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Faculty of Informatics

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Hannes Bogacs
Wien, 23.08.2010

Abstract (Deutsch)

Kunst und Wissenschaft werden oft getrennt voneinander, als unterschiedliche Kulturen behandelt. Diese Unterscheidung ist hauptsächlich auf eine Spezialsierung und Distanzierung der beiden Disziplinien zurückzuführen. Zahlreiche Theoretiker argumentieren für eine Verbindung von Kunst und Wissenschaft um beständige Fortschritte für Gesellschaft, Kultur, akademische Lehre und Industrie zu ermöglichen.

Die Absicht dieser Arbeit ist es, die Überschneidungen von Kunst und Wissenschaft, anhand von Projekten neuer Medienkunst, zu illustrieren. Das Hauptaugenmerk liegt hierbei auf Kollaborationen zwischen den Disziplinien Kunst, Wissenschaft und Technologie.

Grundlegenden Definitionen folgen Einblicke in gegenwärtige Forschungsprojekte und Institution, sowie ein historischer Diskurs über disziplinienübergreifende Errungenschaften. Ein weiteres Kapitel beschäftigt sich mit Forschungsergebnissen und Meinungen von Theoretikern, um für eine nachhaltige Verbindung von Kunst und Wissenschaft zu argumentieren. Der Haupteil dieser Arbeit besteht aus einer Sammlung und Analyse ausgewählter Kunstwerke, welche durch ihre hybriden Eigenschaften und Intentionen wertvoll für wissenschaftliche Forschung in Bereichen wie Biologie, Physik oder Mathematik sind.

Abstract (English)

Generally, art and science are considered to be two different cultures. Scientists believe in the proven and peer-accepted, while pioneering artists often subvert such an approach. The gap between all artistic and scientific disciplines widened because the discrete space of specialized disciplines was more convenient than the longing for total knowledge, as it was in the past.

The result of this thesis is a statement for new collaborations between artists and scientists and a wide-spread integration of both disciplines into modern society. Ultimately, this thesis answers questions regarding the manner in which artists can enrich research processes and art's relevancy in connection with a techno-scientific culture.

This thesis provides an analysis of contemporary new media artworks, which challenge our conception of the relationships between art, science and technology. Furthermore, it is intended to be a guide to art, influenced by scientific and technological innovation, that addresses research activity. The discussed projects are divided into practical categories with a focus on common scientific disciplines, for example, biology, physics, and mathematics. In addition, this thesis explicates historical aspects of art/science cross-fertilization and cites contemporary research centers, festivals, and organizations as examples of how to promote adventageous results of collaborative multidisciplinary art-practice.

Numerous theorists, pragmatists and authors argue in favor of bridging the gap between art and science in order to achieve persisting and important improvements for the prosperity of humanity, culture, academia, and industry.

Art-Based Research in New Media Art

On the Convergence of Art Practice, Scientific Inquiry, and Technological Innovation

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Introduction

"Scientia sine arte nihil est; ars sine scientia nihil est." (Jean Vignot)

The disciplines of art and science are considered to be the twin engines of creativity. Despite this delightful fact, there is a gap between both professions separating them into different departments. As scholar Stephen Wilson stated in his work *information arts*, the prevalent partitioning of curiosity, inquiry, and knowledge is a critical error and undeniably leads to cultural stagnation.[1]

This deficiency might be traced back to miscommunication between the disciplines, initiated by the split of art and science during the Industrial Revolution and continuing throughout the last decades, and demands bridges to reconnect them. As stated by C.P. Snow [2] and Peter Weibel [3], the space between the triangle of art, science, and technology calls for the term of a new 'Third Culture', that closes the gap separating artists and scientists, and results in a concurrence of knowledge.

This space should be seen as an intermediate zone of creativity that builds a vital ground for new and innovative concepts, benefiting from the ideologies and methods of both professions. Such an emerging 'Third Culture' can be an area for people who are willing to intellectually explore multidisciplinary topics to become educated in various fields in order to conceive new ideas and projects.

For example, artists have always used sophisticated techniques and materials, or even invented new methods of bringing their visions to life. They were not restricted by the art-science barrier and, even more so, learned to look at it as a niche for a new form of creativity.[4] The experimentation and collaboration in multiple environments is crucial as a precondition for the works of art presented

in this thesis, where artists contribute to the progression of contemporary and future technologies. Crossing the boundary between the arts and sciences offers unrivaled opportunities to both factions, and results in new insights for the public. It is important to accommodate and equally accept both forms of knowledge so that the practices of the two sides can inform each other.
For instance, today it is impossible to imagine any creative process, such as the production of contemporary electronic music, an author writing or an architect designing without the utilization of a computer, which depicts the demand for artists and scientists to collaborate in order to innovate in ever more complex ways.[5]

It is time for society to free itself from the blinders of these professions and move on to substantial cultural questions. This has to happen in a way in which scientists do not hesitate to partake in inquiries outside of conventional scientific approaches and artists take an interest in specialized technological research agendas. In his *Aesthetic Theory*, Theodor W. Adorno outlines the manner through which art and science may interact with each other while maintaining their distinctive attributes:

> *"The qualitative difference between art and science does not simply consist in using the latter as an instrument for knowing the former. The categories employed by science stand in so obtuse a relation to the inner-artistic categories that their direct projection onto the extra-aesthetic categories inevitably wipes out what the investigation was supposed to explain. The growing relevance of technology in artworks must not become a motive for subordinating them to that type of reason that produced technology and finds its continuation in it."* [6]

The absence of art-science collaborations and the lack of a widespread recognition has begun to change, which manifests itself in the magnificent achievements of contemporary artworks. Artists suceeded in developing and scrutinizing philosophical, cultural and social questions in connection with the aid of cutting-

edge technologies and scientific insights. On the other hand, scientists realized that artists are valuable collaborators who contribute to research and invention by giving rise to provocative questions that stimulate creativity and open up alternative perspectives.[7] Such pervasive activities in both the hybrid areas of art and science are key factors for the continuous and rapid development of our modern society. Ultimately, we have to learn to promote and propagate technology and scientific work in a way just as we do literature, music and the arts. As they have a major cultural role in our era, they must gain importance in the general discourse.[8]

This thesis argues for the cultural necessity of experimental research through cross-referencing a diverse range of contemporary works of art that address assorted scientific disciplines. Furthermore, it is intended to be a survey of art that is highly influenced by science and technology and therefore calls for research activity, which results in a strong argument for art's relevancy in a techno-scientific culture. Through the presentation of projects, located at the frontiers in which art informs research and vice versa, another principal goal of this thesis is to carve out the shared characteristics of both professions. It particularly concentrates on the intersection of technological innovation, scientific inquiry and art practice to answer questions concerning the future of our 'information society'.[9] This work is about how historically sanctioned forms, especially media, are updated, and how new research agendas and technologies outside of the mainstream are identified and are influencing the world around us.

The examined artworks are divided into basic categories of scientific domains and technologies to give the lay reader as well as professionals in art and science a straightforward introduction to this young form of art. One particular chapter concentrates on various definitions of art, science and technology, with a focus on tangible characteristics as they may be understood by the general public. In this context, the annotation of art eludes a conventional art historical interpretation and is extended into the contemporary form of new media art. The chapter provides a close examination of this new field of art and explicates its sub-genres

such as video art, software art, net art, interactive art, generative art and artistic computer game modification. Along with these insights, the rich genealogy of new media art, which promotes a collaborative multisciplinary art-practice, will be revealed and can be understood as a key component of twenty-first century aesthetics. Beyond this, the chapter also concentrates on common themes and tendencies in new media art. It surveys the methods of appropriation and intervention, the importance and influence of the open source movement, hacking/hacktivism, and how to preserve works of new media art. In the context of this analysis of artworks, the term 'art' generally refers to new media art.
The subsequent chapter is dedicated to the connection of art and research. It is about learning at the intersections of art, science and technology and preparing artists for a rapidly evolving post-digital future. As Roy Ascott states:

> *"Artworks of the future will generate new metaphors, a new language, and new methodologies and demand a syncretic approach to today's arts education, realized through connectivity, immersion, interaction, transformation, and emergence."* [10]

Furthermore, the purpose of this chapter is to answer the question how artists can take a viable role in research settings. This will be achieved by pointing out fruitful traditions and characteristics of art that are useful for research and the presentation and discussion of different positions among scholars, as they relate to art-based research and collaborative creativity.

After the clarification of definitions, important terms and the catalyzing effect of art on research, this thesis addresses the historical precedents of art-science collaborations. It revises relationships between art, science, and technology in the past, when both disciplines were not segregated and the longing for total knowledge was the greatest good. Ranging from the Paleolithic Era, when tremendous accomplishments were simultaneously monuments of art and science, to twentieth century's artistic experimentations in photography, cinema, sound

recording, radio, and electronic music [11], this chapter may shed light on the future possibilities of interdisciplinary projects by recalling historical approaches and art movements that combined both professions.

Following the historical discourse, this thesis finds it completion through an inventory of contemporary institutions, such as research centers, museums, festivals, and organizations that promote the adventageous results of collaborative mutlidisciplinary art-practice. In doing so, this chapter emphasizes the contemporary interest in a cross-fertilization between professions, the arts and the sciences. Furthermore, it is intended to be a guide for artists, scientists, and scholars who seek support, access to knowledge and platforms to discuss and advance their ambitious ideas.

Motivation

I chose the topic for this thesis because of my strong personal interest in technology-based art and the longing for a widespread integration of art, science and technology in my own work. I pursue this purpose through studies in art history and media informatics, in which the latter provided a first, practical contact with digital artworks and multi-disciplinary collaborations.

When I wrote my Bachelor's thesis on computer game modifications, I first discovered how artists make use of video games and associated technologies as a digital-art medium in which appropriated content is given an entirely new meaning. Following this thesis, I intensified my interest and studies on the interplay between art and (digital) technology and its application and promotion in connection with the contemporary art form new media art. For example, I realized different projects like *AutomaToneDS*, which is a generative music software for the *NintendoDS*, based on a rule set of a cellular automaton. In addition to that, I also worked on a project entitled *MirrorNeurons*, which is based on an emotion recognition software and is able to detect emotions of a participant and give real-time, interactive video feedback consisting of pre-recorded human facial expressions.

Definitions

This chapter intends to provide a brief overview of terms and theoretical reflections that are crucial for the work of techno-scientifically influenced artists.
Needless to say, it is diffcult to clarifiy the elusive terms science, technology and especially art, which are culturally loaded and discussions concerning their boundaries continue to allure philosophers and historians of art and science.
Due to this quandary, I will present my own thoughts and definitions of science and technology, based upon the writings of theorists within the respective disciplines. The topic of this body of work, however, lends itself to a more precise elucidation of the word art, that is, the accomplishments from the past thirty years, and relevant pieces from the past, which have contributed to the evolution and maturation of new media art.
This chapter answers the questions regarding similarties and differences among the three disciplines, as well as their shifting criteria, and analyzes their disjunction, which is significant for the works of art presented in this thesis.

What is Science?

