate body-position (proprioception) of the Milky Way and a neutrino. These suggestions are ridiculous: multi-sensory interpretation is limited to the human scale, and information on other scales is necessarily more limited and uni-dimensional.

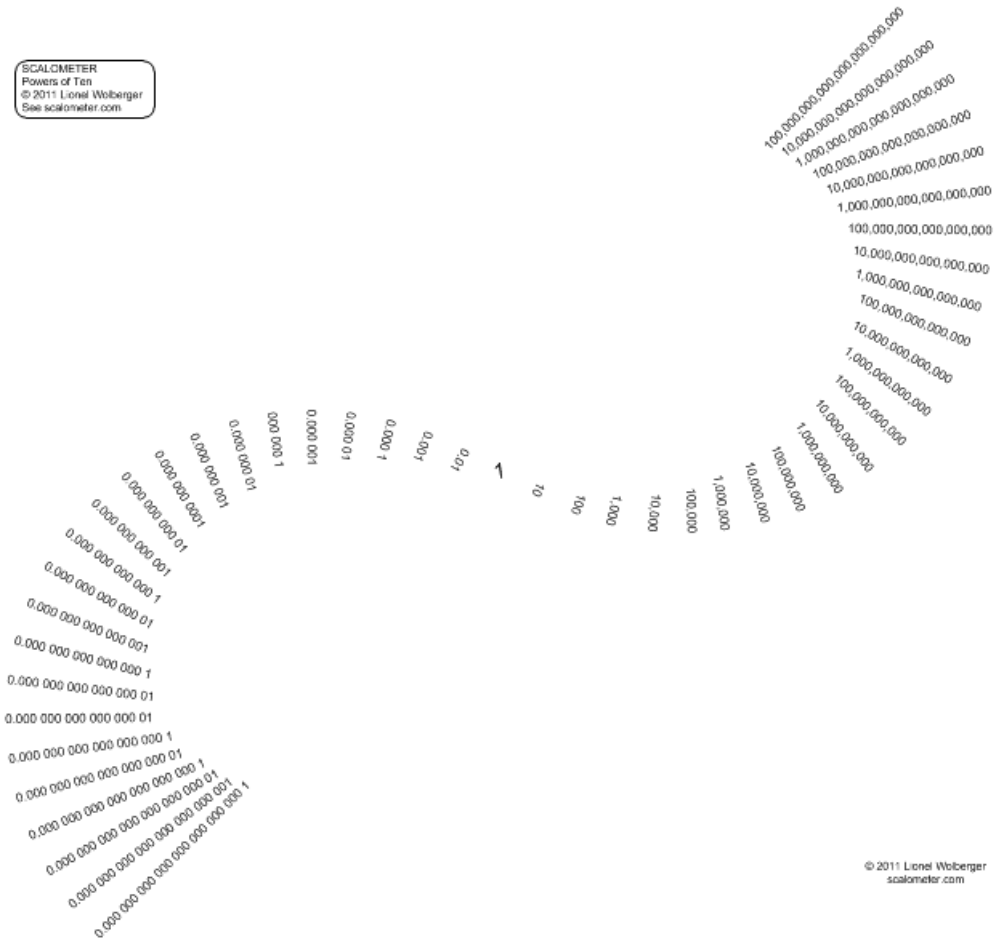

Figure 4 When the powers of ten are rendered in a sigmoid scalometer, distance from the center conforms with the degree to which reality deviates, from expected, linear, norms of expected behavior.

Mapping sensory capabilities to scales helps a reader track the changing nature of the realities measured. The length scalometer below shows such a scalometer. It retains the clock stops of the first rendering above, but instead of numerical values at each stop, it lists a physical phenomenon. For example, stop "12" reads, "Sun <- -> Pluto," representing the distance of the Sun to Pluto, 5,900,000,000,000 meters, a number with twelve decimal places. To these quantified phenomena cartoons of the traditional five senses are added, at relevant locations. Our noses, for example, can detect smells due to their ability to sense molecules at the nanometer scale, so a nose cartoon is positioned near the "-9" stop. An additional cartoon face is added in the center to depict the human self. A circle about the face is thick at stops not directly accessible to conscious report, and open at stops directly accessible to such capability. For example, stop "-7" is not directly accessible to conscious report, since light wave aggregation must occur in the retinal fabric itself before mental awareness dawns in the mind.

The cartoon face represents the identity of the reader. It functions like a mirror, and evokes the mythical story of Narcissus, a skillful archer and hunter who met his doom when he paid exclusive attention to his own image rather than to his external reality. Some self-reflection is healthy and required, but people also need to overcome this innate selfishness, bring critical faculties to bear to ignore our biases, in order to deliberately adjust expectations and act correctly in other scales.

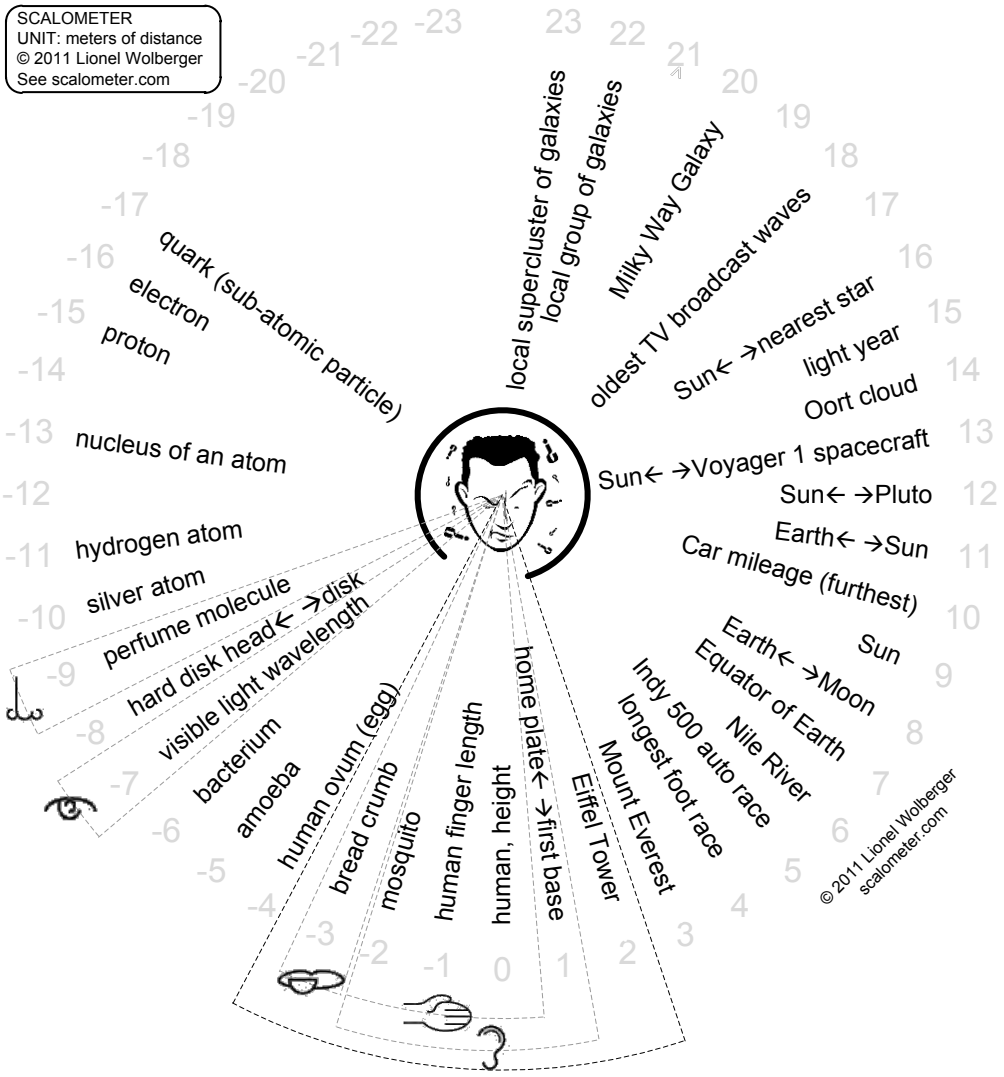

Figure 5 Human sensory and attention capabilities superimposed on a length scalometer enable readers to judge, at a glance, whether information is obtained directly from experience or extrapolated by advanced techniques.

The final distortion discussed here is the gap at the top of the scalometer. No matter what units are portrayed in a super-scale survey, a horizon is reached beyond which aggregation and disaggregation fail, human knowledge ends, and experience cannot be quantified. In the length scalometer, these failures occur at stops -17 and 27 (not shown), or perhaps at other theoretical stops -35 and 53. The mathematical technique of exponential notation makes these scales feel far apart due to the additive number-line metaphor that lies at the heart of the exponential method [4]. But this failure of resolution does not exist primarily on a number line: it exists in the real world where the limits of human knowledge are not far apart, but experienced right here and now. Glashow neatly expressed the mysterious nature of this horizon of irresolvability by superimposing across this gap a snake's head eating its own tail. The snake embodies the symmetry of this void. Like an archer pulling back his bow in order to fly it further afield, scientists work symmetrically in scales about this void, pulling in one direction in order to move forward in another direction. Two examples illustrate this symmetry: to explode the world into its tiniest, disaggregated fragments and reveal the elusive Higg's boson (at stops around -24) scientists construct the largest cyclotron ever built (stop 4); to accurately aggregate the billions of years of life's history scientists explode samples into ever-more fine milligram particles.

Conclusions

Each of us operates on multiple scales. We began as a single cell and matured into a multi-billion celled human being. Our every action requires harmonious operation of trillions of cells, multiple trillions of bacterial flora, and a trillion-trillion chemical atoms. And when we act, we embody one billionth of a world community of seven billion beings like us. Our action, alone or in concert with others, is then applied to affect other scales foreign to our everyday life, as the following three examples illustrate:

- CERN researchers seek the tiniest, most intrinsic discernment of reality—the Higgs boson—by constructing and operating the largest accelerator ever (27,000 meters across);
- Doctors detect cancers in their earliest most disaggregated stages by deploying ever larger and more aggregated computer-enabled scanners;
- Army engineers aggregate and detonate the most explosive energy ever produced by humanity—a thermonuclear warhead—by marshaling the most disaggregated matter known—atomic nuclei.

The reality of our super-scale lives requires successful quantitative and qualitative comprehension of scale. Yet whatever data we collect must be filtered through one and only one scale—the scale and force dynamics of our everyday world. Mapmakers furnish their readers with a graphic guide to correct distortions resulting from this filtering. Such a graphical guide is lacking in other super-scale presentations, partially due to the problem of multiple scale aggregation vs. disaggregation. Yet the need remains, and is greater than ever. Scalometers are proposed as a collection of graphical techniques to solve the problem. Their use will serve to remind ordinary readers how super-scales fail to conform to ordinary expectations, and evoke the mythological character of Narcissus (rather than Atlas), whose story reminds us that disaster stalks us when we reflexively, without caution or adjustment, pay attention only to our ordinary selves, and forget to pay attention to the unexpected reality we encounter in foreign scalar realms.

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Art, science, and 3D fractals

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Abstract

By presenting a short description regarding three dimensional fractals and presenting examples of them among author's artworks, this paper aims to give a more clearly visual spectacle of this new type of computer art to art-math lovers.

Introduction

The historical correlations between mathematics and art are not covered to anyone nowadays. Making use of mathematics and geometry in ancient architecture and music is an undeniable part of the history of sciences and arts. The accurate usage of mathematics in the form of symmetry or golden ratio in Pyramids, Roman and Renaissance architecture, and Islamic tessellations and architecture and the Pythagorean musical ratios could be named as vivid instances of this phenomenon. Perspective was another fruit of such a conjunction. Geometry even played the central role of creativity in the formation of modern movements like Futurism, Cubism, Constructivism, Suprematism, and De Stijl, searching for a new form of geometric abstraction [1].

A significant milestone in this path was the appearance of computers and the beginning of the digital era. Computers introducing a completely modern medium, invited new eventualities to the field and made many impossibilities possible in this new digitally computational medium. Computer art, generated or aided by machine, significantly rearranged the classical correspondences among art, artist, work of art and aesthetics, parallel to the same movement in the postmodern art.

At times it is hard to understand the kind of balance that is required in order for an artist to complete work that uses a combination of technologies and specialised subject knowledge. Their ideas develop as part of a dialogue between artistic intention and the technical realisation this depends on [2].

Another breakthrough was the discovery of fractals by Benoit Mandelbrot in the 70's. Fractals not only changed the view of scientists in different fields toward the complex behaviours of nature, but had also visual results which could be viewed digitally and printed through plotters. Obtaining such images, drawn through large plotters connected to computers, was truly not possible without computer technology. Thus, fractal images played the role of a synthesizer of new developments in science and technology, dissolving boundaries between sciences, disclosing their correspondences and implicating interdisciplinary and transdisciplinary issues [3].

Fractals exploiting classical knowledge and day's technology and science, on the basis of new discoveries of fractal mathematics, another time answered to the traditional request of art for geometric abstraction, but from an utterly different point of view and via a completely different medium.

As Marshalil Mcluhas states [4], "The artist is a man in any field, scientific or humanistic, who grasps the implications of his actions and of new knowledge in his own time. He is the man of integral awareness".

Fractals are abstract visual representations of mathematical codes in computers which represent recently discovered properties of Nature's behaviors like simultaneous order and disorder, chaos, complexity, self-similarity, scalability, and fractal dimension digitally and printed.

Due to exploiting a large amount of fractal concepts and characteristics, these images either have some sort of geometrical aesthetics or motivate the audience's feelings due to their extreme complexity and innovation which cause an aesthetically emotional response. Despite the fact that aesthetics emerges from social, cultural and emotional conditions of specific eras, now the common feeling of audiences toward complex works of art and fractal images results from today's great complexity of human emotions and societies [5]. Peter Halley points out [6]: "Where once geometry provided a sign of stability, order, and proportion, today it offers an array of shifting images of confinement and deterrence".

For decades most of the artworks created with fractals were either two dimensional or three dimensional fractals like Sierpinski pyramid or Menger sponge which played an iconic role without required artistic flexibility to pull out creativity. Three dimensional fractals were rigidly only what they were. Despite the developments in speed and probabilities of computers in computation and image making, specially in 3D image making, basic 3D fractals still caught fancy as little as the past.

Eventually, the considerable efforts of scientists and programmers led to more sophisticated 3D representations of fractals incorporating more complexity and aesthetics in 2007 and a new generation of 3D depictions of fractals, representing the Mandelbrot set at higher dimensions and named as Mandelbulb, emerged in the world of strange imagery [7], [8]. Actually, three dimensionality always provides the probability of more tangible and realistic explorations in any area, from 3D installations to the newly revealed 3D movies [9].

Three dimensionality invited the spirit of believability to the existence of fractals. Mind blowing abstraction, the most dazzling aesthetical property of fractals, has now found build in environments that are theoretically tangible and believable for our minds, still digitally though. The existence of fractals, 2D or 3D, fundamentally depends on digital environment and some of their mathematical basics could not be executed in the real world. One of such basics is the infinity of the details of fractals mathematically. Fractal artists during digital continuous zooms inside fractals, 2D or 3D, can feel this property well. The more they zoom out inside a fractal, the more the self-similar details emerge infinitely.

Artists as well as scientists work with abstract symbols, representations for various realities and working tools. Even the language used by the two groups is similar. Scientists working with mathematics frequently describe a particularly good explanation or solution as “elegant.” . . . The intellectual bridge of abstraction and aesthetic consideration is fundamental to both groups [10].

Fractal art is playing role as a combination of different historical and technological ambitions and achievements of human kind. It has arisen through the newest achievements in mathematics and sciences and fractals are created by the most modern technology of computation and only find meaning in a virtually digital world which could not be even imagined before the 50's. They also embody a postmodern philosophy of complexity and face their audience to completely different interpretations of existence in different dimensions. They present new worlds belonging to fractional dimensions and with properties entirely different from our experiences in the real world. Fractals are one of the straightforward mediums in the efforts of postmodernity in science, art, and philosophy to define or reach worlds rather than ours. At present, these are artists who explore such worlds via numbers and parameters emerging on their monitors and represent selective scenes to the audiences.

Some of the most popular representative mediums to expose artistic aspects of fractals are animations and prints. In spite of the limits of prints in catching the purity of the mathematical concepts behind fractals, other properties like self-similarity make it easier to visualize them in mind. Therefore, it is the aesthetical viewpoint of the artist that decides which spectacle would contain more mathematical and artistic appeals. The artist also keeps the balance between mathematical properties and aesthetical requirements with adjustments in parameters, lights, colors, reflections, and framings and invites the audience to the world directly cranked out of the numbers describing the universe. The world which is better know as the art of complexity.

Johannes Kepler says [11]: "I believe the geometric proportion served the creator as an idea when he introduced the continuous generation of similar objects from similar objects".

In the following you can find a number of author's 3D fractals which have been created with both mathematical and artistic backgrounds in a software known as Mandelbulb3D [12].

In addition, the following couple of paragraphs are selected parts of a section of a more complete description on the creation and features of such 3D fractals from my article "Fractals and the Second Life" [9], which are recommended to more enthusiastic readers:

"Fractal art creation is initiated with an empty space on the screen of a computer. The artist opens pre-existing mathematical parameters in his or her platform and everything is initiated. There exist several adjusting parameters and ability of travelling inside the shape. The artist faces a continuous, endless world inside. He or she can enter into this virtuality in front of him or her step by step. But, it is not just a one-sided journey. The artist has a more important role than a traveller; he or she can also interact with the shapes on the screen and even explore newer possibilities than what he or she has encountered so far. With small magnifications, the journey continues and with adjustments the artist's manipulations are applied instantly.
One of the advantages of Mandelbulb3D is its handy and instant navigator. With this navigator, you can have continuous movement from one place to another and have a more realistic feeling of movements. The ability to interact represents the magical steering wheel of drowning in the digital world of fractals. The artist can actually experience a journey towards the infinitude, walk through the bizarre constructions in front of him or her and encounter more details and complexities. Each time, the traveller has infinite sights around him or her to proceed and he or she can only select one to proceed each time. Along the path, there will be thousands of such routes, which extends the set of possibilities infinitely.
Through this, the artist continues to travel until he or she encounters a sight that he or she finds worth showing to others as a shot of the digital travel he or she has accomplished. This is an explicit difference between fractal art and other types of arts, especially traditional. The artist plays a role as the interactive creator-driver inside his or her own constructed world and experiences as much strangeness as a viewer or even more!"

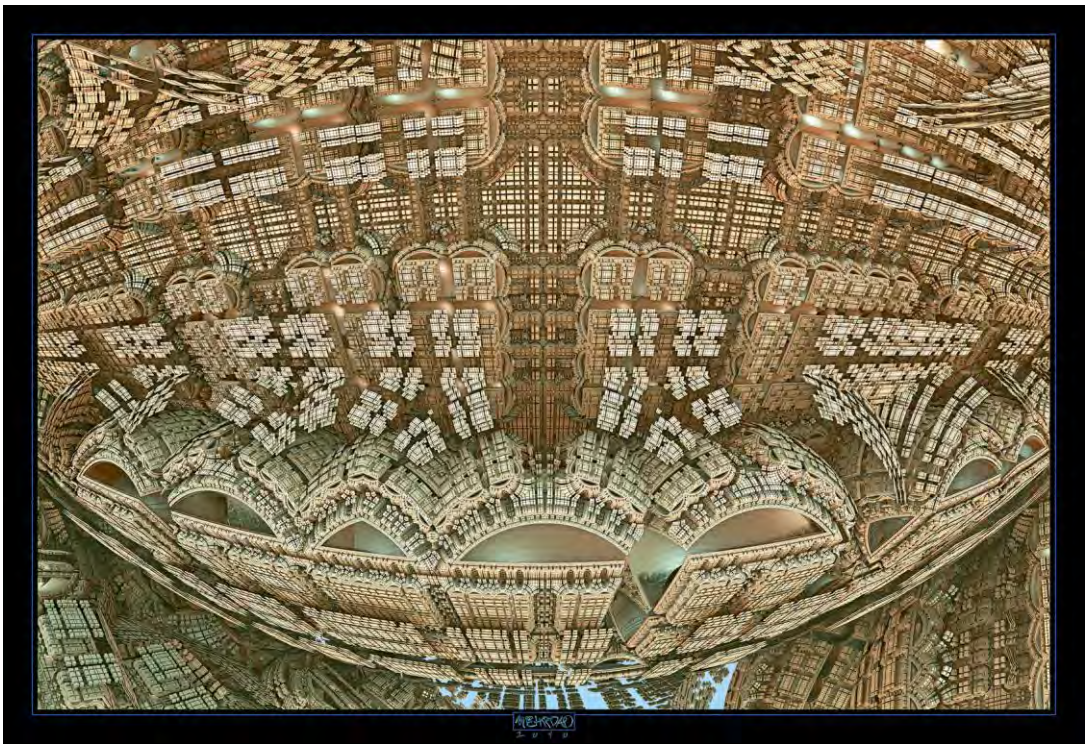

Figure 1: Mehrdad Garousi. Particulate Colosseum, 2010.

Figure 2: Mehrdad Garousi. Mayan Architecture, 2010.

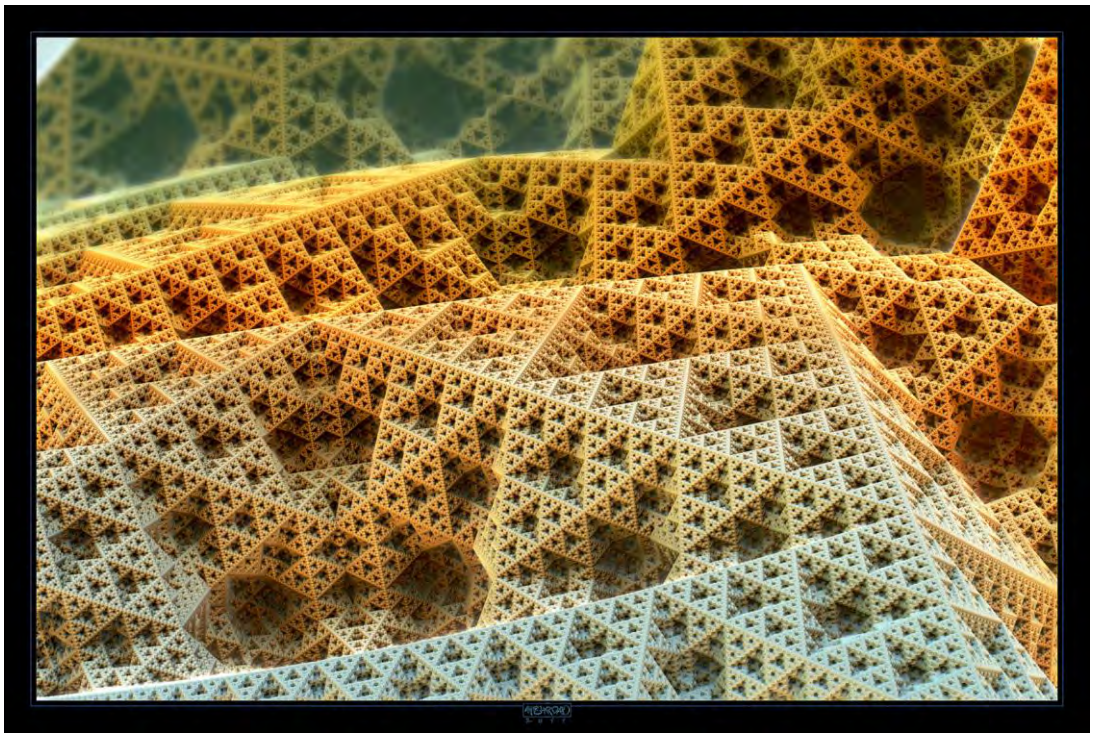

Figure 3: Mehrdad Garousi. Triangles World, 2011.

Figure 4: Mehrdad Garousi. Let's Go, 2011.

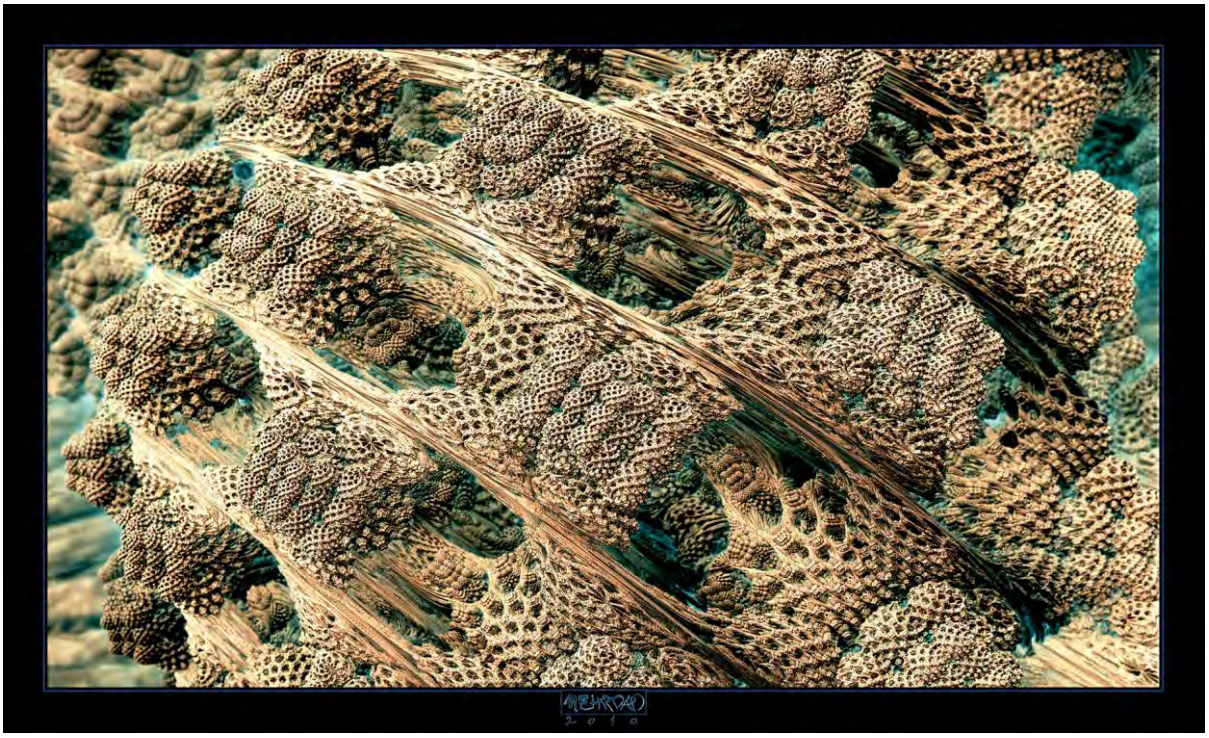

Figure 4: Mehrdad Garousi. Touch, 2010.