The most accurate way to analyze the term science is to explicate a set of core ideas and a number of defining elements, as they can be found in textbooks and theoretical works of scholars who are engaged with scientific topics.
Substantially, science is about the understanding of how and why phenomena occur in the 'natural' world, which is accompanied by relying upon empirical data and a sense of objectivity, as well as guiding observations. Results and insights underly a codification into laws or principles that are commonly expressed in the language of mathematics, supplemented by the continual processes of testing and refining of the hypotheses.[12]
To accompany the statement above, a comparable definition of science was given by philosopher John Dewey in his work *Democracy and Education*:

"Science represents the fruition of the cognitive factors in experience. Instead of contenting itself with a mere statement of what commends itself to personal or customary experience, it aims at a statement which will reveal the sources, grounds, and consequences of a belief. The achievement of this aim gives logical character to the statements." ... *"Ultimately and philosophically science is the organ of general social progress."* [13]

Science, derived from the Latin word *scientia* meaning 'knowledge' is:

"knowledge (of something) acquired by study," also "a particular branch of knowledge," ... *"(the) Modern sense of "non-arts studies" (attested from 1678). The distinction commonly understood as between theoretical truth (Gk. episteme) and methods for effecting practical results (tekhne)"... "sometimes used for practical applications and art for applications of skill. (the) Main modern (restricted) sense of "body of regular or methodical observations or propositions"* ... *"concerning any subject or speculation" (attested from 1725; in 17c.-18c)."* [14]

Science is an extension of our knowledge through investigation or study of phenomena, and can be seen as a prescriptive practice with the goal of a correct prediction and the discovery of enduring principles. It goes along with the systematic retrieval of new insights and their propagation through documentation, publication and teaching. A common distinction is drawn between natural sciences, including natural phenomena, and social sciences, which concerns human behavior and societies.

Condensing all the definitions of the term science, it can be easily understood through the statement of 'knowing why' (certain phenomena and processes occur in the observed physical world). It is an accumulation of metaphors, worldviews, processes, representations and knowledge, which originates from the inquiries that strive to understand and describe the nonhuman world.

What is Technology?

Like in the previous paragraph, the term technology will be elucidated through the help of a variety of definitions by scholars in their respective works.
In a broadly conceived meaning, technology is the process of inventing, which results in making things. As mentioned before, if science can be seen as a practice of 'knowing why', then technology can be best defined by the means of 'knowing how'. The disparity between the two fields is that technologists are mostly interested in creating things (engineering) or refining processes, rather than beeing concerned with the understanding of principles, which is the main task for scientists.[15]

It can be said that the history of technology parallels the history of invention. This, for example, ranges from the creation of the first stone tools during the Paleolithic to today's intricate state-of-the-art technology, including all of the objects, tools and processes that forged them, thus illustrating the shared scientific understanding of the history of technology.

The word technology derives from the Greek *technología* meaning 'craft' and *logía*, which stands for the study of something. Furthermore, technology is:

> *"the practical application of knowledge especially in a particular area : engineering"..."a capability given by the practical application of knowledge"..."a manner of accomplishing a task especially using technical processes, methods, or knowledge"..."the specialized aspects of a particular field of endeavor."* [16]

The term technology gained prominence in the twentieth century during the second Industrial Revolution and became associated with the worlds of science and engineering, which, at that time, excluded workers, women and non-Western people.[17] Today, a contemporary and prominent definition of technology among

scholars is applied science, that is, employing scientific knowledge that is transferred into a physical environment to fulfill specific human needs.[18]

A more conventional definition is that technology designates the techniques for making and doing things, for example, construction, writing, painting, ceramics, and in a more popular usage applied to recent applications, electronics or bioengineering.[19] A holistic commentary is given by Melvin Kranzberg and Carrol Pursell in *Technology in Western Cultures*, as they state that technology is:

> *"man's effort to cope with his physical environment – both that provided by nature and that created by man's own technological deeds, such as cities – and his attempt to subdue or control that environment by means of his imagination and ingenuity in the use of available resources."* [20]

Science vs. Technology

Some differences between science and technology [21]

Science (Goal: the pursuit of knowledge and understanding for its own sake)	**Technology** (Goal: the creation of successful artifacts and systems to meet people's wants and needs)
Key scientific processes	Corresponding technology processes
Discovery (mainly by controlled experimentation)	Design, invention, production
Analysis, generalization and the creation of theories	Analysis and synthesis of designs
Reductionism, involving the isolation and definition of distinct concepts	Holism, involving the integration of many competing demands, theories, data and ideas

Making virtually value-free statements. The search for, and theorizing about, causes (e.g. gravity, electromagnetism)	Activities always value-laden
Pursuit of accuracy in modeling	The search for, and theorizing about, new processes (e.g. control; information; circuit theories)
Drawing correct conclusions based on good theories and accurate data	Pursuit of sufficient accuracy in modeling to achieve success
Experimental and logical skills	Taking good decisions based on incomplete data and approximate models. Design, construction, testing, planning, quality assurance, problem-solving, decision-making, interpersonal and communication skills
Using predictions that turn out to be incorrect to falsify or improve the theories or data on which they were based	Trying to ensure, by subsequent action, that even poor decisions turn out to be successful

The aforementioned characteristics of science and technology give the impression that there is a clear distinction between them. Undoubtedly, the given differences are very important to understand the approaches, goals, and motivations of the respective fields, since they are not self-evident to the general public because of an overuse of the phrase 'science and technology'. Nevertheless, technology can be seen as applied science, which depicts a close connection of both fields. This results in the concensus best defined by *Otto Mayr*, as he states,

> *"practical usable criteria for making sharp neat distinctions between science and technology do not exist."* [22]

In comparing the two disciplines, both are currently working together and inform each other, where science discovers basic principles and technology (engineering)

subsequently applies them to solve problems, with a focus on doing things instead of accumulating knowledge. This is a quite complex situation, in that researchers in technology tend to explore areas that are frequently overlooked by scientists and therefore open up new worlds for science to scrutinize. For example, cognitive scientists discover new insights into the nature of the human mind which build a basis for user-interface researchers to study the methods by which humans and machines can interact. Ultimately, technology and science stimulate each other and create a plethora of new disciplines.[23] [24]

What is Art?

"Art is what artists do." (Nam June Paik)

As already discussed in the introduction, this section does not intend to give an explanation of art in the traditional manner of art history. More so, it will point out the characteristics, movements and lines of reasoning that are inevitable for the understanding of the presented artworks. The chapter is first dedicated to the fundamental aspects of art that are useful and should be taken into consideration by contemporary researchers to widen their perspective and thus enhance their work. The second part concentrates on a more specific branch of art – new media art, which arose in the past three decades, and is highly influenced by technological improvement and mostly addresses the associated social and scientific changes. Providing insights to this new field oft art and its various sub-genres, this chapter also focuses on the origins of new media art and the current approaches, themes, and tendencies of participating artists.

Art in earlier times was undertaken for aesthetic purposes, that is, the creation of beauty, the achievement of realism or the visual exploration of symbols (iconography), and making use of historically validated media like painting or sculpture. The given criteria makes art seem immutable, but it is surely not static,

since it was adopted and redefined throughout the ages.[25]

Nevertheless, some basic characteristics are as follows: art is created through emotion and intuition with idiosyncratic components, it endeavors to integrate values that break with tradition, and evokes an aesthetic response. In addition to this, art values creativity, relies on careful observation of the world, in order to describe it in abstract models, and aspires to innovate while maintaining universal relevance. These attributes link art to science, which seeks similar approaches and features the same aspects. In connection with the artworks presented in this thesis and today's technology-dominated world, these characteristics outline the argument for the cultural significance of including techno-scientific research into a definition of art. [26]

In the course of the effort to explicate the properties of art and elucidate a proper definition, it is also important to investigate the role of the artist. Renowned art historian and critic Ernst Gombrich writes in his widely regarded work *The Story of Art*, that:

> *"There really is no such a thing as Art. There are only artists."* [27]

Recalling the tie of art and science, and relevant for a later chapter in this work, which concentrates on the preparation of artists trained to engage in research, Vibeke Sorensen gives a fitting explanation of artists in *The Contribution of the Artist to Scientific Visualization*:

> *"Artists are … people who create something completely original and new, something beyond the known boundaries of the information base. By using or inventing new tools, they show new uses and applications that synergize and synthesize fields. Artists push the limits of technologies, bringing them to previously unattained goals. Artists as well as scientists work with abstract symbols, representations for various realitites 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." [28]

Having pointed out evident characteristics of art and analyzed the artist's position, it is also necessary to examine common art practices, which have been revised throughout history through the introduction of new media, new contexts, and new purposes. Aside from the traditional approach of reproducing a perspective of visible reality, art also goes beyond realistic representation, which, for example, manifests itself in the works of abstract painters from the late nineteenth century through today. Other methods include the incorporation of found objects or a strong engagement with mostly industrial materials, processes and even conventional products, accompanied with concepts, performances and interventions as art.[29]

Given characteristics and approaches can be found in the contemporary art form new media art, which is the prime genre for the artworks that will be discussed later. As mentioned in the beginning of this chapter, a traditional explanation of art is extended through the introduction of new media art. Whereas the name of this art movement indicates that it embraces new technnologies and cultural forms, new media art recalls many artistic practices and ideas from throughout the twentieth century, which will be further investigated in the following section.

New Media Art

Since this thesis analyzes works of artists that explore the boundaries between art and techno-scientific practice, it is important to introduce the term new media art as a central field of their praxis. This genre developed within the context of a radical shift in the limits of art and the introduction of new technologies, throughout the last century. Similar to a common concern in contemporary art, new media art defines the medium as the key feature in its works. In his essay *Towards a Newer Laocoon*, modern art critic Clement Greenberg describes the medium's relevance for the arts:

> *"Purity in art consists in the acceptance, willing acceptance, of the limitations of the medium of the specific art. … The arts, then, have been hunted back to their mediums, and there they have been isolated, concentrated and defined. It is by virtue of its medium that each art is unique and strictly itself. To restore the identity of an art the opacity of its medium must be emphasized. For the visual arts the medium is discovered to be physical; hence pure painting and pure sculpture seek above all else to affect the spectator physically."* [30]

New media art and related terms like *digital art*, *computer art*, *multimedia art*, and *interactive art* are often used synonymously. The various disciplines that are generally applied to new media art will be explicated at a later point in this chapter. For now, the term new media art is used to describe works that make use of emerging technologies and are concerned with the cultural, political, and aesthetic impacts of these instruments. New media art can be designated as a subset of the broader categories of art, technology and media art, where art and technology refer to practices not necessarily related to media and media art as an art form incorporating media technologies. Hence, new media art is the intersection of these two domains. The term new media art emerged in 1994, when artists, critics and curators began to utilize it in reference to works that are based on digital technologies. For example, interactive multimedia installations, Internet art and virtual reality artworks that exhibit conceptual sophistication, technological innovation, or are socially relevant exemplify this genre.[31]

Art historical precursors

Similar to the aforementioned common art practices, new media art also deeply involves historical concepts and aesthetic values. The illustration below is intended to give a rough overview of art movements and theoretical works of the recent past that underlie new media art and contributed to its development. A full view of this timetable is provided in the appendix of this thesis.