Figure 5: Mehrdad Garousi. Creation Lights, 2011.

Figure 7: Mehrdad Garousi. Apollonian World, 2011.

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Plenary lectures

The Scientific Aspects of Art

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There are many examples of interrelation between different arts (music, painting, architecture, sculpture, etc.) and sciences (mathematics, physics, chemistry, biology). A well known example of such interrelation between mathematics and arts is the conception of gold ratio which occurs in painting, architecture and sculpture. Gold ratio has also been found in pieces of classical music and modern industry. Principles of physics are hidden in construction of musical instruments and used in sculpture and architecture. Painting, jewelry-making, pottery, glass-making, and other arts could not exist without applied chemistry principles.

Interrelation of art and biology is evident because humans are actors of creative work and perception of artworks. There are more questions than answers in these considerations. No one knows why artworks that can change our sentiment, why a piece of art can make various impressions, is perception of artwork absolute or associative, what are the physiological and molecular mechanisms at the root of creativity and perception, etc.

Nevertheless certain data elucidating this interrelation exist, e.g., results of investigation of the rhythmic characteristics of artworks. The perception of their rhythmic characteristics can be compared with rhythmic and relaxation processes in the organism. It has been shown that the characteristic times of artworks correlate with several kinds of physiological and biochemical processes and they depend on action of a wide array of pharmacological factors.

Except for this, it has been revealed that the turnover number (number of molecules of substrate that an enzyme can convert per second) of many enzymes fall within the sound range and can be considered as a pitch (musical note). Such examples represent enzymes of glycolysis. Therefore, it is possible to write the sequence of their turnover numbers as a melody and to play.

The list of interrelation examples of art and exact sciences can be continued.

Art versus Design: The confusion between brain tools and hand tools

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Throughout the history and prehistory of culture, there has never been a clear differentiation between art and design. As long as figurative art was the exclusive paradigm of visual art, this lack of differentiation did no harm to culture. The breakdown of the figurative paradigm a century ago came about due to two major reductions of art: The reduction of art to color and form, that was mistakenly called "Abstract Art", and the reduction of art to objects, which is better known as "Ready Mades" or "Found Art". Following this mindless reductionism the lines of demarcation between art and design were totally abolished. Thus, art was reduced to design, and culture has been impoverished, but this illusionary misconstruction did not obliterate the differences between true art and design.

The objective of my talk will be to expose a few of the dozens of differences which exist between art and design. In order to focus on the differences between art and design, a comparison would be presented mostly between figurative art and industrial design: while there is design in nature and design in the animal kingdom, there is no natural art nor any art produced by animals. While art products are brain tools or extensions of the brain, all products of design are hand tools or extensions of other organs of our body. And yet, both hand tools and brain tools, are impossible without mind tools which are probably, the most fundamental organizational tools of intelligence. These are structural tools which I have called "mindprints", are common to all branches of culture. To name just a few: connectivity-disconnectivity, symmetry-asymmetry, transformation-invariance, hierarchy-randomness and more. Art deals with pictorial universals or class-names, design deals with particulars or objects.

Art is inductive and implicative while design is deductive and applicative. Art creates changes in states of mind, while design creates changes mostly in states of affairs. Art is exclusively cognitive, while design is mostly an instrumental domain. Art deals with organization of symbols and symbol systems. e.g. a painting depicting a house. . Design deals with organization and characterization of materials. e.g. a house. Art creates symbolization of imagery or concrete entities. Design creates concretization of images or symbols. Art engages in interpretation, invention, description and metaphorization of order relations. e.g. Magritte. . Design engages in concretization of orders part of which it invents, and others, which originated in science or technology. There are many more distinctions which will be presented at the conference. In short, art belongs, together with mythology, literature, poetry, philosophy, science and mathematics, to the noetic or second order reality, which gives meaning and existence to the entities of the phenomenal or first order reality, which are objects of nature or man-made, including those of design and technology.

Session 1
Art, Science and Society

The Beauty of Soap Bubbles

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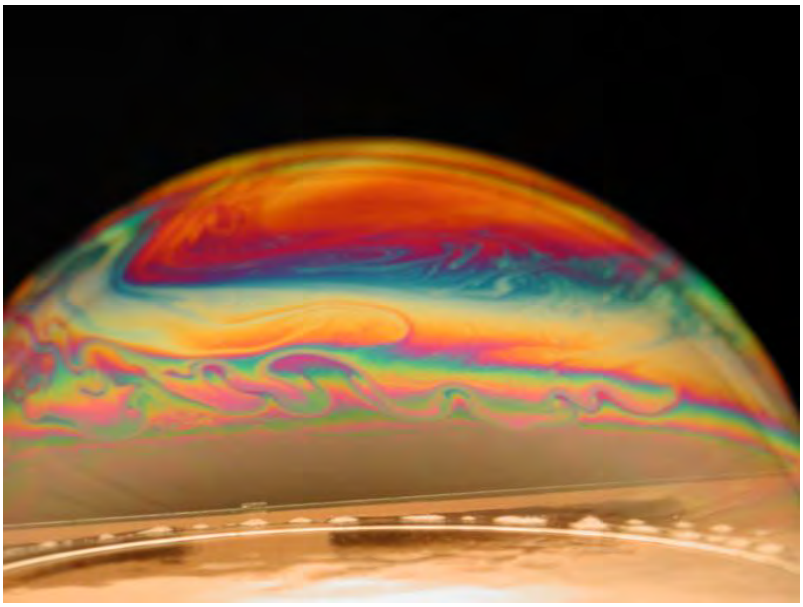
Blowing soap bubbles is a favorite children's game, but a closer look at them reveals fascinating technology, science and beauty.

Understanding how soap works to remove grease from soiled surfaces takes us to the level of the molecules. The molecular soap chains that float in a liquid detergent attach themselves to grease on one end and to water on the other, enabling removal of stains. These tiny molecular chains enable the formation of films that are actually made of water that is coated with soap molecules on both sides. These films can form stable bubbles that last for some time and when kept under high humidity have been shown to last for up to a year.

When light hits a soap bubble it is reflected from both its inner and outer surfaces. This double reflection results in interference that forms a spectrum of colors and the color at each point depends on the thickness of the film at that location. Because the thickness of the bubble film changes, the colors reflected from its surface will change, and at times in a stormy way.

In my presentation we will have a close look at the beauty of soap bubbles, outline the principles that govern their formation, illustrate interaction between them to form minimal surfaces and demonstrate the consequences of their interaction with light.



Beyond certain knowledge

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During the last 150 years, science and technology played a disruptive role in the life of individuals, and society. It is hard to imagine a modern world without concepts such as the quantum theory, theory of relativity, and the sequence of DNA, and without technologies such as the transistor, the telephone, the personal computer, and the internet. In an attempt to use the toolkits developed by the scientific leaders, modern academics and engineers avoid in their work ambiguity, subjective statements, emotional reactions, and uncertain perception. Thus, modern university researchers and technologists seek "certain knowledge". Certain in the sense of "exactness", "universally true", "experimentally measured". Unfortunately, "certain knowledge" can not cover most of the important aspects of human life. The richness and multi-facet aspects of human situations can not be exhausted by a scientific theory or other rational approach. Thus, it would also be hard to imagine ourselves without folklore, tradition, and the cultural heritage of our specific national or ethnic group, with whom we identify. Even if we would, this appears to be a very poor society. Art goes beyond "certain knowledge", and even beyond rational understanding. With roots in the fundamental identity of society, it provides further meaning, identification, values, joy, and integration to individuals. Scientists and engineers, seeking a better society, will continue doing a partial job unless they incorporate art in their daily work. But there is no room in modern academic system to do that unless new rules of evaluation and teaching goals are developed. I will discuss the challenges and educational benefits of this change of paradigm. Presently, I also like to present some pieces of sculptural artwork dealing with aspects of our life, like sorrow, belief, intimacy, compassion. In doing them, I produced them as "pieces of understanding" beyond words.

Common Pitfalls for Science, Art and Society

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During the past fifty years, a special superficial form of relativism (or, as it is sometimes regarded, post-modernism) has penetrated into the discussion in many areas. In brief, it is based on the idea that all points of view are equally valid. While relativism philosophy is much more complicated as well as defensible than that, this "politically correct" approach has become too influential to be neglected. It is time to (re)claim that not all explanations are equally true; not every noise can be considered as worthy music; not all moralities are equally good. In my talk I will discuss these points through examples that may be perceived anywhere between amusing and terrifying, depending of course on the personal views of the listener. I will try to show that open mindedness, "out-of-the-box" thinking and creativity lives perfectly well together with the notion that previous achievements should be judged and valued.

TRIZ* as a common denominator between Science, Technology and Art

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Human history from ancient times till now clearly demonstrates that man's thinking processes are a dominant power in his life, especially in the realm of creative thinking. Diverse fields of human being like Science, Technology and Art are not possible without creativity and innovative thinking. This in turn requires development of a problem solving strategies and innovation methodologies.

Among all problems solving approaches there is one named TRIZ (Theory of Inventive Problem Solving) occupies special position. TRIZ was developed in the former USSR by the exceptional thinker, engineer and science fiction writer G. S. Altshuller who essentially extracted knowledge from nearly 3 million of the world's patents, encapsulated the major principles of inventive practice and set them into a generic problem-solving framework.

TRIZ starts with the understanding and proper formulation of the problematic situation itself and developed unique contradiction philosophy. Such "applied dialectics" philosophy aims to (1) recognize, (2) define and (3) resolve (**eliminate)** contradictions using ~40 Inventive Principles. The final result of stage 3 in TRIZ terms is called invention (or practical solution). From the above, TRIZ approach is almost the complete opposite of traditional problem solving strategies in which the emphasis is firmly placed on the importance of achieving 'optimum' **compromises** between conflicting problem parameters.

The aim of this work is to prove that TRIZ effectively strips away the boundaries which exist between different sectors of human activities like Art, Science and Technology, and points the way to a generic systematic creativity and innovation methodology. This will be illustrated by thorough analysis of the innovation examples from the modern Science, Technology and Art.

Nietzsche's Contestation of Science: The relation between art and knowledge

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In *The Birth of Tragedy* (1872), Nietzsche construes the origin and the genealogy of science as a '*new* problem', i.e. as a problem of science itself which is 'seen for first time as problematic and questionable' (KSA 1:13). From this new epistemological perspective, he attempts to describe the 'birth of thought' (KSA 2:38), action and human behaviour, through a more general criticism of modern reason. However, Nietzsche attempts to overcome criticism, for criticism helps him to know 'the terms of culture', and also to transcend the entire pre-existing scientific knowledge, so that he will be led to the achievement of his universal goals (KSA 2:46). In this article, I analyse the nietzschean criticism of modern reason and the relation he proposed between art and knowledge which both respectively related to philosophy and science. In *The Philosopher* (1872), the basic idea is proposed: 'the philosopher of *desperate knowledge* will be consumed with blind science: knowledge at any price' [KSA 7:428 (19, 35)]. Furthermore, the *tragic philosopher* should play the role of the healer of culture and get into the core of language and science. But what is the treatment that is proposed, and, how the philosopher manages, in the end, to overcome the cultural struggle between wisdom and science?

Golden Ratio in Art and Science

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Interest to the structural proportions of human body is ancient and there was initiated by sculptors and artists, more other disturbed by the canons of anthropometric beauty. For example, in the messages of Leonardo da Vinci there is the list of rules of the ancient architect Mark Vitruvia, which he recommends to the sculptors and artists to use in the artistic works.

In the middle of 19 centuries Adolph Zeising experimentally investigated ontogenetical properties 2-segment growth modulor of human and has shown, that at newborn umbilicus divides growth half-and-half, and in the subsequent ontogeny 2-modulor growth monotonously converges to a proportion of golden section. In the middle of 20 centuries the known French architect Le Corbusier has added to Zeising's modulor 3rd golden segment and has suggested to use such standard in modern design. In the beginning of 80th years Sergey Petuhov were offered by another gold 3-modulor, constructed on a basis wurf, which used in projective geometry.

In the present work basic attention is spared to the geometrical anthropometric aspects which are examined from point of invariant theory. Traditionally in anthropometry it is accepted to represent *ontogenetical development* in a time scale of age. We shall name the temporal scales of the module elements as the *age modulor*. Modern anthropometrical data allow to construct age modulors for all basic modules of the person. All such modulors have approximately identical nonlinear form. Allocation in each module the additional characteristic — total length, enables us to enter new concept of the *growth modulor*, when the length of each segment represented by function of a total length of module. This concept is not used yet in modern anthropometry, but it conducts to new fundamental representations as growth modulors are *practically linear*.

Session 2
Scientific and Technological Education through Art

Drama in the science classroom: theatrical tools for teachers

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Introducing art to the science classroom may hold many advantages to learners. The art and the science can help and inspire each other, thus bridging the traditional gap between the sciences and the humanities creating a holistic learning experience [1-3]. Drama in the science classroom has been shown to aid the cognitive learning process, and may increase students' motivation and interest in science [4]. It allows the introduction of feelings and creativity to the science class and may increase the feeling of 'ownership' of the science learned [5]. Despite the many advantages of introducing drama to the science classroom, teachers are reluctant to adopt such techniques due to lack of security and familiarity [6].

The talk will describe a teacher professional development created within the framework of S-TEAM (Science Teacher Education Advanced Methods), an EU funded project joining 25 participating institutions from 15 countries. It aims at familiarizing teachers with techniques allowing the introduction of drama to the science classroom with two main aims: (1) Provide teachers with drama activities and tools that can make their lessons more lively and personal and improve understanding of scientific phenomena and the impact of science and technology on society; (2) Provide teachers with presentational tools adopted and adapted from drama and theatre which may enhance their teaching.

The presentation will include practical examples and provide concrete examples of cases where the art of drama made science more lively in the classroom and helped improve understanding of the scientific phenomena and socio-scientific issues.

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3. Ødegaard, M. *Gene-ghost: Exploring the borderland of knowing, biotechnology and Henrik Ibsen's dramatic world.* in *10th IOSTE Symposium*. 2002. Foz do Iguaçu, Paraná, Brazil.
4. Ødegaard, M., *Dramatic Science. A Critical Review of Drama in Science Education.* Studies in Science Education, 2003. **39**(1): p. 75 -101.
5. McSharry, G. and S. Jones, *Role-play in science teaching and learning.* School Science Review, 2000. **82**(298): p. 73-82.
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Science is the Story: an interactive exhibition at the Bloomfield Science Museum Jerusalem

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Science is the Story interweaves 27 children books with interactive scientific displays that are relevant to the story and the experiences of its main character.

Books from the canon of children's literature, were chosen to present a wide range of scientific topics and technological principles. The nexus between the literature and the science was carefully articulated in the form of a scientific question: The children are invited sit on a fakir stool to answer to the question: How can you touch a hedgehog without being pricked? High quality interactive exhibits were included, when appropriated to the content: Inspired by a book about a happy louse that lives on the head of little children, children are invited to look at real lice through a microscope. The children play with spinning plates like Chinese acrobats, build a barrel and hide inside and listen to the sound of crickets. Parents and children (and grand parents) enjoy their beloved books in new ways and learn to love new ones.

This presentation will deal with ways to link between the science and the literature in a science museum, high lightening the science without damaging the literary appreciation. For example: The design of each exhibit includes an open book that shows the text and the illustration originally giving inspiration to the exhibit. In addition, the name of the book, the writer and illustrator were written in a bookmark, to contribute to literacy skills. The exhibition displays are organized by the decades in which the books were published, with three or four books per decade, reflecting the changes in aesthetics, language, illustrations, and messages over time.

Can Science Make you cry? Theatre at the Bloomfield Science Museum Jerusalem

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Since its' inauguration in 1992, the Bloomfield Science Museum Jerusalem has offered its' visitors "mini theatrical interactions" of different formats, that had dealt with scientific ideas. Science and Theatre sound like they don't belong together. Being convinced that science is part of human culture, conveying the spirit of the time, it is closely related, influenced and influencing other cultural areas, we naturally put the two together. By using its conflictual nature, theatre complements the activities in our museum, provoking emotion and curiosity, thereby enriching the level of openness and understanding of the museum's visit. This emotional level helps absorb scientific terms and principals. It portrays creativity and imagination as a non-separable part of the scientific process.
Under the title "Science Theatre" we include a wide range of styles and formats. Most are especially devised and produced for the museum and closely linked with its' content. Each show being a cultural event on its' own accord, is presented as part of a wider range of activities.

This presentation will deal with theoretical basis for use of theatre in museums in general and in science museums specifically and discuss different forms and examples carried out at the Bloomfield Science Museum

Computerized Composition in Music Education

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Today, the conservative approaches featuring study groups which dominant features are uniformity of content, time, and place, are common in musical education at school. The increasing use of computer provides a means for educational momentum by offering new instructional options and shifting the emphasis from group activity in the music class towards individual activity. The computer offers the isolation required for individual studying and creative work. The computerized musical environment allows a student who has no extensive background in music or playing an instrument to experience the foundations of music and composition while being free of the pressures of the group. The computer offers several features which help with music composition: it records, plays, graphically displays (not only in "traditional" notation), and offers ready-made elements.

This way, the student can discover personal means of expression by making decisions related to composition in regards to the elements of music, such as rhythm, melody, orchestration, and style. The computer allows the learner to fulfill three main roles in the music world: composer, performer and listener, and to connect to music in a manner that creates an indirect connection with its different components.

Computerized composition in schools is part of the national curriculum in several countries, including the USA, the UK, and Australia.

The lecture will include a demonstration of computerized composition activities and works by students.

For further information, please visit the site http://www.music-creation.net which is entirely dedicated to this area (the site is both in English and Hebrew).

Magic, Mentalism and Science

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From the time of the ancient Greeks, and up to the current day magicians, the art of the obscure and the occult has attracted much interest. The tricks of the trade evolved slowly with time, from the Egyptians' mosaics depicting the first magician doing *cups and balls* tricks, and up to current day mentalists who claim to mold and shape human perceptions, memory and beliefs. The interest of the public, however, remained constant.

In many ways, Science is the opposite of Magic. The benefits of Science take place over a very long time. Magic's rewards, especially stage magic, are immediate: a rabbit appear, a dove takes flight, or the magician reads your thoughts. These visual and impressive effects remain long in the mind of the viewers – indeed, sometimes for life. Why not, then, combine Magic and mentalism (psychological magic) with science education, to drive the points home in a bizarre and beautiful fashion?

In the presentation I will present part of a show that revolves around Science and technology, all the while using psychological magic and interacting with the crowd to create a long-lasting impression and strengthen the learning process. The show has been performed successfully in front of audiences of teenagers from various schools and has won much appraise. I will also explain some of the methods used, which can be utilized by teachers and scientists to both aid in capturing the attention and highlighting important points of the material learned.

Acting Science: Science in theatre for young people

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In the public eye science and art seem to be separate cultures, yet they share some qualities as some scholars have suggested [e.g. 1, 2]. These similarities yielded various collaborations of art and science, for example theatre plays on science and scientists [3], the use of scientific methodologies in theatre research [4], or the use of visual art and drama in science education [5, 6]. This presentation will focus on studies on theatre plays for young people on science. It will adopt a humanistic science education perspective, which aims at providing science with a humane, socially relevant and appealing face [7]. The perception and cognitive and affective learning outcomes of two educational science plays for elementary school children were studied. "Atom Surprise" is a play on the topic of matter which was presented in two environments: a public school and a private school. "Darwin's Journey" is a play on basic concepts in evolution and was presented in a major science museum in Israel. Research tools included questionnaires and interviews. Findings indicated that both plays successfully conveyed the educational messages they aimed to. Children's recollection of the scientific facts and concepts was highly intertwined with the narrative. However, children were not able to apply the concepts they learned in the play to different contexts. In one of the settings, the public school, girls showed higher gains in conceptual knowledge compared to the boys. In both plays, children were sensitive to the theatrical elements with humour often mentioned as arousing positive emotions. While the plays did not seem to change children's views of science, they did change children's views of learning science. In the lecture more details will be given on how children perceived the plays and how the findings may help artists and science educators in future projects.

1. Ødegaard, M. *Gene-ghost: Exploring the borderland of knowing, biotechnology and Hnrik Ibsen's dramatic world.* in *10th IOSTE Symposium*. 2002. Foz do Iguaçu, Paraná, Brazil.
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Session 3
Being an Artist, Being a Scientist, Being Both

Do re math: mathematics, music and visualization

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Abstract: the talk – or rather: the very lively presentation – will bring together music, modern technological features and even food, as to illustrate different periods of time in the evolution of mathematics. Mathematics, art and music form an ancient trivium, since the Greeks (and even before). In modern times, Gödel, Escher and Bach form a well-known trio from a book by Douglas Hofstadter. Often, the discovery of similarities in other eras and cultures is somewhat artificial or ambiguous, but in the proposed talk these comparisons are made rather lightheartedly and so the speaker is hopefully excused for some farfetched statements.

Thus, a black light demonstration will visualize that Greek science was supposed to have come from the heavens, while a laser set-up will be used to illustrate geometric theorems by Pappus and Pascal. On a background of Bach, the "Belgian theorem" about conic sections will be illustrated by ice cream and Einstein's relativity by dynamic geometric objects, though this time on notes of Grisey (as well as of some music from Tirol!). Schoenberg's screams will emphasize the cutting of a topological Klein bottle into "halves", and the music of Machaut's Kyrie will make the "golden section taste" even better. And perhaps, if the circumstances allow it, the presentation will be concluded by fractal snacks with hexagonal French fries.

What does the brain tell us about abstract art?

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Based on recent brain imaging studies, I speculate that abstract art enables us (our brain) to experience, and attend to, the initial (deconstruction) stages of visual processing - namely, to the basic building blocks of vision: lines, colors, and location in space. Thus, abstract art "liberates" our brain from the inevitable automatic process of categorizing the visual information into meaningful objects (faces, landscapes), as representative art does. Being "free" of the need to match visual information with known physical objects enables an active reflection and a dialog of the viewers with his/her inner world; this process apparently invokes positive emotions in the viewers' mind.

Characterization and modeling of patterns by an intelligent system

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The article presents an intelligent system with a structure of an artificial sensory-neural network. The fundamentals for the specification of the system structure stem from the statistical theory of chaotic phenomena and evolution of natural patterns that are briefly explained in the introduction. The neural network obtains from the sensory network several samples of input patterns and extracts from them characteristic relations between elements composing the patterns. Based upon self-organized learning, which optimally preserves the information presented by patterns, the system forms a representative set of characteristic samples of relations and stores them in the memory of the neural network. These samples are further applied by the system when generating examples of completely new patterns, but with similar stylistic properties as those exhibited by patterns utilized in learning. In the article the operation of the system is demonstrated on examples of patterns generated by acoustic emission, turbulent phenomena, laser and other manufacturing systems, etc. It is also explained how the system can be adapted to characterization of various artistic styles in the fields of music, painting, and sculpturing. In the first case the system creates a time series of musical notes, in the next one a figure, etc. The meaning of the memorized characteristic samples of relations is explained based upon presentation and analysis of some sculptures of the author. The main purpose of the research work on the presented system is to provide a basis for development of intelligent manufacturing systems capable of autonomous self-organized creative work and producing items with proper stylistic characteristics.

Music score reading and its relation to solving a mathematical problem

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- What is the conductor's role? How do his hand gestures influence the musicians' performance?
- What are the mental processes involved in the translation of the music score into certain hand gestures?
- How does the conductor organize the huge amount of notes in the score sheets in his mind?

This unique lecture will deal with the aforementioned questions, and demonstrate the similarity between analyzing a music score - consisting of thousands of notes, written for different instruments which are simultaneously playing at various levels, in different keys, and at different rhythmical values - and solving a mathematical problem consisting of an organized set of codes which are to be deciphered by the conductor.

Using live music demonstrations, as well as recorded audio segments, maestro Barak Tal analyzes the well known Mozart's "Eine Kleine Nachtmusik" Serenade in terms of the musical phrases and the different roles played by different instruments, and shows how the mathematical formulae appearing in the score are converted into live music through the communication of his hand gestures to the musicians.

An Intelligent Learning Decision Support System for Jewelry Features Design

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This work presents an Artificial Intelligence aesthetic-driven Decision Support System (DSS) for jewellery design. Eysenck (94) proposed that: "Creativity denotes a person's capacity to produce new or original ideas, insights, inventions, or artistic products, which are accepted by experts as being of scientific, aesthetic, social, or technical value."