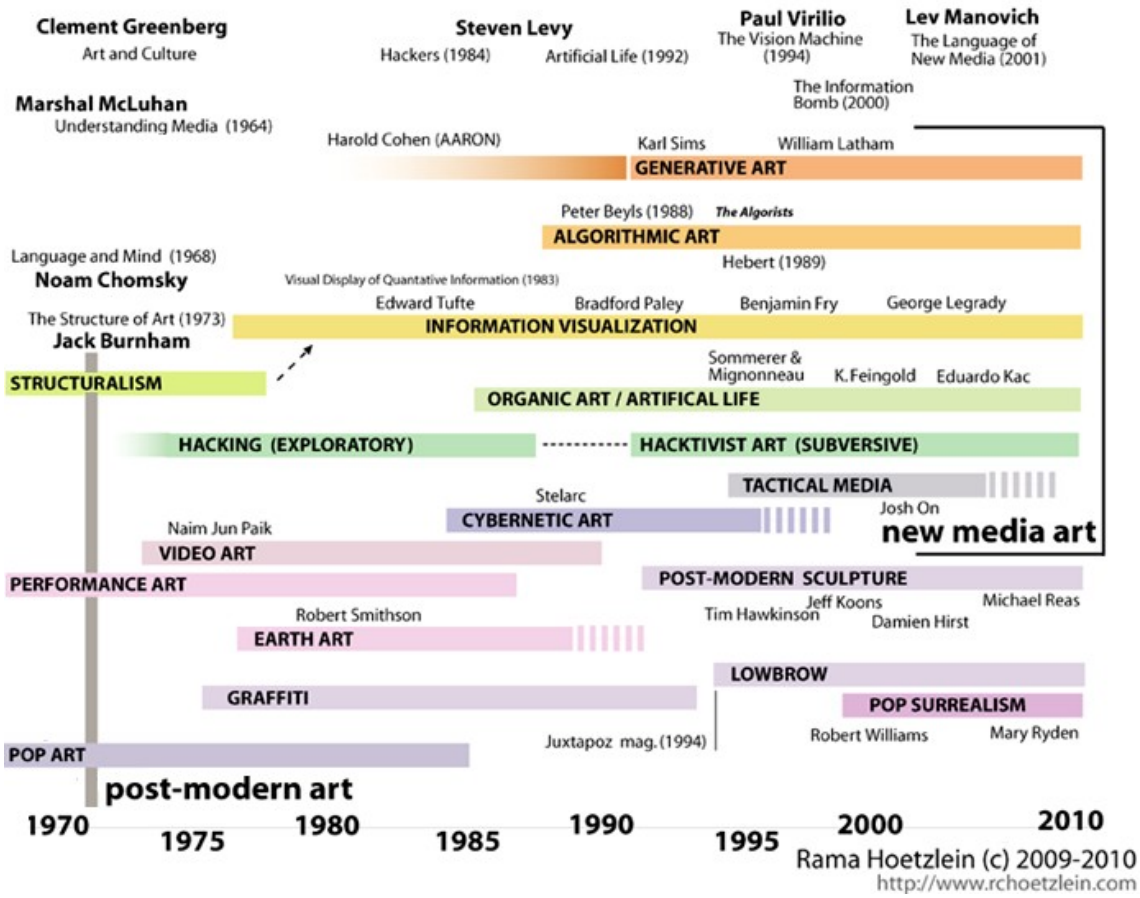


Figure 1: An excerpt of the timeline of 20th century Art and New Media.[32]

The content of the following pages is intended to investigate historical art movements that were instrumental in the development of new media art. It revises concepts and ideas of *Dada*, *Pop Art*, *Fluxus* and *Conceptual Art* as well as points out artists who have influenced new media art.

A close connection between new media art and the *Dada movement*, which emerged in the second decade of the twentieth century, can be found in the experimentation with new artistic practices and ideas incorporated into both art forms. Dada was a retaliation against the industrialization of warfare and the mechanical reproduction of texts and images, while the practice of new media art can be seen as a response to the information technology revolution and a widespread digitization.[33] Conceptual and aesthetic roots of new media art include many recurring Dadaist strategies such as collage, assemblage, photomontage, political intervention, performance and the readymade.

Figure 2: Duchamp - Fountain (1917)

Figure 3: Warhol - Brillo Boxes (1969)

Another theme is the *incorporation of found objects*, as demonstrated in *Marcel Duchamp's readymades* of the early 1900s, as a precursor to appropration, which is involved in a plethora of new media artworks (the task of appropriation will be clarified later in this chapter). For example, many new media artworks assemble digital material in radically new ways, giving them an entirely new meaning and purpose, which implies a shift or even a dismissal of a set of values.[34]

Likewise, *performance art* in its earliest stages, dating back to the 1960s, as well as the *Fluxus movement*, which was concerned with fusing different artistic media and disciplines together, paved the way for contemporary new media art performances. Much like the interventions, happenings, actions and live art from the past, the works of new media artists are based on similar approaches, and are carried out through performances in cyberspace or physical space with the augmentation of digital artefacts.[34]

Another antecedent from the same time period is *Pop Art*, which, like new media art, refers to and is engaged with commercial culture while simultaneously distancing itself from this source of inspiration. Many new media artists work with the actual media from which they borrow instead of transporting them into forms that would fit into the conventional art world. For instance, the video game is a

cultural medium that is commonly exploited by new media artists.[34]

Conceptual art, focusing more on ideas than on objects, is another important precursor of new media art, since many projects do not even have to be seen or recognized as artworks. Greatly influenced by this art movement that can be traced back to Duchamp's readymades, which were already highly conceptual, new media art is also frequently conceptual in nature. Examples are computer programs that are made with the intention to run for a time period of one trillion years in order to fully unfold an artistic concept. Likewise, other pieces do not need to be completed or even realized to exist as artworks.[34]

Finally, the introduction of the portable video camera in the late 1960s and the associated emergence of *video art* also corresponds to new media art. Most notably, video art pioneer *Nam June Paik* and several others paved the way for contemporary video installations, which are an integral part of many new media artworks. In this approach, which was deployed in the beginnings of video art, new media artists still explore the boundaries of this medium itself through video performances, video sculptures or documentative aspects of artistic practice across other disciplines.[34]

After this historical discourse explicating the roots of new media art, the following pages provide an overview of the different categories associated with the umbrella term new media art. Generically, new media art describes artworks, which incorporate elements of new media technology, and are commonly categorized by the respective medium they are based upon. For example, *interactive art*, *software art*, *Internet art* or *video art* are well-known genres and will be investigated among others.

New media art genres

This section is intended to give a partial overview of new media art's most prominent subgenres, in order to be able to recognize and differentiate individual art practices and artists' favored media in the context of their work.

The field of *BioArt* is an outstanding illustration of art-science collaboration, since the works and observations of contributing artists function as major resources for scientists. The term BioArt originates from pioneering artist *Eduardo Kac's* artwork *Time Capsule* from 1997 and started to be widely practiced since the beginning of the twenty-first century. Generally, the predominant medium for bioartists is living matter consisting of cells, DNA, proteins and living tissue. The technologies of biological research, such as genetic engineering, cloning, and tissue culture are utilized in this branch of new media art. Artists adopt frameworks, tools, research findings and processes of contemporary biological analysis for their practice. BioArt also raises controversial ethical questions due to the creation of living beings and participation in life sciences.[35] [36]

The *modification of video games* is traditionally utilized by the game industry, but experimentation with games has also become a common task of artistic practice. The first modifications were created by skilled players in the 1980s with the assistance of level editors or by altering a games' source code. In the 1990s, the modifications of artists like *Joan Heemskerk* and *Dirk Paesmans* (Jodi) in their project *SOD* (1999), began a movement that considers video games to be a digital-art medium and a source of inspiration for artworks. Artists in the field of inventive computer game modification employ computer games' rich elements such as interactivity, narrative content, aesthetics, ideas and the delivery of a message. Ultimately, artistic techniques in this field include modifying existing games for artistic purposes (online performances, intervention, painting, sculpture), using games' 3-D graphics engines to generate individual computer animations, which is called *machinima*, and creating *art games* from scratch.[37] [38]

Generative art does not describe an autonomous art movement, but refers to art that relies on various scientific theories, for example, information theory or complexity science. Artworks, which must be self-contained and operate with some degree of autonomy, can be identified in the underlying creative processes and not only from the results.[39] The term generative art is given to *"work which*

stems from concentrating on", often randomized, *"processes involved in producing an artwork"*. A common approach to define rules that control artworks is automation *"by the use of a machine or computer, or by using mathematic or pragmatic instructions."* [40] Practices in generative art range from the c*omposition of music*, the *creation of paintings* and the *exploration and application of processes in physical and biological systems*.

Hacktivism, blending the words 'hack' and 'activism', is *"the nonviolent use of illegal or legally ambiguous digital tools in pursuit of political ends. These tools include web site defacements, redirects, denial-of-service attacks, information theft, web site parodies, virtual sit-ins, virtual sabotage, and software development."* [41] By combining programming skills with critical thinking, artists generally aspire to promote political ideology, free speech, human or information ethics, and social change.[42] An example of this appears in *McKenzie Wark's* book, *A Hacker Manifesto*:

> *"Whatever code we hack, be it programming language, poetic language, math or music, curves or colourings, we create the possibility of new things entering the world .... In art, in science, in philosophy and culture, in any production of knowledge where data can be gathered, where information can be extracted from it, and where in that information new possibilities for the world are produced, there are hackers hacking the new out of the old."* [43]

Interactivity is a key concept in the plethora of new media artworks for which the goal is to involve spectators. *Ernest Edmonds* and *Stroud Cornock* defined categories of interactivity that can be applied to such artworks and are defined in the following terms: *static*, *dynamic-passive*, *dynamic-interactive* and *dynamic-interactive (varying)*. A static artwork does not respond to its context, but enables the spectator to experience a personal, emotional or psychological reaction. Kinetic artworks are examples of dynamic-passive objects, which are controlled and

modified by internal mechanisms and can be passively observed by viewers. The criteria of the previous category also applies to dynamic-interactive artworks with the additional attribute that individual or multiple protagonists take an active role in which they can modify the object. Dynamic-interactive (varying) artworks include the conditions of the last two categories in combination with a modifying agent, which depends on previous interactions, thus making the output of the work unpredictable.[138] *Interactive art* is commonly presented in the form of multimedia installations, virtual reality environments or web-based art, and focuses upon the representation and efficacy of objects. Many artworks can be defined as responsive environments, in which a participant's input is needed in order to explore the functionality. Over the past 15 years, interactive art has become an emerging hybrid discipline not only artists, but also architects and designers participating in the creation of new interfaces for gathering user input. Interactive art is strongly linked to performance art, as well, in which artists encourage participants to take an active and creative part in the realization of their work. Contemporary interactive artworks mostly feature computer systems and sensors that respond to participants' actions. However, historical antecedents can be traced back to *Marcel Duchamp* and his interactive work *Rotary Glass Plates,* from the 1920s, or performances, happenings and cybernetic artworks from the 1960s.[44] [45]

As the term *internet art*, or *net art*, already implies, artists choose the Internet as the primary medium for their works. This does not happen in a manner in which art is simply digitized, published and distributed over the Internet, but rather, net art refers to the Internet as a whole and takes advantage of its interactive interface and the possibility to connect to various social and economic cultures. Net art can be produced through websites, e-mail projects, Internet-linked networked installations, (interactive) streaming video, audio or radio, and networked performances in chat rooms, online games and virtual worlds such as Second Life. [46] The term net art was coined by artist *Vuk Cosic*, who encountered the phrase 'net.art' in a garbled e-mail message in 1995. With the rise of the Internet and the implied cultural and economic shifts, net art gained a key role in the new media art

movement.[47]

Software art is closely related to the aforementioned disciplines of *game modification* and *net art*. Nevertheless, the term software art is specifically used to address works that are non-interactive or not intended to be games. Works in this field seek various approaches, like conceptual and literary strategies in more strictly code-based artworks, pieces that seek to formulate a critique of the social functions of software, and works that explore the visual and experiental potential of software-based artistic processes.[48] Aside from the fact that programming, independent of its final product, is already a creative act itself, examples of software art are the creation of artistic tools, code poetry, conceptual software, data collage, algorithmic appreciation, plagiarism and system dysfunctionality.

As mentioned in the previous section regarding the art historical precursors of new media art, *video art* is one of the most influential disciplines within the new media art movement. Video art is rooted in the nineteenth century's discovery of the electron and the cathode ray tube. This accomplishment made it possible to electronically transmit and reproduce images, and, as of the 1950s, to record and manipulate images as well as sound. In the 1960s, artists began to incorporate television sets into their installations, in order to address the importance of television as a symbol that shapes culture. Such works were produced outside of the ideological and format restrictions of broadcast programs, and drew from communication and information theory. Since the 1980s, the computer has had a major influence on contemporary video art, which includes techniques such as digital editing, graphics and image manipulation. Today, works of video art are commonly presented in form of installations or as part of performances.[49]

Approaches and themes

Having briefly described various fields within new media art and its art historical precursors, this section concentrates on recurring approaches of artists and established themes. It surveys the collaborative nature of new media art and how

it has pioneerd new forms of authorship, as well as the appropriation of external content, new media art's affinity towards the open source community and hacker culture, artistic interventions, and the impact of surveillance. Regardless of the previously presented subgenres, the following themes are immanent to a majority of new media art projects.

The practice of new media artists is strongly characterized by ***collaboration***. This manifests itself in form of temporary expedient groups or long-lasting partnerships. In order to realize ambitious new media art projects, a multitude of technological and artistic skills are required. Aside from a practical motivation to collaborate, artists are sometimes ideologically motivated to work together. A common form of these coalitions are collectives, in which new media artists take the oppositionary stance to a single artist as a solitary genius. The collaborative approach in the new media art movement follows the shift from passive audience reception to active participation, as it previously appeared in the happenings of the 1960s and 1970s. As mentioned, the interactive works of new media artisits require audience members to interact with the pieces, which respond to the user input, but are not necessarily altered by it. Ultimately, it can be stated that new media art depends on collaboration that is either in person or over a network, in order to realize complex, multi-disciplinary projects.[50]

Throughout history, artists have always influenced and imitated each other, while in the twentieth century, new forms of ***appropriation*** emerged. Generally, appropriation is defined as adopting, borrowing or sampling existing elements, such as ideas, symbols, artefacts, forms or styles, to create a new work. Historically, such an approach dates back to Marcel Duchamp's readymades, or Pop Art's recycling of commercial objects. Today, appropriation that is enabled by unrivaled possibilties due to new technologies, has become so common in new media art that it is almost taken for granted. The unregulated access to images, sounds, texts, and various other media through the Internet and file-sharing networks, as well as the 'copy' and 'paste' features of computer applications, are key aspects in this

development. Given these facts, artists face intellectual property issues, which can cause legal consequences if copyrights are infringed upon. Elucidatory examples of current appropriation in new media art are the sampling and remixing practices in digital music, where borrowed musical fragments are recombined into new tracks. [51]

In the 1990s and 2000s, the significant artistic strategy of appropriation faced restrictions through intellectual property laws and policies that increasingly governed access to found materials. The movie and recording industries, as well as other corporate content owners, expressed their strong concerns about unauthorized reproduction and distribution of their property. The prevalent situation led to the successful enforcement of copyright protection and put new media artists in a position to look for alternative means to author and distribute their work. Given this problem, new media art became linked to the ***open source movement***, that is, an approach in software development in which a program's source code is freely available and shared with other programmers in order to remedy problems and extend the software. Like collaboration, the open source movement shares many characteristics with new media art, through its reliance on the Internet and peer-recognition as a primary motivator for artists or programmers. Contemporary new media artists adopted these open source methods to work together with colleagues and make their work available to the public.[52]

Intervention is another important approach in the work of new media artists, which is mostly engaged in order to critique society by undermining established electronic and human systems. The preferred medium is the Internet, which functions as an accessible public space for artistic intervention. It grants artists access to a wider, non-art audience outside of the conventional museum or gallery setting. For example, artists use networked computer games as a platform to subvert an intended purpose of a game. Other artists take advantage of the online auction site eBay to sell unusual objects and gain attention. Finally, new media

artists also expand their interventionist actions into the physical public space.[53]

Today, modern network technologies connect the entire globe and dispel geographical distances. With the help of devices such as webcams, individuals may appear present or have an effect on an intended location, which results in ***telepresence***. Several artists make this phenomenon the central point of their work by creating, for example, websites that let people around the world remotely control various devices, such as robots.

Surveillance, which has been a major public topic since the mid-twentieth century, is another significant subject of the new media art movement. In the past, surveillance was seen as a monitoring instrument of the government and raised concerns about an invasion of privacy. Currently it also functions as a form of voyeristic and exhibitionistic entertainment, and sees a rise in technologies such as networked cameras, biometric identification systems, satellite imaging, and data mining. Many new media artists widely explore institutional surveillance and its infiltration of privacy.[54]

Collecting/preserving new media art

In the past, artworks of great mastery needed to exceed time and space. In the instances of sculpture or painting, this is not a major issue, but in the context of new media artworks, preservation presents a challenge. This difficulty can be traced back to the fact that new media artworks are technologically reproducible, often temporary art forms such as live art and installation, and strongly bound to the styles and media of their respective time periods. The purpose of this section is to provide approaches and suggestions regarding the preservation of new media artworks.[55]

Typically, new media art has a transient nature and contains eccentric aesthetics and technologies, which pose a challenge to gallerists and collectors. In addition to this, new media artists often have an anti-commercial stance and face

technological problems in order to present their work in galleries. Finally, works are often immaterial or depend on equipment that quickly becomes outdated and obsolete. Artists have taken various approaches, such as providing copies of their work on storage devices or producing works that take the form of physical objects, recalling framed paintings, for example. New media art, however, is particularly difficult to preserve, but a small number of strategies exist that can accomplish this feat. Some of these are: documentation (e.g., screen shots), migration (e.g., replacing outdated HTML tags with current ones), emulation (e.g., software simulations of old hardware), and recreation (e.g., reproducing old work with new technology).[56]

Ultimately, it remains unclear if new media art has run its course as a movement. The boundaries separating new media art from traditional forms, like painting or sculpture, have become indistinct and new media artworks will seemingly be absorbed into the culture.[57]

History of Art-Science Intersections

> *"The serious artists is the only person able to encounter technology with impunity, just because he is an expert aware of the changes in sense perception."* (Marshall McLuhan)[58]

The periods during which art and science had a vital relationship have often been characterized by cultural fertility. This chapter is intended to give an overview of historical art-science intersections as an argument for the necessity of both disciplines to reunite and inform each other. History shows that these fields have not always been segregated. For example, in prehistoric times, persons were often what we might call artists and scientists in one. Today, artists seem revolutionary in their approaches and ideas, but in fact they are recapitulating aspects of art/science cross-fertilization from the past. Following sections will provide insights into the dynamic relationship of art and science, beginning with accomplishments of the Paleolithic and ranging to art movements of the twentieth century.[59]

Paleolithic

The *paleolithic cave paintings* have been identified as the first significant act of painting. Many contemporary archeologists believe that this early visual art is, by far, more than just representational and informative. These paintings are evidence of the creators' extraordinary figurative skills in illustrating three-dimensional animals, which are clearly created with a distinctive individual style. Analysts propose that their power comes from the painter's careful observation of animal

physiology and behavior. In fact, cave painters were intense researchers in areas such as anatomy, zoology, and physiology. They created the first illustrations of scientific observation that reveal a sophisticated understanding of animal life processes. Some paintings may have presented useful literal information about animal behavior, but they are also encoded with a symbolic meaning.[60][61]

Figure 4: Cave painting – Wounded Bison (Altamira Caves, c. 14.000 – 12.000 B.C.)

Aside from these paintings, which are considered landmarks in the histories of both art and science, Stone Age people desperately needed to improve their hunting methods. The first stone tools and weapons were followed by the foundation of metallurgy and material sciences, leading to the creation of new artefacts that succeeded on both aesthetic and functional grounds. Paleolithic metalsmiths, which are renowned for the aesthetic power of their metalwork, were also critical in the history of chemistry through their identification of different metals and the respective characteristics.[62][63]

Another example of the early fusion of artistic, religious, and scientific functions is the prehistoric monument *Stonehenge*. The architects of Stonehenge were innovators in both engineering and astronomy through the careful placement of monoliths to indicate the positions of heavenly bodies at various times of the year.

To summarize, the Paleolithic era can be named as a time period during which the greatest accomplishments were simultaneously monuments of art and science. [64]

Renaissance

The *Renaissance* was also an era marked by an extensive art/science cross-fertilization. Furthermore, art became defined in terms of painting, sculpture and architecture. Scientific insights also gained great importance for artists, which, for example, is demonstrated through their use of the golden ratio as an aesthetically pleasing proportion.[65]

As the Italian term *Rinascita*, later translated into French *Renaissance*, meaning 'rebirth', already indicates, was it a time during which artistic and scientific activities flourished. In this context, rebirth stands for the rediscovery of ancient classical texts and learning, and their applications in the arts and sciences, as well as a revitalization of (European) culture in general through the results of these intellectual activities.[66]

Figure 5: Da Vinci – Study of streaming water (1509 - 1510)

Perhaps history's most well-known integrator of art and science, *Leonardo da Vinci*, was one of the most significant figures of the Renaissance. Besides his improvements upon the mathematical constructions of perspective, he also made sketches of diverse phenomena that drew his attention. Da Vinci, however, also had an interest in practical issues, and therefore was engaged with technological development.