Manual design of jewelry is in wide use, and requires creativity, craftsmanship, and is time consuming. When compared to designing using Computer Aided Design (CAD) systems, CAD systems, provide the designer with realistically rendered features which are available from various viewpoints, giving the designer a clear understanding of the final result. Tools for options of transforming each one of the features, are provided instantly. Our approach is to try to understand design creativity by "mimicking" it, using Artificial Intelligence (AI). Our goal is to build a Learning decision Support system which can be used to experiment the processes of a wide range of influences on the designed jewelry feature. Each of the resulting changes on the designs is stored, by choice of the designer, and a learning framework is established for future work. The proposed system is to be embedded in a CAD system and is aimed to provide the designer an ability to a more intelligent tool.

Science of Music and Music of Science

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The lecture will present revealed and hidden connections between Music and Science. From Pitagoras in Greece, through Kepler Laws and the Music of Spheres, to Hydrogen spectral lines, gentle strings of interconnectedness tie Music with Science and vice versa.
These strings indicate that Science owes Music much more than does Music to Science.
Demonstrations such as creating sounds with an aluminum rod, hearing through light, hearing music without ears, etc. will be used to support the above arguments.

Artistic painting for industry

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The goal of this presentation is to present an invention that was developed by Decopaint Ltd chief artist. The presentation will demonstrate the strong link between art and innovation, which lead to successful R&D project

Decopaint Ltd, 2009 winner of "Entrepreneur of the Year" Contest is an Israeli leading company of decorative professional painting and environmental art projects.

Over the years Decopaint have developed special artistic painting techniques in order to improve the appearance of old buildings, industrial zones and urban environments and to achieve better quality of life.

In recent years and due to needs that emerged from the field, decopaint initiated new developments in the chemistry field.

The invention:

MPC is a liquid, which can be applied on different materials. The use of this chemical solution serves as a protective and isolating layer, which repels various glues and prevents adhesion of environmental contaminators.

Usage of MPC on buildings, bridges and other public facilities will reduce maintenance costs, support legislation and protect property value. Applying MPC will also significantly contribute to environmental care.

Session 4
Art and Design in Industry

Symposium "Generative Art as Science of Poetics"

Chirality in Architecture

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Chirality is the property of potentially having for an object a left-form and a right-form. A pair of hands is a classical example; a pair of oppositely spiraling horns is another one. To be labeled "chiral" it is enough that one of the forms exists in reality; a standard screw (a spiral too) is chiral and right-handed, and in most cases a left-handed counter screw (Fig. 2b) is not produced. Spiral elements in high-rise buildings are well known, and their spirality renders them chiral as well, with either right-handedness (following the screw-definition) as in the Mode Gakuen Spiral Towers in Nagoya, or left-handedness as in Calatrava's Chicago Spire. In both cases, the opposite handedness is a realistic possibility and could have been selected for construction. Chiral buildings are quite common, much beyond spiral high-rise buildings, and yet we are unaware of a routine reference to the following basic question: Having designed a building which is chiral, which form should be constructed – the left-handed or the right-handed one? That question, as we show, is of importance in particular in the context of the relation of the chiral building to its natural and urban surroundings and environment, which, in most cases are chiral as well. In the natural sciences the investigation of handedness effects is central and appears in many of its branches; for example, the fact that our bodies are built from left-handed chiral amino acids and not from right handed ones, continues to occupy the life sciences since first discovered. In architecture, which relies heavily on shape, form and symmetry, considerations of chirality – a key structural descriptor – are practically non-existent. It is the aim of this lecture to familiarize the audience with the language and concept of chirality, and to describe the intimate, relevant link between chirality and architecture.

Towards a theory of space networks and space subdivision

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3d networks and the associated hyperbolical sponge surfaces, represent the most fundamental aspect of our space phenomenology and as such, they seem to pose a critical aspect in all material sciences as well, on the nano-scale of structural bio and inorganic chemistry and all the way up to the cosmological scale of galaxies and stars and their bounding universal structure.

The nature of these networks and the associated sponge surface space partitions determine the structure of space and the level of its order. It can be perceived as an extension of graph theory, dealing geometrically with any plurality that may exist, of focal entities and their inter-relations in nature and in the realm of the theoretically imaginable.

Exploration and comprehension of this phenomenology and its most conspicuous imagery forms the core of space morphology and is a prerequisite to the systematic evolution of a space networks theory and the formulation of a related theory of space.

The presentation is meant to explore the landscape of this spatial imagery and to discuss its topology and its primary parameters, while reserving special attention to its ordering principles, the emerging classifications and hierarchies and their symmetry-uniformity characteristics.

The number of already discovered ‘uniform space networks‘ is reaching to infinity. The associated 2d - manifolds - space partitions, whether finite or infinite, may reach a staggering complexity and overwhelming beauty.

A thorough and systematic exploration of these patterns and configurations, while essential for the evolution of the networks and the structure of space theory, might also inspire material science research, art, architecture and probably even innovative physical space structures.

Objectology

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"Objectology" is a formal study that explores the reciprocal relationship between science and design and examines the impact of computerized technologies on design in the contemporary world. The study uses techniques of generative design but chooses manipulations which express values related to the evolution and history of the products. Forms are examined within a historic, biologic, genetic and perceptual approach. The study raises questions about the past and future of the objects and thus adds a fourth dimension to three-dimensional shapes: the dimension of time.

The study focuses on the form, detached from its function, material and technology. This detachment leads to an analytic approach similar to abstraction, held in scientific researches. Studies of this type disconnect the object of research from reality in order to analyze a certain phenomenon. The use of scientific methodology in a formal study frees the designer's act of 'making', allowing him or her to create unexpected forms.

In fact, computerized software allows designers to build three-dimensional forms regardless of material and technology. This phenomenon is reflected by treating the material as a texture which can be mapped onto any form and replaced according to the will of the designer. This option both frees and detaches the designer from the limitations of the material and of the production technology.

The products of this study are forms which remain in the virtual world in which they were created; they are forms which represent the object as an abstract concept. Gray forms which are similar to the display of models in three dimensional software- raise the question of whether the software is, in itself, a new design language. I claim that the use of computerized tools in design shows not only a technological development, but also a new paradigm in design.

Graphical symbols of three cultures in concept design of Bezalel Academy of Arts

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Concept of New Campus for the Bezalel Academy of Arts and Design was designed by the author and prepared by his team in 2007 for the international architectonic competition. Area of this Campus is located in the Center of Jerusalem, the Capital City of Israel, close to the historic center of the Old Town of Jerusalem, which area is of very important for three great cultures connected with the monotheistic religious – the Judaism, the Christianity and the Muslim Religion. The Academy is established by the Jewish society in the Capital City of the Israel State in the multicultural context and surrounding therefore I have decided to enhance the graphical sings of these three main cultures in the space of the future campus. It was obvious to me, that the form of the David Star, has to be dominated. Therefore it should be visible in the shape of the main buildings. In the site area one could notice the form of half of a circle, which may resemble the crescent – popular graphic form in Islamic culture. The general suggested axis for this area is created by the direction of the main nave of the Christian church. That is why the author has put these graphical forms (David Star, moon-crescent and cross) in the tile floor of the whole area. Buildings of the New Campus of the Bezalel Academy have to be of modern architectonic view corresponding to the traditional forms and colors applied in this area.

A discussion on Frank O. Gehry and Nationale-Nederlanden

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Frank Gehry, one of the important figures in contemporary architecture constitutes the framework for this conversation along with an overview in the architectural line, in particular his work the Nationale-Nederlanden, will be reviewed with initial findings based on mathematical concepts such as symmetry, similarity, and equivalence. In general, a review of the architect's works from the past up to the present, shell forms within his architectural projects elaborates in particular in the Nationale-Nederlanden building.

In an attempted examination of a building, also known as "Dancing House", questions like; Can strong and weak elements within the symmetry of the structure being mentioned? What kind of balance is there in connection with in its region? With which architectural period does it establish a similarity? What kind of conclusions can be drawn when shell architecture is examined as sculptural work? And similar questions were asked as they tried searching for an answer. Therefore, along with the place for the meeting by a nice coincidence, the first results of this study yet not completed, are planned to be shared with listeners.

MIC MYIDEALCITY- A Virtual Ideal Jerusalem

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M.I.C. Project examines the potentiality of cyberspace technologies and virtual worlds as social and representational urban tools. My Ideal City commissioned by the EU involved four virtual representations of the cities: Jerusalem, Copenhagen, Trento and Lisbon, as ideal utopias. Using Real time 3D gaming engines these utopias are explored by participants logged in as avatars that could virtually wander, interact and examine the ideal reflections from any computer over the world. This paper expresses our process of realizing the complexities of our Ideal Jerusalem.

Data Analysis: at start we questioned residents through focus groups from various communities to suggest their vision of ideal Jerusalem. The ability to view a future in this complex city was limited to a passionless non fantastic/ no mutual future setting a very low Utopia horizon.

Contested City: We Started visioning Jerusalem as a conglomerate of semi-autonomous groups and communities that themselves are characterized simultaneously, by contradictory processes of seclusion and expansion. Beside the constant territorial competition, ideal, cultural and symbolic stresses are part of the daily life. The diversities exist at any level (as stated by city's names Jerusalem/ Yerushalayim/ Al Kutz).

Specific Urban-scape: The Virtual model is based upon Jaffa Street from western entrance towards the old city's walls. Cutting through dominant communities of Jerusalem the street is an interface of opposite forces of friction, intersection, anxiety and probability.

Idealization Processed into an abstract creative conceptualization, the Ideal is based on 2 constrained systems: Data analysis (resident's visions) and the specific urban-terrain (Jaffa).

Visualization: entering the pulsated clustered city, Jaffa Street layered by history and kaleidoscopical facades holds 8 stations as new utopias to be explored. Each station links a geographical site to a theme of ideal dream. The semi-utopias provide new urbanities by juxtaposing and superimposing distant parts of the city then to be explored, realized and questioned by the virtual wanderers.

Session 5
Technology – the Third Culture?

One, two, three or four cultures: A second look

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C. P. Snow's *Two Cultures* (1959) and his *Second Look* (1963) generated a lot of discussions on the relationships between art and science. Snow himself emphasized that "some of the more valuable discussions have been taking place in languages not accessible to most English-men, such as Hungarian, Polish and Japanese" (1963, p. 54). Snow's list should be definitely extended by works in Russian where the phrase *Physicists and Poets* (*Fiziki i liriki*) was preferred. Indeed, the "distance" between the two sides was much less in Central and Eastern Europe. It was not unusual that someone was at "home" in both art and science, e.g., Borodin (composer and chemist), Chekhov (writer and physician), Lev Tolstoi (writer and educator of arithmetic), Migdal (physicist and sculptor) in Russia; F. Bolyai (mathematician and playwright), J. Bolyai (mathematician and musician), L. Németh (writer and physician) in Hungary; Ion Barbu / Dan Barbilian (mathematician and poet) in Romania. Also some interdisciplinary groups were established: Moscow-Tartu School of Semiotics (V. V. Ivanov, Lotman, Toporov, Uspenskii), Commission for the Complex Study of Artistic Creation of the Russian Academy of Sciences (Meilakh), Institute "Prometheus" in Kazan' (Galeev). Comprehensive books on symmetry in art and science were written by scholars in Russia (Vul'f, 1908; Shubnikov, 1940; Shafranovskii, 1968; Shubnikov and Koptsik, 1972), Poland (Jaśkowski, 1952), Romania (Roman, 1963), Bulgaria (Sheikov, 1977), Hungary (Hargittai, 1983), Serbia (Jablan, 1984), and also in Israel (Rosen, 1975). The book by the Israeli philosopher Avital is a masterpiece of discussing art *versus* non-art (2003; Chinese transl., 2009). In the Far East, the Yin-Yang concept represents the unity of two opposite sides, which can be extended to art and science. The Japanese Society for Science on Form (*Katachi no kagaku kai*) was established by scientists and artists. At the opening of the first ISIS congress *Symmetry: Art and Science* (1989), I suggested a new terminology, instead of "two cultures": I insisted that we have just "one culture", but it is "split culture" (borrowing the term from brain research), and it is essential that the two hemispheres of our culture – art and science – should be linked as the *corpus callosum* does in the case of human brain. On the other hand, there is an opposite possibility, too: not to reduce, but to extend the number of cultures. Thus, the importance of technology in our age makes possible to speak about a "third culture". One may also argue that art (creative arts) and arts (the humanities) are also different, and we have a "fourth culture", as well. There is even an interesting analogy: both artists and engineers may need workshops – here the same expression is used in both cases. However, I still believe that from methodological and educational point of view it is better to emphasize the unity of culture and to speak about just one culture, with two hemispheres and two further major fields at each side:

- art (creative arts) and arts (the humanities) are linked by art history, theory of art, aesthetics, etc.
- science and technology (engineering) are linked by applied science (engineering science).

Bridging the two sides is a more difficult task, although it is relevant in an age of overspecialization, where we face various complex problems. The triennial art-science congresses and exhibitions of ISIS use the concept of symmetry – in a broad sense, together with proportion, harmony, balance, rhythm, invariance, etc. – that may bridge the two sides or the four fields: (1) Budapest, 1989; (2) Hiroshima, 1992; (3) Washington, D.C., 1995; (4) Haifa, 1998; (5) Sydney, 2001; (6) Tihany at lake Balaton, 2004; (7) Buenos Aires, 2007; (8) Artists' City Gmünd, near Salzburg, 2010; (9) planned in the Greek island of Crete, 2013. These events always generated some interesting novelty, which were not planned: from the solution of the Kepler problem in geometry to the breaking of "Leonardo's code" in the case of his Vitruvian man. There are good pieces of evidence that the conferences where the representatives of the two hemispheres (or the four fields) of culture are coming together have a growing importance. We should continue…

Where does the form come from?

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The paper proposes a concise overview of the relationship art-technology-science in architecture. It consists of three argumentations, illustrated by examples from historical and contemporary architecture, both built and non-built.

Firstly, it suggests that architecture as a social art has always been immersed in its technological context. Since antiquity Its aesthetic (artistic) surplus has been related to perfect mastery of technology, and often achieved through playful challenging of the limits of technology. Significantly: the creative making was related to form and evolved in the architect's imagination: The archi-tecton was precisely the one who was able to imagine and manage the many partial elements into the complex form of the architectural artifact.

Secondly, the paper will describe how the quest for a rationalized knowledge changed the relationship between technological , artistic and scientific counterparts of architectural making. Until Modernity there was much "knowing how" , in Ryle's terminology, some of it secret, but no "knowing that", no science in the sense of abstracted quantified principles. When aspect of architecture were associated with scientific formulations (e.g. in statics, mechanics, strength of materials) - separate fields emerged: the engineerings.

Thirdly, recent technological developments in computation and fabrication will be presented. They will be connected to the idea of parametric design, that affects a most profound aspect of the architect's artistic. In parametric design form is the rational result of factors that define and determine the architectural artifact , hence an alternative to the function of artistic imagination.

The paper will attempt at interpreting this radical change as a variation on traditional making, and discuss the claim that the imagined architecture - i.e. the core of the aesthetic making, has always been schematic and partial , and relied on elaborate know-how (i.e. technology).
It will then visit precisely the contemporary equivalent of the traditional technological stratum , and delineate the question of form making in this new framework of conception and production.

Biomimicry: a bridge between science and technology

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Biomimicry is a multi-discipline that promotes learning and emulating nature's forms, processes and ecosystems to create more sustainable human technologies and design. The meaning of the word Biomimicry is “imitating life” (Bio=life; mimic=imitate). Biomimicry is the science of emulating nature's best biological ideas to solve human problems.

Biomimicry is the next revolution in sustainable technology developments, and is the bridge between science and technology. Biomimicry enables the development of sustainable products, processes, and systems inspired by the genius of nature.

In the art of nature, that come to fruition in fantastic structures like the termite nest, the overwhelming colors of the morpho butterfly, and the sophisticated models of the gecko foots - the form always supports' a function. In nature, the form and function are united and the result is nature as we now her - magnificent. Today, the forms in nature are a source of inspiration to artist on one hand, and the functions of these forms are the source of inspiration to engineers on the other hand. We see more and more innovations inspired by nature in discipline such as architecture, medical devices, robotic, energy, transportation, communication and more. The use of biomimicry methodology in research and development, encourage developers to look at nature's art as a source of inspiration to develop the form and function together, and not to solve the function challenge first followed by the design of the form by a separate team.

Interactions between Art and Science

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About the interaction between Art and Science, Cheng-Dau Lee, Nobel laureate in Physics said: "Science and Art are not separated from each other. They assist us in observing nature. With the help of Science we can discover the routines (laws) of nature; through Art we can describe the emotions of nature."

In this lecture a new approach the author has developed will be presented by which scientific laws are demonstrated by artworks of different artists. This makes science more understandable and perceptible. The interaction between Art & Science is demonstrated here by facial combination of Albert Einstein (1897-1955), the greatest theoretical physicist of all times, Mona Lisa, the most famous painting in the history of Art, and Leonardo Da Vinci (1459-1519) who painted Mona Lisa, the first to utilize the close interrelationship between Art and Science.

The following subjects will be demonstrated by artworks: Archimedes Law, Newton's Laws, Einstein's special relativity, Thermodynamic Laws well as a few of Murphy's Laws. And finally Mona Lisa's Gaze rule will be presented that educates people how to look at pictures.

Flax and linen products in the history, art, science and technologies of nations of the world

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Plants accompany human life throughout all history of civilization: food, clothes, medicines, forage for animals and building materials. Although plants give aesthetic pleasure, keep balance between person and nature. Not only plants influence people, but also people change plants. Development of science, new techniques and technologies of cultivation, processing and use of plants change human culture, its life style. Each level of technologies corresponds to relevant communication type of duet "plant and person". Most powerful communication is present by one of the most ancient agricultural crops - the flax.

This plant was used in Ancient Egypt, Ancient Greece, in the Roman Empire as raw material for making clothes. Flax has good antibacterial quality. Pharaohs have been wrapped in linen fabrics. The well-known Turin shroud was also made of a linen fabric. Pictures of great artists of the Renaissance were written on the linen canvases impregnated with linen oil. Linen oil was also used in icon lamps; flax waste was a good fuel material to heat rooms. Short flax fiber served as warm and sound-proof filler in building. Linen sails opened the world and made real great geographical discoveries.

Till the middle of last century flax was the most demanded material. However introduction of synthetic fabrics has moved flax on the second plan. Now ecological situation is becoming worse every year which draws attention to flax again.

In conditions of global warming many agricultural crops suffer from drought. Agricultural science created grades of flax which are steady against adverse factors of environment. Modern agro technologies of flax cultivation and technology of its processing have given new properties and possibilities. Flax is applied for manufacturing of non-polluting building materials, linen wall-paper, fabrics, clothes, technical products; oil of seeds goes for animal forage or natural drying oils and oil paints; flax seeds are used in a dietary food.

Now flax is cultivated all over the world, uniting scientists, selectors, engineers, artists of different countries. Flax is a plant of the world and peace, reflects interests of all mankind, unites cultures, promotes ecologization of life and provides new opportunities of development worldwide.

Clusters in Data Mining and Communications: An Aesthetic Perspective

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We use clustering in courses of Data Mining, Algorithms in Computer Networks, and in many final projects done by our students. The obtained clusters depend on the intrinsic nature of the data, which may be as different as genomes, published texts, internet sites, wireless sensor networks, etc. It is also the result of the clustering method used in the cluster analysis or the cluster grouping. Some of the methods require an *a priori* decision about the number of clusters the data should be divided in. The stability of the obtained constructs is also a factor to be taken in consideration. Various symmetric or asymmetric metrics may be used, influencing accordingly the results. The obtained clusters may be represented easily as a 2-dimensional projection on a plane, using colors to emphasize their properties. These illustrations have a certain esthetic value, and may be analyzed as such. The presentation contains descriptions of such clusters, used at the Software Engineering Department, both in teaching and research. Their aesthetic analysis follows, using tools taken from the domain of visual art perception.

Demonstrating the Pure-Data Real-Time Audio Control Environment

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Abstract – Pure-data (Pd) is a visual programming environment developed for the real-time control of audio and graphics and the creation of interactive computer music. Pd was originally developed at UCSD by Prof. Miller Puckette, and has been developing for over ten years as an open-source, multiple programmer application.

A Pd program, or 'patch', consists of four basic types of on-screen 'boxes': Atoms contain a number which can be modified in real-time. Messages contain multiple atoms and provide instructions to objects. Objects include standard mathematical and logical functions as well as specialized music signal processing functions. Comments can also be placed on the 'patch' to provide explanations.

In this demonstration, a tutorial will be presented, emphasizing the scientific side of musical composition – controlling amplitude and frequency, and using functions such as filters and modulation to create music. MIDI (musical instrument digital interface) will be discussed as the main protocol for programming music. Finally, a Pd patch will be presented for the control of spatial audio in an interactive musical environment.

Astrophotography: Art or Science?

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Astrophotography is a field that deals with documenting celestial objects. Its history goes parallel with the history of ordinary photography since the middle of the nineteen century.

Many professional photographers consider astrophotography as the tougher and most demanding field in photography. However with the hardness come the value and the same photographers will say that astrophotography is the diamond on the crown. The resulting images have considerable aesthetic value.

Astrophotography use the best optics money can buy the most precision mechanics and the top-notch electronics available. These modern technologies make it as a first class tool in Astronomy and Physics scientific research. A lot of the 20th century discoveries in these field of science were done using Astrophotography.

Can we treat this highly technical field also as an art?

What turn a scientific image into an artistic photograph with high aesthetic value?

How much of the photographer mind is put into the image and how does it turn it into a piece of art?

These questions will be answered followed by the best astrophotography images done by Israeli photographers.

Astronomical documenting in Classic Art

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From early times until these days famous painters from the renaissance era used painting to record and tell about astronomical events.

- What is the big star with the tail appearing in Giotto's painting "Adoration of the Magi"?
- Why did Pietro Lorenzetti Paint the Crescent Moon in his "Last Supper" painting?
- How accurate are Vincent Van-Goch sky paintings?
- Is there any value to astronomical painting today?

These questions and others will be answered in a lecture followed with examples from the history of art and today.

"Hands free" - Controlling an audiovisual performance through body movements in space

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This presentation will introduce different user interfaces that are used to control and manipulate audio and video data through body movements in space. The hardware that is used in the above user interfaces, includes the theremin and the Wii remote controller. The software that is used to process and convert the different types of data, is MaxMSP. The presentation will begin with a review of these basic components within the limits of their traditional use. Later on, it will introduce some unique and custom applications such as the following:

1) The "Terebel" (an acronym of theremin and the Hebrew word "Nevel", which means harp) - An interface that allows it's user to play an imaginary harp that functions as a MIDI controller.
2) The "Magic flute" - The use of the Wii nunchuk's circuit board to control and manipulate data through gesture recognition.
3) Playing the Wii remote - Different possibilities for live and interactive audiovisual performances, played on the Wii remote controller.

The presentation will include live musical and visual demonstrations.

Session 6

Symposium on Arts and the Brain

Brain Creativity, Mathematical Imaging and Special Visual Stimuli for Neurofeedback Systems

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We are proposing a novel theoretical approach for mathematical modeling of living and thinking systems, brain cognitive functions, such as creativity, based on neuronal networks biochemical reactions discrete chaotic dynamics (CRDCD) [1].

We are speculating that emerged discrete time & space distributions of the neuronal networks states (2-3D patterns) are responsible for the brain's creativity as well as for any other brain cognitive functions. For example, before artist starting to paint, the "image" should appear in the specific part of the brain in a form of the distributed chemicals or "activated neurons" within the neuronal networks.

Based on the obtained results we will demonstrate that the CRDCD theory and resulted mathematical models could be used for simulation of neural networks dynamics and brain creativity in a form of emerged artistic patterns, ornaments and mandalas [2].

Possible applications of the presented theoretical approach: put more light on the origin of the brain cognition and creativity, development of a new generation of artificial neural networks and "artificial brain" systems, mathematical imaging, neurofeedback systems used EEG based visual stimuli in a form of mandalas [3].

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Hemispheric Specific Music as a Potential Treatment Modality for Functional Disconnection in Neurobehavioral Disorders

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ADHD, Autism and other neurobehavioral disorders continue to increase at an alarming rate. New research has led not only to a better understanding of what is happening in the brain in these conditions that has opened the door to various new non-pharmaceutical treatment modalities. It appears that these disorders seem to be related to a single foundational problem of functional connectivity and synchronization between large cortical networks. This desynchronization and subsequent underconnectivity lead to a functional imbalance impeding communication between brain regions. This functional imbalance seems most pronounced between the two hemispheres of the brain.

Various combinations of visual, auditory, somatosensory, cognitive, immune, endocrine, behavioral, emotional, and autonomic imbalances have all been well documented. It has also been shown that there is not so much a processing deficit but rather a processing imbalance. For instance children with autism in both auditory and visual modalities have been shown to have enhanced local processing along with diminished global processing. We think that the best approach to treatment also needs to involve multiple modalities. The goal of this type of treatment must be hemisphere-specific to restore functional balance and temporal coherence between large cortical networks.

Music has been shown to have a positive effect on these disorders but all music is a combination of right and left hemisphere activation. There are hemisphere specific auditory features of music and sound that have been well documented, however no one to our knowledge has combined all of these features into hemisphere specific music. We propose that Hemisphere specific music as part of a multimodal treatment approach may be the best approach to restoring temporal coherence in children with neurobehavioral disorders who also have documented auditory processing imbalances.