Given these facts, Leonardo da Vinci was by no means unique in his interests in both art and science. In fact, he was a member of a culture with the ethos that included the idea that one could not be a good artist or scientist without vital interest in both fields. The artists of his era were trained in science and engineering in studios that included skeletons for anatomy studies and structural components for studying engineering. More practical examples of this interrelationship are studies of flow dynamics, which assist an artist to depict objects in flight, or investigative dissections that enabled artists to become better painters and sculptors of the body.[67][68][69]

Leonardo da Vinci was one of the most versatile artists that ever lived, and a paradigm for many artists to come. As an individual, he combined the activities of an artist, scientist, technologist, and inventor. In addition, he was one of the first persons to close the gap between art and science again. Although art, like other physical sciences that are engaged with the observation and description of phenomena, was considered to be a branch of science around that time, da Vinci claimed that it should be even more valued than science, since art relies upon the special talents of its maker.[70]

Da Vinci, as well as others, had a notion of 'deep seeing', which manifests itself in the understanding of underlying processes of the world, which was conceived as an essential tool for the making of art. Through the attempt of penetrating underlying forces and principles, seeing involved more than just perception.[71]

Modern Art

During the upheaval between 1880 and 1930, both science and art underwent radical revolutions and had already become separate fields. However, many analysts trace the important influences on abstract art to this period. For example, the invention of photography, the theory of relativity or the understanding of bacterial origins in disease.[72]

Similar to these scientific and technological inquiries, artists initiated approaches that collapsed the conventions of perspective and representation, opinions concerning artistic materials and contexts, and art's relationship with social and technological impulses. While new technologies of perception, communication and production were omnipresent, science increasingly relied more on theoretical constructs than on strict empiricism. At the same time, artists incorporated abstract approaches through the means of understanding and representing the essence of reality.[73] New inventions in fields such as photography, cinema, electrical machines, radio, and electronic music stimulated artistic experimentation.[74]

The resulting explosion of such experiments during the first decades of the twentieth century was documented by artists in manifestos. Their response ranged from vivid engagement with theories such as time and space, to utopian attempts of creative individuals to model a better world through the help of science and technology, to disbelief of and resistance towards scientific and technological 'progress'. For example, the *Futurists* expressed an enthusiastic admiration for the beauty of the dynamic modern world. Others, like the *Constructivists*, propagated art as a unifying bond for modern society, *Bauhaus* and *Socialist art* urged participation within industry, and *Dadaists* added ironic commentary. Although artists were hesitant to bridge the gap between art and science, they often saw the necessity to 'borrow' from scientists and integrate aspects of science into art.[75] [76] [77]

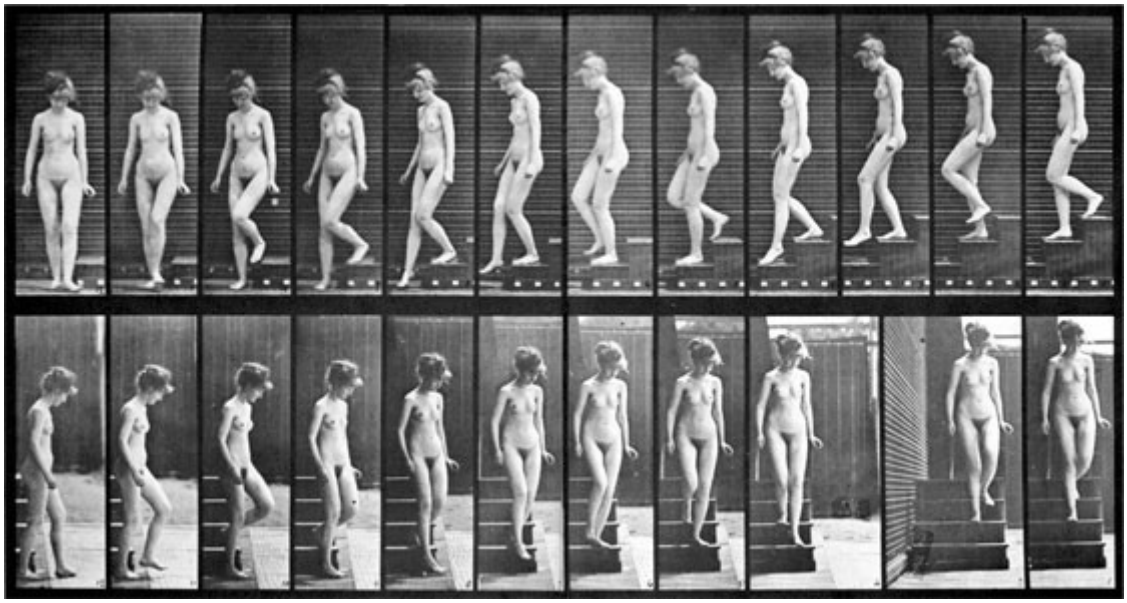


Figure 6: Eadweard Muybridge – Woman Walking Downstairs (c. 1887)

As mentioned before, the *Industrial Revolution* initiated the division of art and science, and this rift remained until the beginning of the twentieth century, when society and artists began to change their attitudes towards industry and technology. On one hand there was the image of the artist as a genius whose creative abilities lie mainly in an intuitive approach, while on the other, they could not reject the importance of science and technology for the arts.[78]

Futurism

This art movement was launched in Italy in 1909. The *futurists* loved machines, speed, noise, cities, and took technology and modernity as their inspiration. Furthermore, they portrayed the dynamic character of twentieth century life. The art glorified the machine age and war, and promoted Fascism.[79] Futurism exalted the dynamism of the modern world, especially science and technology. Nevertheless, their ideology was a major influence on various types of art, beginning with literature and expanding to mediums such as painting, sculpture, industrial design, architecture, cinema and music.[80] Although the art movement itself is regarged as extinct, Futurist ideals remain a substantial part of modern Western culture.

Constructivism

The modern art style, *Constructivism*, was initiated by the artist *Vladimir Tatlin* in Russia around 1919. It was an artistic and architectural movement that favored art with a social purpose rather than creating 'art for art's sake'. Constructivist art is characterized by a commitment to total abstraction and a holistic acceptance of modernity. Furthermore, it is often very reductive, diminishing artworks to their basic elements, and makes use of new media (e.g., textile or set design). Constructivist activities also had a tremendous influence on the *Bauhaus school*, which will be further explicated in the following section.[81]

The Bauhaus School

The German *Bauhaus school* was an crucial pioneer in the reunion of art and science/technology since the disciplines diverged during the Industrial Revolution. It is one the most influental design and architectural movements since the Renaissance.

Rooted in the *Arts and Crafts movement* of the late nineteenth and early twentieth centuries, the multi-disciplinary design school was founded in Weimar by *Walter Gropius*.[82] In his *Bauhaus Manifesto and Program* from 1919, he states:

> *"Today the arts exist in isolation, from which they can be rescued only through the conscious, cooperative effort of all craftsmen." … "Architects, sculptors, painters, we all must return to the crafts! For art is not a "profession." There is no essential difference between the artist and the craftsman. The artist is an exalted craftsman. In rare moments of inspiration, transcending the consciousness of his will, the grace of heaven may cause his work to blossom into art. But proficiency in a craft is essential to every artist. Therein lies the prime source of creative imagination. Let us then create a new guild of craftsmen without the class distinctions that raise an arrogant barrier between craftsman and*

artist! Together let us desire, conceive, and create the new structure of the future, which will embrace architecture and sculpture and painting in one unity and which will one day rise toward heaven from the hands of a million workers like the crystal symbol of a new faith." [83]

The school swiftly became renowned for its modernist approach to art education. Students were taught by visiting artists from all over Europe in workshops such as metal, wood sculpture, glass painting, weaving, pottery, furniture, cabinet making, three-dimensional works, typography, wall painting, and others. Further training included material sciences, anatomy, physical and chemical theory of color, and rational painting methods. The goal of the Bauhaus school was to train students in a craft, as well as in drawing, painting, and science and theory.[83]

As mentioned before, the Bauhaus movement strongly participated in industry by encouraging their students to design mass-produced goods. The school succeeded in developing an international reputation for innovative work in the field of architecture, graphic design, interior design, industrial design and handicraft until it was shut down by the Nazis.

Figure 7: Gropius – Armchair (F 51) (1920)

Figure 8: Schlemmer – Bauhaus Stairway (1932)

Intermedia

A more contemporary example of interdisciplinary activities is the art concept *Intermedia*, which was launched in the 1960s by the Fluxus artist *Dick Higgins*. Intermedia defines works that conceptually fall between media that are already known. For example, Higgins names the happening as an intermedium, which lies between collage, music and theater. There are also parallels between the happening and music in works such as those of composer *John Cage*, who explores the intermedia between music and philosophy, or self-playing instruments that are an intermedium between music and sculpture. Furthermore, performance art, visual poetry, and sound poetry can be considered intermedia.[84]

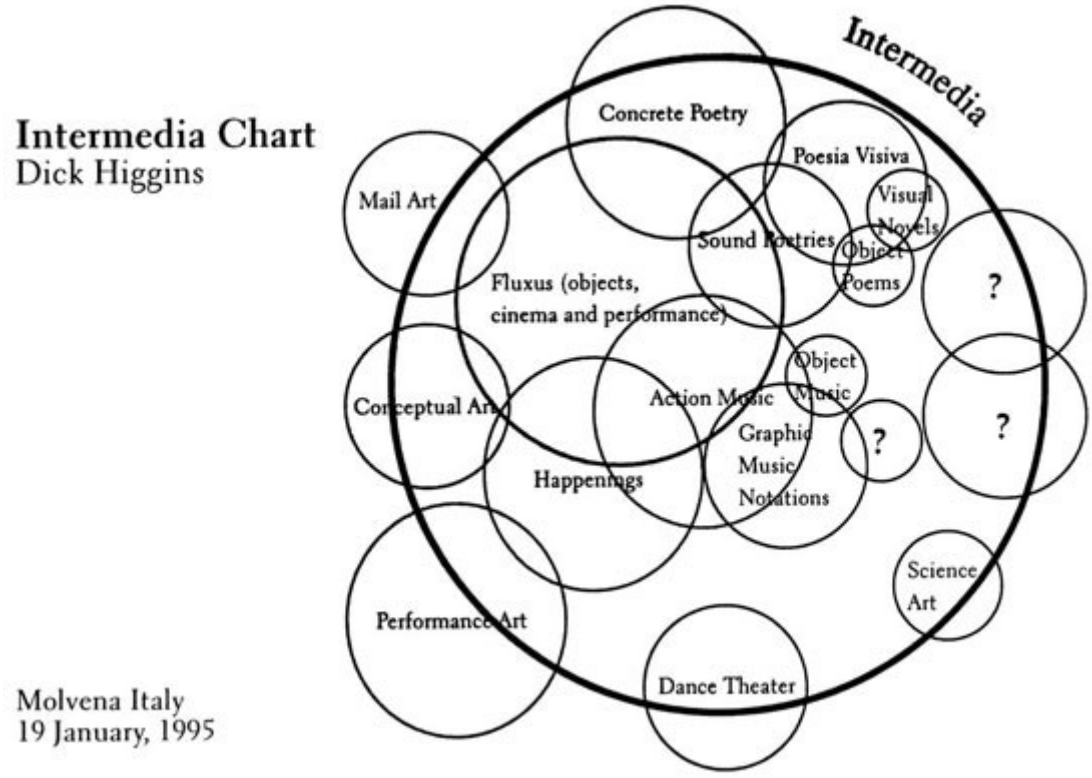


Figure 9: Higgins – Intermedia Chart (1995)

Art and Research

> *"Paintings are but research and experiment. I never do a painting as a work of art. All of them are researches. I search constantly and there is a logical sequence in all this research."* (Pablo Picasso)

Having investigated historical art-science interesections, which affirmed the urgency of collaboration and integration of both disciplines at the present day, this chapter concentrates on the approach of art as research by surveying different positions and arguments from various scholars. It attempts to answer the questions what researchers can provide to art, what artists can contribute to research and how creativity is shared collaboratively. Furthermore, it concentrates on art characteristics that are practical for research, and how artists can increasingly partake in scientific inquiry in a rapidly evolving post-digital future.

Scientists began to realize that artists are not simply producing captivating visualizations of data, but can also be creative partners who enrich innovation and invention, and whose insights and methods can reform and augment intellectual vision.[85] On the other hand, especially in the context of the works that are presented in this thesis, artists participate in cross-disciplinary education and collaboration, and locate the connection with scientific or technological research at the conceptual core of their work. Moreover, science-related arts are important to make information come alive for a broader audience, demystify science, and empower the public to participate in the general debate.[59]

Given these facts, scientist and technologists should be eager to engage in artistic experimentation, and artists should appeal to researcher's thinking and doing in order to create a fruitful future that will be enriched if this expansion of interest becomes a part of the definition of art and science. Much like art, scientific and technological research should be viewed as cultural creativity and commentary.[9]

Art-based research

Shaun McNiff defines art-based research as "the systematic use of the artistic process" in order to understand and examine experience of researchers and those who engage with the same research topic. Much like science, art-based research implicates the use of systematic experimentation with the purpose of gaining knowledge about life.[123] Furthermore, *McNiff*, a theorist in the field of *practice-based research*, writes that the domain of art-based research is,

> *"a more focused application of the larger epistemological process of artistic knowing and inquiry,* [which] *has come into existence as an extension of a significant increase of studies researching the nature of the art experience in higher education and professional practice."* [124]

Distinctive features of art-based research include the willingness to encounter one's project with questions and a readiness to create new methods in order to adjust to a particular situation. In contrast, human sciences have a tendency to work with established research methods and alter their questions based upon their applicability to the methods. Ultimately, it can be said that "the art of art-based researchers is to extend to the creation of a process of inquiry." [123]
Psychoanalyst *Sigmund Freud* defined a similar approach, which is also an essential guide for art-based research, for successful cases in his work *Recommendations to physicians practicing psycho-analysis* from 1912:

> *"Cases which are devoted from the first to scientific purposes and are treated accordingly suffer in their outcome; while the most successful cases are those in which one proceeds, as it were, without any purpose in view, allows oneself to be taken by surprise by any new turn in them, and always meets them with an open mind, free from presuppositions."* [125]

In accordance with Freud's statement, a modern researcher should seek her own

clearly defined structure of operation in which methods can be more lasting than theories. The ultimate goal is to establish a relatively simple and consistent methodology for artistic inquiry. In addition to this, it is important that researchers focus discussions of methodologies on practice, rather than the final result of such structures. Artistic expression is usually very personal, heuristic and introspective, which therefore means that in art-based research, there should be a strong focus on how work can be useful to others and is related to practices within the discipline. In research, and likewise in art-based research, emphasis on the method is useful to avoid confusion, as it often liberates the researcher from the hindrance of structuring her work during the inquiry.[123][126]

Though science and art-based research share the focus on a clearly defined method, science seeks replication and constancy of results in experiments, while the arts appreciate variations that arise from systematic practice. Within the whole complex of knowing, both are complementary, since science tends to reduce experience to core principles and art expands and amplifies it. Additionally, science concentrates on that which can be objectively measured and art identifies immeasurable aesthetic aspects of a specific work. This manner in which artists look at phenomena, that is, from a perspective of aesthetic significance, offers insights that would not have emerged from scientific inquiry. When comparing artistic and scientific knowledge, it would be a critical error to reduce one to the other and, therefore, it is more intriguing and fruitful to examine similarities and differences between the approaches in both domains and how they can inform each other.[123] A possible strategy to enhance the two disciplines is given by *W. E. Beveridge* in his work *The Art of Scientific Investigation* as he states that,

> *"original knowledge occurs when ideas are placed in new relationships to one another, a process that typically requires crossing the boundaries of previously separated domains, such as those constructed between art and science."* [127]

In conjunction with the previous statement, a useful attribute of art-based research

is its capability to offer new ways to approach problems. Rather than addressing research obstacles in a common scientific way, it may be even more helpful to also focus on knowing them in creative ways. On the other hand, scientists are equipped with rational thought and knowledge based upon facts derived from evidence in the material world.[128] Ultimately, art and science can come together by working from positions of mutual respect for their differences and scepticism that is balanced by specific research into each other's respective fields.[129]

A subtle example of applied contemporary art-based research can be found in the area of nonfiction documentary films. *Morgan Spurlock*'s film *Super Size Me,* from 2004, is an exemplar of the way in which any person can investigate how science and art can collaborate in examining a particular phenomenon. Spurlock puts himself in the center of an experiment in which he consumes McDonald's products for 30 days and documents physiological changes, such as weight and blood values, that are directly related to his consumption of fast food. This example reveals a research model that emerged from contemporary art and culture, and how artistic practice and scientific inquiry can be applied simultaneously.[123][130]

Especially in the context of the works that are discussed in this thesis, it becomes increasingly common that artists have begun to recognize the willingness of scientists and technologists to work together on projects of mutual benefit. For example, the field of interactive media art will shift and mutate into an interzone that will spawn a new level of human computer interaction. Such developments, which are enabled by art-based research, will ultimately lessen the divide between art and science and between various kinds of research.

How are artists similar to or different from scientists?

Previously mentioned as an important catalyst of art-based research, this section investigates both the scientist and the artist to specify differences, and even more importantly, similarities between the disciplines. *Vibeke Sorensen* introduces keypoints that have been adopted for this analysis in her work *The Contribution of the Artist to Scientific Visualization*[28]:

Reciprocal Esteem and Shared Background

Many scientists have cultivated a respect for art through their education in the practices and history of aesthetics, as well as their contributions to the artistic community through their attendance of events. Through their patronization, scientists gain a fuller appreciation of the challenges intrinsic in the creation of art, and thereby, come to acknowledge the arduousness of the artist's craft. Correspondingly, many artists, particularly those who utilize machines and modern technologies in their own field and, therefore, have an understanding of the intricacies of scientific work, applaud the accomplishments therein. Generally, it can be said that there is equal admiration and ample shared interest and involvement between the artist and the scientist.[28] Moreover, there are increased claims that researchers are creating art and are willing to assign the word art to their work as they would use the terms of science.

Principles of Art

As discussed earlier in this work, artists and scientists both employ nonconcrete denotations and depictions to describe their work. In addition to this, the terminology of science and art is analogous. For example, as Sorensen points out, the term 'elegant' is utilized in both fields in order to define works of art or a clear scientific solution or explication. Similarly to artists, scientists employ their individual aesthetic predilections to the graphic exhibition of data. Such factors

evidence that scientists may be envisioning ideas in a manner similar to the artist. For both fields, it is of the utmost importance to connect scientific generalizations with an artistic awareness.[28]

Art and the Scientific Method

Similarly to the manner in which scientists integrate artistic elements into their research and presentation of data, artists often find it to be of great assistance to utilize the scientific method in their field. This can occur deliberately or unintentionally. For example, artists may begin with a hypothesis that they check and regularly adapt throughout the testing period until the outcome proves their inital idea. This practice can result in the artist addressing specialized scientific issues, even if the antecedent reason for investigation emerged from a dissimilar inspiration. Regardless of the their intentions, an artists' creation of a unique variation of investigative methods introduces fresh ideas, supplementary approaches, and novel concepts to the established methodology and practices of scientific research.[28]

Visual Thinking

It is understood that visual artists conceptualize ideas in a graphic manner, that is, coming to understand the objective of their projects through the creation of concrete drawings and three-dimensional sculptures. Similarly, scientific researchers regularly visualize obstacles in their work through their utilization of spacial models and generated pictorial graphs. The techniques of scientific research gain a great advantage through the application of graphic displays, in that it is possible to approach the visualization of a problem in a different manner than one can an abstract concept. Unfortunately, due to the gap which lies between the field of science and the humanities, which could assist in the development of such visual models, graphic conceptualization has yet to be fully realized as a possible method of research. Conceptual and descriptive visual skills are therefore

extremely valuable for one working within this field and should be integrated into education early on in order to utilize them effectively [28]

Clarity and the Ingenuity

Both scientists and artists rely not only upon facts and research, but also engage their creativity through imaginative and intuitive thinking. Individuals working within a visual or innovative field many times depend upon 'educated guessing' or depend upon their immediate notions. Although this can appear inexact, it is understood to be constructive, due to the fact that instantaneous impressions draw upon prior knowledge that has been acquired and put aside. Even if it is disparate from the original data, the application of intuition may structure the information in a varied manner and combine seemingly unrelated data in order to form something logically profitable. Cooperation between the two types of conceptualization, that is, logical thinking, which includes mathematical, verbal, and visual understanding, and free thinking, which encompasses a person's faculty to work with hypothetical conjectures, can lead to fascinating queries and developments. This manner of thinking is beneficial for the artist, as it assists them in the course of visualization or conceptualizing a complex idea, and, likewise, aids scientific researchers in realizing complications in their work and the corresponding answers to such difficulties.[28]

Artistic Design and Scientific Engineering

A visual artist generally works with a database of information that largely consists of forms and figures. Designers, for example, change the placement of stored data and employ this information for use in a previously imagined model, while fine artists utilize realized patterns to build upon and extend them. In the situation that the fine artist cannot create upon an existing model, she also has the necessary skills to create new representational patterns upon which to realize her data. Artists, like scientists, concern themselves with the visualization and

concretization of a concept or obstacle, while designers and engineers provide a materialized copy of the ideas created by the fine artist and the scientist, utilizing an existing template. Due to these differences in conceptualization and application, in the context of a research setting endeavoring to impact the scientific outlook and achieve a greater insight into humankind's surroundings, a fine artist will certainly be more compatible with the scientific environment than a designer.[28]

The given keypoints indicate that, even though there are some ideological differences between the domains of art and science, there are many similarities in the practice of artists and researchers. In order to enhance and ultimately bridge the fracture between the professions, practioners of art and science must accept inspiration from each other.

Characteristics of art that are useful for research

The following traditions of the arts, which are potentially valuable for research, are noted by *Stephen Wilson* in his work *information arts*[86]:

- *A tradition of iconoclasm means that artists are likely to take up lines of inquiry devalued by others.*

- *The valuing of social commentary means that artists are likely to integrate widely ranging cultural issues into their research.*

- *Artists are more likely than commercial enterprises to incorporate criteria such as celebration and wonder.*

- *Interest in communication means that artists could bring the scientific and technological possibilities to a wider public.*

- *The valuing of creativity and innovation means that new perspectives might be applied to inquiries.*

In addition to this, the arts can offer insights into the meaning of scientific data and the design of research activities. They can provide nontechnical responses and ideas in order to address the needs and perspectives of the general public in a more effective manner. Artists can act as research and development innovators by refining or inventing new technolgies. The arts can function as an independent zone of research where rejected, discounted, and unconventional investigations can be cultivated. Finally, as *Feyerabend* suggests in his work *"Theoreticians, Artists, and Artisans,"* researchers could benefit from art's awareness of the absurd and the paradoxical.[87] [139]

How does research function in artists' work?

The methods commonly used in research also have the potential to enhance artists' work. *Wilson's* suggestions of how this relationship can function in order to improve creativity are as follows[88]:

> ***Exploration of New Possibilities:*** *The artist's work itself functions as research into the new capabilities opened up by a line of inquiry.*

Artists use technolgies in unconventional ways, resulting in the technologies themselves taking on a new meaning.