Acclair's Art Valuation Service: A Critical Exploration of Neuro-metric Technologies and the Human Experience

Eyal Fried*

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Acclair is an independent art/research body exploring the field of Augmented Cognition in everyday situations through the design and implementation of "Near-Future" services and "Neuro-Environments". It was started in 2004 as a conceptual project exploring the notion of "brain fingerprinting" in the airport security context. Acclair combines cognitive neuroscience research with cutting-edge consumer technologies and interaction design, while offering a critical look at contemporary everyday life, and suggesting practical, feasible potentiality. As a way of both scientific investigation and interactive exhibition, Acclair has developed a unique tangible experience (the Art Valuation Service – AVS) that explores the implicit cognitive activity of people as they engage with art, while moving and behaving in an uncontrolled environment. The AVS introduces a logical system that creates real, tangible value for participants' brain output, and makes scientific, financial and technological sense. In this implementation, implemented most recently in November 2010 during the STRP Festival in Eindhoven, multiple wearable, EEG-based, consumer-market, brain-computer devices were worn by visitors recording their reactions as they were roaming the festival space and experiencing a series of tagged artworks. It has offered visitors a fascinating experience, but more importantly, a rare view at the output of their own brains and immediate rewards corresponding with the quality of this output. Data from visitors was stored in the "neuro-cloud" for further analysis, visualization and valuation. Interpretation of data is based on the Neurocapital™ methodology. In its essence, the Neurocapital model attributes market value to brain output. It is in effect a bio-currency that each person owns intrinsically by living and interacting with the world. Acclair believes that this biometric currency will become increasingly valuable in the relationship among and between individuals and institutional entities. All information, visuals and videos can be found at www.acclair .co.uk

Creation and Inclination
A journey through the depth of Leonardo da Vinci's soul

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Leonardo da-Vinci, considered as the father of science, technology and modern research, was revered in his lifetime already as one of the greatest Italian Renaissance artists. His works were gifted with outstanding human intellect, creativity and innovation, rising beyond aesthetic values, psychological meanings, bearing his soul and essence tangibly. His works were considered in his eyes as a spiritual process expressing his inner world, drawing from the depths of his soul to the creation of material lust. By framing various methods and practices, this work will focus on
the seam between the psychology field and the artwork of da-Vinci.

Da-Vinci expressed his clear determination in his writings, explaining that the painting must rely on the base of scientific research. When painting rocks, he was careful to draw them geologically accurate and when painting plants, he put his emphasize on describing them correctly both in seasonal and botanical terms. Therefore insisting the creative process will be an ongoing mental one, reflecting and expressing his inner world.

Psychoanalytic Studies in the man's life showed a contradictory figure. On the one hand he showed human compassion to the sufferings of people and animals alike, thus leading a vegetarian life. He strongly opposed the war he called 'mad brute', yet offered his services as a military engineer designing various weapons of destruction. He was a man of the world and at the same time, a loner who kept his scientific work in private, as well as his thoughts and feelings. Freud, for example, analyzed da-Vinci's personality in psychoanalytic tools in an attempt to understand his inner world through his childhood memories. While examining this and more approaches and practices, this work will try to understand the mutual influences between the psychoanalysis and the works of da-Vinci.

Rational Muses: New Approach to Science and Art

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From the beginning of civilization until nowadays perception of art and science, their interference and significance have been changing greatly. In the 20th century most branches of science tended to specialize and divide each field of knowledge into separate areas. However, an inverse process had started by the end of the millennium. Interdisciplinary areas appeared at the intersections of a variety of science branches, displaying usual fields of knowledge from new aspects.

Following these trends, I would like to discover points of contact between art and science, and to envisage ways of their further interaction.

Art and science distanced from each other within the scientific and technological progress. Although aesthetic aspect can be found in any exact science, it is usually left out.

Scientific developments (more stable colors, new alloys, and modern technologies) are widely used for creating pieces of art, widening the range of techniques. Art, however, can use science not only in a utilitarian way – science can provide inspiration for creativity. Similarly, art can help science to be expressed metaphorically. Education plays a significant role in the new approach, which synthesizes art and science. Aspects of aesthetics and creativity are hardly ever touched upon in teaching exact sciences. An attempt of considering any scientific discipline in the light of art can be potentially useful for both, teachers and students.

A possibility to reveal aesthetics of some teaching aspects allows us to appeal to the subject of beauty, make teaching process emotional and link scientific theory with individual feelings, which is highly beneficial for the studies. Researching historic and aesthetic aspects of scientific theory connects theoretic part of the subject with its application, and develops systematic thinking and profound view of the world.

Throughout history art and science have been combined into philosophic and practical bonds, and it seems interesting to reconsider a similar approach on the modern level.

Artistic Writing as a Counter-Balance to Scientific Writing in The Age of Mechanical Reproduction

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As a graduate of both a Scientific education program (Cognitive Science at The Hebrew University) and an Artistic education program (Royal Academy of Art In The Netherlands) I have came to doubt the semantics and lexicon being used in both of these domains. As a consequence I started to develop my own manner of writing which would try to encompass both of these, almost distinct languages, into one *lingua franca*, a kind of bridge language that attempts to bridge the different paradigms of thought – the artistic one with the scientific one via the apparatus of writing that deals with shifts in modern technology and industry.

For the presentation of my talk I will write a private diary in the weeks leading up to the conference , which I will read live in the conference, taking the theme of the extra-subjective point of view of the writer/artist and his or her writings, in relation to a world in which the dominant point of view is a scientific one.

In such manner the text I will deliver will be in fact a kind of performance (art) in which I am the leading author and actor.

The writer persona I will present attempts to bridge the cultures of Art, Science and Technology. In my view the (artistic) writer tries to grasp reality much in the same way a scientist tries to grasp the observable world and the life events that constitute them. The tension between observing and writing, exploring and articulating, existing and comprehending will be further explored in my presentation.

Exposition

Water_ boat… 2/3_H_20, 1996

Katharina Prinzenstein*

Freelance Social Scientist and Methods' Researcher. Head of the Office of the Equal Treatment Working Group of the University of Technology, Vienna, Austria.

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The Object describes the story of the worlds' (fresh)water-cycle: The natural areas deliver freshwater for industry and the "civilized world". - We use and waste it in a way that streams out polluted and greasy material into the sea:

So the calculation runs as follows: 2/3 of the world sustain life, 1/3 endangers it. Let's re-install the equilibrium!

http://www.unet.univie.ac.at/~a8401943/sustainability/2_3H_2O/boat_pictures/album/index.html

That boat-with-the sea inside can be used for exhibition in or in the lobby of any room - not outdoors: Data: 170 cm x 56 cm x 130 cm (columns), weight: about less than 50 kg.

This recycling art's object has an integrative-material-approach: Most items had been used before differently (e.g. washing machine), so by constructing I needed less resources than otherwise and I met some special challenges to manage the specific characteristics of the materials.

http://www.unet.univie.ac.at/~a8401943/sustainability/2_3H2O/boat_pictures/album/index.html

Catch a ride to the other side

Alon Chitayat*, Lila Chitayat

Jerusale, Israel

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Objective

TaxiLink Project (commissioned by ARS Electronica) is an interactive installation which enables users to experience an authentic distant taxi ride.

TaxiLink creates a link between a taxi driving in Jerusalem and participants from distant locations abroad.

Sitting in the static TaxiLink booth, the passengers join a live ride in and around the old city of Jerusalem, experiencing a personal interaction with a real-life taxi driver screened through a rear view mirror.

Through live video and audio transmitted from the driving cab , the passengers experience a genuine ride though they are physically miles away.

Overview

TaxiLink was developed as a multi-layered experience of an urban virtual tour, offering a brief yet meaningful experience of Jerusalem. The intensity of this encounter is two-fold, since the passengers see the city once through their eyes and again, as seen through the eyes of an authentic local driver.

By recording a personal journey, absorbing, gazing, collecting glimpses along the way, one will end up with an unexpected personal virtual experience.

The users choose their destination, starting the trip at the point where the previous one ended.

It is the road that we focus on rather than a set destination. The urban icons become meaningless and the place is exposed to chance and singularity.

The taxi is a private hub that travels through public spaces, influenced by the pace of the city. It provides a unique communication experience of a temporal intimacy.

www.Taxilinkproject.com

Frozen vertical flow

Noah Shamir*

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As a physicist, I am always fascinated by vertical ice forms. The freezing point of flowing water is determined by its hydrodynamics and specifically by the velocity and mass of the flowing water volume.

Presented are 3 photographs of vertical ice structures, taken in Utah, winter 2008.

Growth-front-nucleation based bottom-up approach to spherulitic growth of peptide nanotubes

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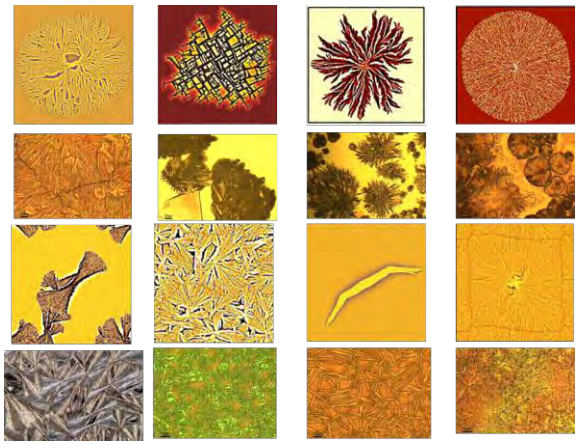
Understanding and utilization of multi-hierarchy self-assembly for preparing macromaterial using nanomaterials building blocks via the bottom up approach is one of the key issues in nanotechnology. In the specific example of peptide nanotubes (PNT) arrangement, a variety of techniques for multi-hiercy of self assembly has been developed. We have previously shown a multi hierarchy self-assembly process using a simple bottom up methodology resulting in the formation of spherulite films of peptide nanotubesMaterials of substantially different molecular geometry (e.g., oxide glass, uric acid, graphite, insulin, and PNT) lead to very similar spherulites, raising the possibility that a coarse-grained description neglecting the molecular details can be feasible for describing spherulitic solidification. Indeed, recent simulations based on the *phase-field theory*, which relies on coarse-grained order parameter fields; neglecting thus the molecular details, yield growth morphologies that are very similar to the experimental ones. An essential question is whether these similarities are only superficial or closer connections can be established among these substances. This requires a detailed comparison of the mechanism of polycrystalline growth in experiment and theory. In this work, we compare crystal growth experiments on peptide nanotubes with phase-field simulations. Relying on the observed similarities, we propose the phenomenon of growth front nucleation as a new paradigm for bottom up approach based on multi hierarchy self-assembly of peptide nanotubes. Furthermore, we identify this multi-hierarchy self-assembly system as a new test bed for the polycrystalline growth puzzle.



Shaped to Survive: Pattern formed by *Paenibacillus vortex* social bacterium

Alexandra Sirota-Madi[1,2,*], Ina Brainis[1], Eshel Ben-Jacob[1,3]

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[3]*University of California San Diego, La Jolla, California, USA*

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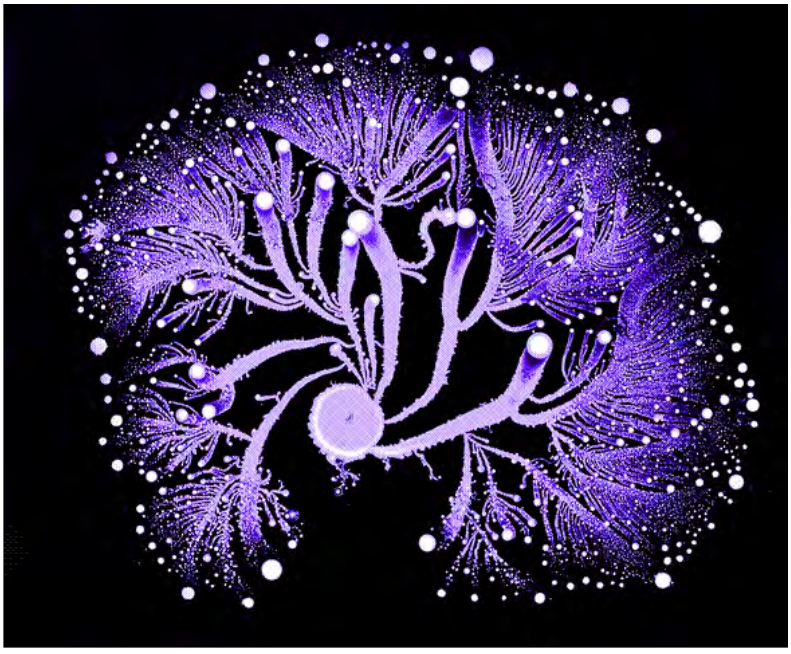
Paenibacillus vortex is a bacterial species discovered in the early 90's. It is a social microorganism that forms colonies with remarkably complex and dynamic architectures. These facultative anaerobic, spore-forming bacteria are found in a variety of heterogeneous environments, such as soil, rhizosphere, insect larvae, and clinical samples.

To face the challenges posed by these environments, *P. vortex*. produce a wealth of enzymes and proteases as well as a great variety of antimicrobial substances that affect a wide range of microorganisms. The possession of these advanced defensive and offensive strategies render the *P. vortex* bacteria as a rich source of useful genes for agricultural, medical, industrial applications.

A successful behavioral strategy utilized by *P. vortex* is to cooperatively form and develop large and intricately organized colonies of 10^9-10^{12} cells. Being part of a large cooperative, the bacteria can better compete for food resources and be protected against antibacterial assaults. When grown on hard surfaces, *P. vortex* generates special aggregates of dense bacteria that are pushed forward by repulsive chemotactic signals sent from the cells at the back. These rotating aggregates (termed vortices) pave the way for the colony to expand. The vortices serve as building blocks of colonies with special modular organization.