> ***Exploration of the Cultural Implications of a Line of Research:*** *The artists use the new capabilities to create work that explores the narratives and conceptual frameworks that underlie the research.*

Artists utilize technologies to comment on their implications.

> ***Use of the New Unique Capabilities to Explore Themes Not Directly Related to the Research:*** *The technologies provide a new way to address any number of issues not directly related to the technology.*

Artists incorporate various technologies in order to comment upon other technologies or aspects of culture.

> ***Incidental Use of the Technology:*** *Research provides a wealth of new images and materials.*

Artists may be fascinated by new images or technolgies, while their development is not essential to the artists' work.

How can artists and scientists cooperate with each other?

Having discussed the similarities and differences between artists and scientists, and the results of integrating scientific inquiry into artworks and artistic creativity into research, one can address the manner in which artists can practically supplement the research process. A common research process is broken down into five parts.[28] Sections to which the artist can contribute are highlighted and further explicated:

1. **Identification of the research problem**

   Artists are valuable for the conceptualization of visual models and describing the expected results. This particularly applies to artists with a scientific background, whose own works are related to research and, thus, can be beneficial for creating new insights at an early stage.
2. Description of the experiment
3. **Running of the experiment**

   Artists can be instrumental in refining the gathered data, testing, and modeling for subsequent study by pushing a medium to its limits
4. Studying of the results and drawing conclusions
5. **Dissemination**

   Displaying the results in an aesthetic format for communication purposes is another crucial task in which artist can participate. Furthermore, they are able to improve the understanding of a final design through their proficiency in visual communication and media.

In conclusion, it can be said that a research process is enhanced when scientists collaborate with artists who have sufficient scientific backgrounds. They can assist in identifiying problems at an early stage, stimulating dialog with scientists and giving significant feedback regarding long term implications. Finally, artists can be useful for unique and novel representations of data.[28]

Collaboration and creativity

Having investigated the domain of art-based research and the relationships between aspects of artistic practice and scientific inquriy, this section presents a view on interdisciplinary creative collaboration. Projects in which artists and technologists work together are the main areas for the investigation of how collaborative creativity occurs. In addition, an analysis of such an environment provides an understanding of the nature of collaboration and the acquired findings that can be applied to enhance future projects and to eliminate barriers in interdisciplinary collaboration.

Co-Creativity

Artists working in the field of digital art are engaged with constructing complex computer systems in order to implement their artistic intentions. This can happen in a way that the artists attain personal technical expertise or collaborate with technologists. The latter involves multi-disciplinary teamwork which has implications for the creative process. Therefore, the notion of *co-creativity* is central to the digital art practice, demonstrated through the following three dimensions. First, *interaction between artists and digital technology*, where an artists creates with a computer using software applications or programming language. Second, *interaction between artist and audience*, which takes place when an artists involves the audience in the making of art through forms of interaction. Last, and most important for the following section, is the *interaction between artist and technologist*, which occurs when artists work in partnerships with technical experts, that is, in creative collaborations.[131]

The subsequent analysis of interdisciplinary creative collaboration is based on a research program that observed collaborations of artists and technologists during the *COSTART* artist-in-residency studies at Loughborough University in the United Kingdom.[132]

Models of co-creativity/collaboration

The COSTART project observed collaborators with various backgrounds, skill sets, and experience levels that are engaged in a creative process in order to solve a problem through their collective efforts. First of all, the COSTART team located *three main activities* that are inherent in collaborations, and are as follows:[133]

- *creative conceptualization* (the ideas and motivations of the work)
- *realization* (implementation or making)
- *evaluation* (of the outcomes whether product or process)

Given these activities, the aim was to *model roles* that are played by each party (artist and technologist) in the creative process. Therefore, the COSTART team constructed a simple *collaboration model* (see Figure 10) that provides an overview of the three main activities in conjunction with the participants.

	Artist	technologist
Concept		
Construction		
Evaluation		

Figure 10: The partner/activity matrix.[134]

This is followed by a second model (see Figure 11), which depicts activities of the partners in a collaboration. A darkly shaded square indicates a strong level of activity in the role of each collaborator, while a lightly shaded square denotes a significant but not leading role, and no shading signifies little or no role. These results of the study enable a precise differentiation of varied forms of co-creativity, and are derived and listed below the following diagram.[134]

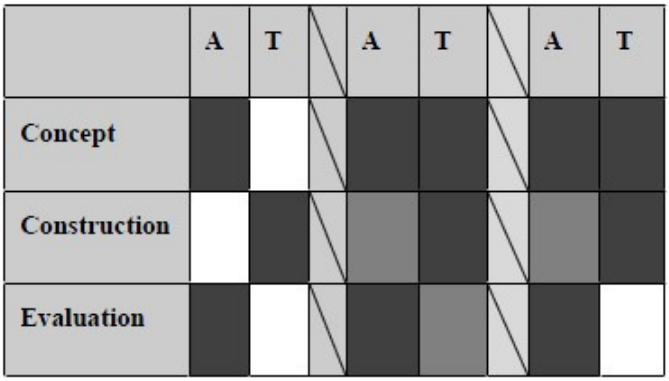


Figure 11: Assistant model, full partnership, and partnership with artist control.[134]

- *assistant model* (the role of the technologist is merely to implement the concept of the artist – depicted by matrix 1 of Figure 11)
- *full partnership model* (both collaborators are fully engaged in all creative stages but are not necessarily controlling them – see matrix 2 in Figure 11)
- *partnership model with artists control* (the artists is responsible for the evaluation of the results – shown in matrix 3 of Figure 11)

The *assistant model* is the most common form in the setting of a commercial creative team, in which participants are responsible for different phases of a project. Usually, collaborators would join the project for a limited peroid of time to fulfill certain tasks and then withdraw from it. However, the second model, defined as *full partnership*, offers significant advantages for a creative collaboration, the benefits of which will be further explicated.[133]

Creative collaboration through partnership

The full partnership model combines complementary interests even though the outcomes of each individual team may be distinct. As observed in the artist-in-residence studies, the most successful ongoing partnerships operated in ways that served concurrent interests, but simultaneously produced relatively diverse artistic outcomes. In such a manner, the collaborators can achieve mutual benefits

and, at the same time, retain ownership of their individual achievements. In order to enjoy these advantages, it is necessary to abandon individual control of the creative process and different, but complementary, roles are fitting to achieve that end.[134] Based upon the experience of the COSTART project, the subsequent passages will discuss the requirements for a successful partnership.

***Devising a shared language*.** Communication with other collaborators is often an essential part of the creative process for the exchange of ideas. The ability to communicate can be impaired by differences in the group member's professional vocabulary and concepts. The success of reaching a mutual creative vision and the exchange of creative ideas depends on the ability of the collaborators to devise a common language. This is particularly necessary when discussing technical issues. There are various potent approaches to support the creation of a shared language. One way is to help team members understand and learn the respective professional vocabulary through the support of automated interpretation systems. [135] Another approach is the use of metaphors, which can be reused by collaborators if they were successful, or, on the other hand, team members can learn from unsuccessful ones. A natural tendency for people is to develop and communicate stories as a way of informally disseminating important project-related information.[136] Finally, another possibility is the development of a pattern language which captures solutions to a persistent problem in patterns in order to stimulate thought.[137] All approaches mentioned in this paragraph can permanently improve communication and make collaborations more productive and harmonious.[133]

Sharing knowledge resources. For an effective working relationship, it is necessary that both parties share knowledge resources in order to expedite tasks and avoid difficulties of a technical and artistic nature. Generally, it depends upon the collaborators' complementary, rather than identical, skills. Further, a self-sufficient partnership must know its limitations and carry out further research if their knowledge is insufficient. Self-sufficiency in technical know-how can be in

itself a stimulus to creative thought. The ability to learn through the sharing of knowledge is adavantageous due to the generation of options, which comes to fruition especially when a new way of thinking is applied. For example, in one such a case in the COSTART project, the artist was able to understand the basic logic of programming after its process became clearer.[134]

Success factors of creative collaborations

Researchers of the COSTART project distilled findings into factors that promote creativity in art-technology practice. A selected summary is provided below.[134]

Technologists require:

- *good communication skills as well as technical skills;*
- *the ability to listen and as a result of this learm from listening;*
- *the ability to resist course of action that are technically feasible but not artistically valid.*

Artists require:

- *heterogeneous resources for a broad range of needs;*
- *access to high-end facilities;*
- *access to appropriate expertise;*
- *an ability to reflect and learn from technologists.*

Successful collaborations require:

- *a shared language;*
- *a common understanding of the artistic intentions and vision;*
- *time to establish a relationship and recover from mistakes.*

For successful collaborations it is important to establish the ideal conditions and to provide models of how to collaborate in order to achieve mutual benefit for both parties. The COSTART team believes that successful collaboration can be learned by building upon these lessons gathered from experience and applying the results of research to similar ongoing project environments.

Art and Science/Technology collaborations

Throughout the past few decades, organizations and institutions emerged that recognize the potential of art science collaborations. In response to the mainstream art world's hesitancy, they have provided technical expertise, financial support and resources that enabled facilities to be created and complex projects realized.

This chapter is intended to identify and describe institutions that are dedicated to collaborative multidisciplinary work and scientifically influenced new art forms. The following list ranges from exhibitions and museums, which provide a public context for popular audiences to experience innovative work and define research ideas as core themes. Furthermore, it features organizations that encourage collaborative work, communities of artists, engineers, scientists, critics and publishers that provide a nurturing environment in which ideas and resources can be shared and expanded. Lastly, this chapter will specify emerging university programs that pursue experimental art practice and creative research.[85]

Leonardo/ISAST

Founded in 1968 in Paris, the peer-reviewed journal *Leonardo* is the prime forum for scholarship in its field. The topics of the broadly international publication range from worldwide art and technology spectacles to the use of virtual reality in modelling proteins and the visualization and interaction applied to computer games. By promoting works at the intersections of art, technology and science, Leonardo serves an international art community and, furthermore, encourages collaboration.The *International Society for Art, Science and Technolgy* (ISAST) was founded in 1982 to support and extend Leonardo's objectives. Both, Leonardo and ISAST collaborate with international organizations such as the International Symposium of Electronic Art and the UNESCO Digiarts Portal.[89][90]

Throughout the past thirty years, Leonardo has become the leading institution for the publication of interdisciplinary projects and documentation of interdisciplinary practice. Its scope encompasses prestigious print journals and book series, which are published by the *MIT Press*, that help to make information about the domains of art, science and technology available to a wider public. Aside from this, Leonardo is mentioned in this chapter because of its approaches and efforts in spreading scientific and artistic literacy globally, establishing sustainable environmental practices and encouraging freedom of thought and imagination.

YLEM - Artists Using Science & Technology

YLEM is an international organization whose members are engaged with the intersections of art, technology and science. From the beginning on, YLEM, founded in 1981 in California, was implemented to act as a platform for artists engaged in science and technology to communicate new developments in the respective fields. Similarly to Leonardo, YLEM also published its own journal.[91]

Although YLEM has been inoperative since 2008, it must be mentioned for bringing humanizing and unifying forces of art into science and technology. Members of this organization are still zealously active in new media art, and their works such as interactive art, kinetic sculpture, robotics, holograms, film and video can be viewed in YLEM's online art gallery.