Accomplishing such intricate cooperative ventures requires sophisticated cell-cell communication. Communicating with each other, bacteria exchange information regarding population size, a myriad of individual environmental measurements at different locations, their internal states and their phenotypic and epigenetic adjustments. The bacteria collectively sense the environment and execute distributed information processing to glean and assess relevant information. Next, the bacteria respond accordingly, by reshaping the colony while redistributing tasks and cell differentiations, and turning on defense and offense mechanisms, thus achieving better adaptability to heterogeneous environments.



Application of intelligent systems for modeling of natural and artistic patterns

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In the article I should describe the neural-network-like structure of a intelligent system capable to learn from presented records of patterns characteristic relations between elements composing these patterns. Based upon self-organized learning the system forms an optimal set of characteristic samples of relations which it further applies when creating new patterns. The operation of the system would be demonstrated on examples of patterns created in turbulent fields, laser manufacturing systems etc. It would also be explained how the system could be adapted for characterization of various artistic styles. In relation to this I should briefly present my sculptures and explain what do the characteristic samples of relations represent.

A picture of my sculpture is included below, while several others are presented in the window of at my web page

http://lab.fs.uni-lj.si/lasin/www/~grabec/art/index.htm .

"Hands free" - Controlling an audiovisual performance through body movements in space.

David Gordon*

Israael

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This presentation will introduce different user interfaces that are used to control and manipulate audio and video data through body movements in space. The hardware that is used in the above user interfaces, includes the theremin and the Wii remote controller. The software that is used to process and convert the different types of data, is MaxMSP. The presentation will begin with a review of these basic components within the limits of their traditional use. Later on, it will introduce some unique and custom applications such as the following:

1) The "Terebel" (an acronym of theremin and the Hebrew word "Nevel", which means harp) - An interface that allows it's user to play an imaginary harp that functions as a MIDI controller.
2) The "Magic flute" - The use of the Wii nunchuk's circuit board to control and manipulate data through gesture recognition.
3) Playing the Wii remote - Different possibilities for live and interactive audiovisual performances, played on the Wii remote controller.

The presentation will include live musical and visual demonstrations.

Atom Surprise

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Plays on science may be categorized into three groups: (1) plays on science and society, (2) plays on scientists and (3) plays in which the science is an integral part of the plot [1]. Plays which fall in the latter category are rare. "Atom surprise" is such a play. It is a forty minute, two-actor play for elementary school children on the topic of matter with a strong influence of physical theatre. A boy and a girl enter science class for the first time. Through interactions with the teacher, a magic adventure and a treasure hunt they become familiarized with the world of matter and the concepts of mass, volume, atoms, molecules and the three states of matter. In addition to the science themes, there is also a repetitive prosocial theme throughout the play of children's (high and low) self-esteem with respect to science, school and other students. A great deal of deliberation took place while constructing the play to make it enjoyable to all viewers regardless of their inclination to science. The play has been approved by the Theatre Committee of "Sal Tarbut Artzi" (a body authorized by the Israeli Ministry of Education for approving and funding artistic activities in schools). In the presentation, parts of the play will be shown and will be accompanied by comments on how the play was constructed as well as findings from a research conducted on the play.

Motion

Ehud Gazit*

Technion, Israel

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Studying different events of movements and changing, by using several physical phenomena. All works has some degree of non-linear and/or fractal and/or coincidental characteristics behavior.
Instalation.

Art healing

Loifer Vladimir*

Israel

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I'm the doctor and the artist.

And, as has always been an artist to heal. Naturally, I in my work use the relatively recent advances in science and technology.

It is on one side.

On the other hand, I'm an artist and use science and technology to create my work in computer graphics or DIGITAL ART.

And the third part, I use my paintings as a medicine. And the most interesting thing is that absolutely no side effects!

In this exhibition of my artworks reflect my perception of the universe, man sciences and nature.

Exhibition of my artworks can be seen always at-
http://fineartamerica.com/profiles/dr-loifer-vladimir.html?tab=artwork

Who ate the Cosmic Soup ?

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It’s an animation short film made entirely with food is inspired by myths and scientific theories.
The film is 13 minutes long. It tells the story of the universe, from 'before the beginning' through the Big Bang, to the beginning of life on earth, then evolution, the appearance of mankind, through to the very end.
Scientists often describe the condition of the period 'before the beginning' as a 'cosmic soup'. In making this film, I decided to take this metaphor literally: all appearances to the contrary, everything in the film is made out of different kinds of food. For instance, the nebulae are made out of milk, the solar system out of egg yolk, the night skies out of burnt pancakes, the trilobites out of jelly, and the humans out of ginseng roots.
The English voice over is by Bill Nighy and the French voice over by Denis Lavant.
The film was co-produced by ARTE, the CNC (Centre National du Cinéma), the the CNRS (the National Center for Scientific Research) and the ICS (Institut du Cinéma Scientifique). Scientific advice was given by the astrophysicists Jean-Pierre Luminet and Marc Lachièze-Rey.
Links to the film and the making of « Who ate the cosmic soup ? » on the ARTE site :
http://www.arte.tv/fr/mouvement-de-cinema/Court-circuit-le-magazine-du-court-metrage/184414,CmC=1764828,CmPart=com.arte-tv.www.html
Making of (clic on MAKING OF) :
http://php.arte-tv.com/court-circuit-off/index.php?page=magazine&mag=EM322

Astronome Gastronome

The exhibition includes large macro-photographies which are made with food prepared to look, once photographed, like astronomy photography. The astrophysicist Sébastien Charnoz, a doctor at the CEA (and professor at the university Paris Diderot, comments the photos as if they came from a spatial telescope and I wrote the recipe of each picture under his comment.

« Espace Cuisine », broadcast on the web about Astronome Gastronome for Le Journal de l’Espace, Web TV of the CNES, by Daniel Fiévet and JP Courbatze.
http://www.dailymotion.com/video/xbd6d0_espace-cuisine-jde-decembre-2009_tech

Chemical Cuisine:
Looking at a lab through the eyes of a kitchen

L. Engel*, J. Shklovsy, Yelena Sverdlov, Prof. S. Krylov, Prof. Y. Shacham-Diamand

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In recent years, polymers have become a popular building material in the micro-processing of tiny medical devices. They are cheaper than standard materials and can be biocompatible. Polymers are often praised for their optical properties which enable optical applications, but when you look at them you can't help but find them fascinating from a purely aesthetic perspective. In fact, they sometimes look downright palatable.

Here, we present two different kinds of polymers. The first is an electro-active (responds to electricity) hydro-gel (water based) that has been doped with different nano-particles that change its conductive properties. Before the doping, it has a jello-like consistency and is clear. When different nano-particles are introduced to the gel, they are absorbed by diffusion, bringing about a striking change in the volume, color and texture of the gel. Although this gel in its final form is FDA compliant, we do not recommend eating it as its monomers are carcinogenic.

The other polymer that we work with is a fully biocompatible silicon rubber called poly(dimethylsiloxane) (PDMS). We develop freestanding, micron-scale membranes of this material and have included photographs of these layers that were taken with a microscope with a magnification of 2500. Because it is so thin and elastic, the optically transparent layer tends to fold over onto itself just like a dangling piece of plastic wrap. Air bubbles can also sometimes get trapped below the membrane surface, creating striking patterns.

Polymer processing has an obvious parallel to cooking as different ingredients are mixed and then heated to create each polymer. In fact, each process comes with its own "recipe" that include a final step of baking. We are working on building a device that integrates different polymers to enrich the growing toolbox of polymeric micro-processing. You could say that we are trying to come up with a new dish.

Posterauma

Neri Bloomfield Academy of Design and Education (WIZO), Israel

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Graphic design students at the Neri Bloomfield School of Design and Education in Haifa studied various aspects of environmental and sustainability issues affecting our society today. The students familiarized themselves with the public and scientific debates concerned with these issues.

Creating a poignant graphic statement and effecting changes in consciousness and thought patterns cannot exist without intellectual rigor and investigation.
The design process becomes a journey of intellectual discovery when the object of study by students is beyond the discipline of design per se.

Visual communication is a vehicle for expressing ideas. By exposing students to the current discussion around environmental conservation, sustainability, scientific issues, unwanted phenomena and processes taking place due to the human impact on the environment we create identification with the subject matter and thus a more committed and responsible message by any given student.

The purpose of this type of exercise is to expose students to written and documentary materials, increase their awareness and enable identification with a topic in question. The second goal is to enhance their ability to communicate via verbal and visual means.

The purpose of these posters is not ornamental and we hope that due to their visual and verbal power they will constitute a fertile ground for discussion, awareness and action.

More info on the project at: www.posterauma.org

The Mirror of Narcissus

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Numbers from a trillion trillions to a trillionth of a trillionth unfurl as wings in a void, representing the advance of science into vast realms and tiny spaces. The two are linked like a mirror's reflection and depend on one another: consider CERN being 27 km wide in order to measure a particle that is smaller than a billionth of a millionth of a meter. But the mirror captures us as well. When we focus only on measurement we are like Narcissus, enamored of our reflection and missing the truth, to the point of endangering our lives. More power, more food, more money will never bring enduring wealth and happiness, as neither will less power, less food, less money, being mere self denial. The void that lurks, waiting, beyond the mighty and the tiny, is a gap that is forever mysterious, but speaks in a small still voice a message clear to all who care to listen: destiny is not encompassed by the measure of our striving, it waits in the quiet between each beat of your heart.

Media: Ink on paper, 70 x 100 cm.

Topology and Map-coloring in Wood

Stephen G. Lipson*

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One of the best-know areas of mathematical topology is that concerning "map-colouring problems". The famous "four-colour problem", states that on a closed or open two-dimensional surface a map of any complexity can be painted with at most four colours, such that no two regions with a common boundary have the same colour. Although the problem was posed by Guthrie in 1852, it was only proved by Appel and Haken in 1976, after more than a century of effort, that four colours suffice. A similar problem has been posed in one dimension; three colours seem to be sufficient to paint the sections of a linear manifold such that no two adjacent ones have the same colour (I know of no proof of this). In three dimensions on a torus, the maximum number of colours sufficient to paint a map was proved to be seven by Heawood in 1890. A delightful discussion of these problems appears in the book by Rouse Ball (1938). This sculpture in wood (2011) illustrates implementations of the above three solutions, where each colour is the natural hue of a hardwood. The base (two-dimensional) is constructed from brown oak, cherry, Brazilian rosewood and American walnut. The ring (one-dimensional) is from tulipwood, jacaranda and cocobolo. The suspended torus is from purpleheart, ebony, yellowwood, mahogany, zebrawood, yew and cypress.

Reference: W. W. Rouse Ball, "Mathematical Recreations and Essays", Macmillan (1938), revised ed. 1962.

Men

Svetlana Belinsky

I am an artist Svetlana Belinsky. I would like to tell you my story, and why I decided to participate in this Conference.

Nowadays this kind of sentence wouldn't surprise anybody: “I’ll take my cell phone to take pictures”. To you, scientists, my astonishment with a cell phone might seem a little naive, but to me as a typical user, in this small device a whole epoch with all scientific achievements is concentrated. Dozens of functions are built into this small device: telephone, calendar, alarm-clock, notebook, photo and video cameras, microphone, radio, Internet, etc. You can reach any person in the whole world and get any information you need!

When my mother was a young girl, she read by candlelight, I remember primus, *kerogas*, kerosene; a time when nobody had a TV set at home. Today science and technologies reached astounding achievements. Nobody would be surprised by rockets and *sputniks* in Cosmos or by super-telescopes studying galaxies. MAN will soon land on Mars! The medicine and microbiology achievements are extraordinary: the cardiac and other organs transplantation, a human genome is pervasively transcribed. Isn’t all of this a miracle?

But a MAN was the one who has noticed, has studied, has discovered, has deciphered, has described, has invented, and has introduced all these miracles.

How did all this originate? Where is the source of all sciences, art, and culture? All this began with a primitive drawing in a cave, a ritual dance of a hunter, from the elementary arithmetic. A drawing resulted in anatomy, medicine, perspective, geometry; a dance caused music, theater; 1+1+1 resulted in mathematics.

Only MAN with his brain, curiosity, and hard work has come through centuries from these primitive drawings to today's knowledge and super technologies. Times and environment have changed, the countries and civilizations disappear. Only a MAN remains a MAN.

But who will tell about a MAN, his unique inner world, feelings, emotions, and hopes? All these topics are the aim of literature, music, and fine arts.

I am a modest representative of one of the types of arts, and I am trying to tell you, how I understand the world of a MAN and a WOMAN...

Discover the Science Behind Magical Phenomena!
Scientific – Technological Performance

Madatech – The Israel National Museum of Science

Corresponding author: yifat.shteren-levy@madatech.org.il

Nature's Elements Meet in an Extraordinary Scientific Presentation, Demonstrating Light, Fire, Sound, Water and Color Effects

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