Ars Electronica

Ars Electronica began in 1979 in Linz (Austria) as a festival for art, technology and society. It has a long history of exhibitions and competitions for technology-based experimental artistic work, and became an internationally renowned platform for digital art and media culture. The *Prix Ars Electronica*, which functions as a showcase of excellence, was realized in 1987. In 2006, over 3000 works were submitted to compete for the *Golden Nica* award. Aside from the competition, there was a Prix gala and large public symposia, which included themes such as nano-

technology, network culture, artificial life and bio-technolgy. Furthermore, there is a permanent museum that is dedicated to the conveyance of knowledge and skills, as well as a media art lab.[90]

Ars Electronica should be mentioned for its extensive contributions to the Digital Revolution that brought state-of-the-art technology within reach of the general public. Besides showcasing digital artworks in the unique on-site museum, the Ars Electronica festival has gained an incredible reputation, and is the largest and longest-serving festival for electronic art worldwide.

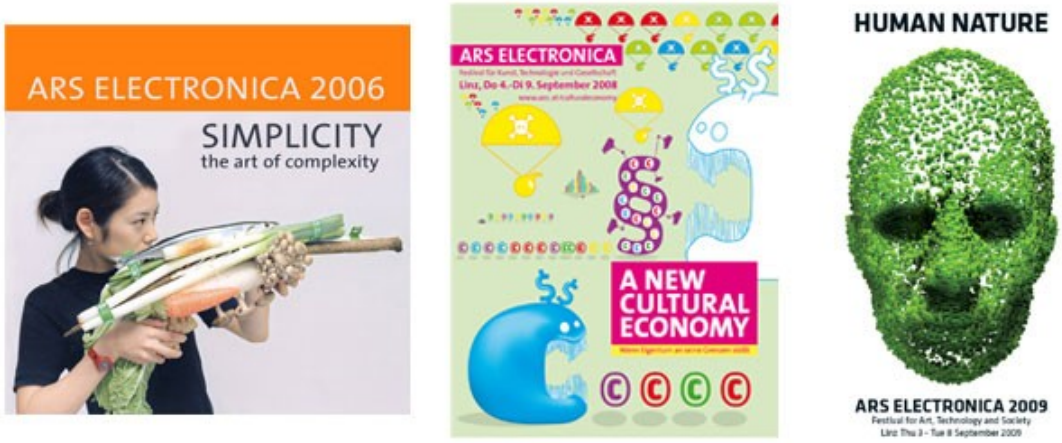


Figure 12, 13, 14: Covers of Ars Electronica festival booklets from 2006, 2008 and 2009.

Zentrum für Kunst und Medientechnologie (ZKM)

The *Zentrum für Kunst und Medientechnologie* was founded in 1989 and has its permanent location in Karlsruhe (Germany). It is a leading international interdisciplinary research institution that supports the creation and exhibition of works at the intersections of art, science, and technology, with an emphasis on new media. It combines production and research, exhibitions and events, as well as publication, documentation and dissemination of scholarship about the respective fields. Artists from around the world have produced major works during residencies at the ZKM. Since its permanent home was completed in 1997, the ZKM has manifold resources at its disposal like a museum of contemporary art, a media museum, an institute for visual media, an institute for music and acoustics, and an institute for media, education, and economics. Since 1999, the ZKM is under the

direction of *Peter Weibel* and probes new media in theory and practice, working closely with the University of Karlsruhe, the local industry, and is supported by the government and the EU.[90][92]

Similar to the Ars Electronica Center in Austria, the ZKM is featured in this chapter because of its long history of promoting technology-based experimental artistic work. Most notably, the ZKM is internationally renowned for its artists-in-residence projects and respective outcomes that are permanentely exhibited in the museum.

V2_ - Institute for the Unstable Media

*V2_* is an intercultural center for art and media, which was founded in 1981 in Rotterdam (Netherlands). The institute is engaged with the relationships and interactions between different media, as well as the connections between art and scientific disciplines. Besides exhibitions, lectures and workshops held at the V2_, its goal is to bring artists, scientists and civil organisations together in order to encourage interdisciplinary collaborations. The institute also features media labs where artists can realize their projects.[93]

Over the past few years, V2_ has established ongoing dialogues for the development of specific (art) projects involving research and presentation within a broad network of specialists. Furthermore, the institute must be mentioned for its unique approach of practice-oriented research that explores electronic media through critical reflection.

The Kitchen

The Kitchen is a non-profit art collective that was founded in 1971. It was one of the first institutions in America to embrace emergent fields such as video and performance art. Furthermore, the Kitchen also presented new visionary work within the fields of dance, music, literature, and film. The resulting environment, which was very advantageous for experimentation and cross-disciplinary

explorations, helped to launch the careers of a plethora of artists that were important in the development of electronic art.

Today, the Kitchen is an internationally acclaimed art institution and a vital link between the past and the future of experimental work, which continues to support the careers of contemporary artists.[90][94]

Rhizome.org

Rhizome.org was founded in 1996 and incorporated as a non-profit in 1998 to promote global discourse and exchange between the new media community. The platform includes an extensive archive, *Rhizome News* and *Rhizome Digest*, and programs to enable new works and organize online exhibitions. The diverse *ArtBase* archive encompasses artists' statements and biographies. The *TextBase* includes discussions and critical articles from the *Rhizome mailing lists*, which have been collected since the organization was founded. Generally, the website is an open platform for exchange and collaboration, with the goal of encouraging and expanding communities that have formed around emerging artistic practices, which are engaged with technology.

In 2003, Rhizome became an affiliate of the New Museum of Contemporary Art, when both institutions identified a shared commitment to emerging art and ideas. In 2002, *Carnivore* (2001 – present), a collaboration between Rhizome.org co-director *Alex Galloway* and the support of Rhizome and *Eyebeam*, was awarded the Prix Ars Electronica.[90][95]

International Symposium on Electronic Art (ISEA)

Since its initiation as an international nonprofit organization in 1990 in the Netherlands, the series of symposia known as *ISEA* has played a significant role in founding and maintaining a network of organizations and individuals that are active in the field of electronic arts. The association encourages interdisciplinary academic discourse and exchange within art, science and technology.

Between 1998 and 2008, fourteen ISEAs took place in ten countries on four continents. Today, it is a crucial annual event that combines theoretical symposia with electronic art exhibitions.[90][96]

NTT InterCommunication Center [ICC]

The center was founded in 1997 in Tokyo by the Japanese telecommunication company, NTT. The goal of this innovative cultural facility is to improve communication between artists and scientists in order to build an affluent society for the future. By doing so, the *ICC* aims to become a network linking artists and scientists worldwide, as well as a center for information exchange.

Nowadays, the ICC is widely known for hosting exhibitions, workshops, performances, and symposia that discuss media artworks, which employ the newest electronic technologies. Finally, the ICC also publishes quarterly journals to distribute information.[97]

PARC PAIR

Xerox initiated an artist-in-residence program called *PAIR*. The idea behind the interdisciplinary Palo Alto Research Center (PARC) is putting creative people in a nurturing setting in order to encourage innovation. The program brings together artists who use new media and researchers, who often use the same media in different contexts, to establish a problem to work on, with the definition of this quandary becoming part of the collaboration. This results in both compelling art and scientific innovation.[98]

The PAIR program is a remarkable example of bringing the fine arts directly into a working environment, which results in mutual benefit for the artist as well as the company. Furthermore, this program is a role model for corporate support of the arts with the simultaneous creation of new scientific innovations and interesting art.

SymbioticA

SymbioticA is an artistic laboratory dedicated to the research, learning, critique and hands-on engagement with the life sciences. It emphasizes experimental practice and facilitates a program of residencies, research, academic courses, exhibitions, symposia, and workshops. Furthermore, SymbioticA provides an opportunity for researchers and artists to pursue curiosity-based explorations free of the demands and constraints within the current culture of scientific research. As a research center within the School of Anatomy and Human Biology at the University of Western Australia, SymbioticA enables intrinsic engagement with scientific techniques.[99]

SymbioticA is the first research laboratory of its kind and propagates a better understanding and articulation of cultural ideas surrounding scientific knowledge. In 2007, SymbioticA won the Golden Nica in Hybrid Arts at Prix Ars Electronica.

ART+COM

ART+COM is a German organization that was founded in 1988 and focuses on research that integrates perspectives of computer technology, communication, and design. The organization has been dedicated to the future of new media since it was founded and believes that the most innovation comes from an open interdisciplinary process. Further, it is a fusion of ideas and new technologies where specialists from the arts, science and industry work together.[100]

Today, ART+COM is among the leaders in the field, working on projects for industry, culture and research. Besides winning awards at international festivals, the organization is also well-known for its commercial development work.

The Arts Catalyst

UK-based *Arts Catalyst* is an organization founded in 1993 that offers public lectures, workshops for students, publications, and research opportunities in which artists and scientists can collaborate. Its primary focus is the commissioning and presentation of new artists' projects, as well as the engagement of a large and diverse audience. By making use of an innovative art practice, Arts Catalyst aims are to break down the metaphorical wall between science and the public.[100]
Since it was founded, Arts Catalyst has promoted the understanding and cooperation between people from various disciplines. Through the accreditation of a plethora of artists' projects, the organization has opened up crucial spaces for debate, engagement and reflection in connection with science-related art.

DXARTS -Center for Digital Arts and Experimental Media

DXARTS is a program at the University of Washington that offers a creative research convergence zone for artists and scholars who seek to research beyond the conventional arts. DXARTS embraces an extensive range of art practice, theory, and research in multiple disciplines. Faculty and students have the opportunity to focus their work on a particular area of experimental art such as digital video, digital media art, computer music and sound art, computer animation, and many more. Students of this particular program have backgrounds in both art and in technical disciplines, such as computer science and biology.[99]
DXARTS is featured in this chapter as an example of developing university programs that feature a multi-disciplinary curriculum. Comparable courses will gain increased importance in academia and pioneer long-standing innovations upon which future artists and society can build.

Discussion and Analysis of New Media Artworks

Having argued for the importance of a universal integration of both art and science into our modern society, this chapter concentrates on specific artistic projects that are associated with common scientific disciplines. The categories range from *biology*, *physics*, *kinetics and robotis*, *mathematics and algorithms*, and research dedicated to the growing amount of *information* in the twenty-first century. The described projects address additional areas of hybrid artistic inquiry, for example, *telecommunications*, *telepresence*, *wireless or locative media*, *games*, and several others. Artists and scientists who are involved in such projects have a strong belief that both professions can enrich each other in several ways.

The following chapters discuss and analyze artwork that is closely connected to scientific and technological research, featuring pieces of both established and emerging artists. Extending beyond the culture flow, the following works are provocative, intriguing, and remarkable through their unusual perspectives of exploring research. By doing so, artists, scientists, and inventors create genuinely new possibilities. None of the disciplines are complete in themselves, but together they create a comprehensive picture of what research really is and what it could mean.[117]

Each chapter contains a discussion that is followed by an analysis of selected works and is accompanied by a brief summary of additional projects for further investigation. Finally, there are notes regarding the similarities and differences between the artworks associated with the different disciplines.

Biology

Biology has a long history in connection with artistic practice. For example, artists made paintings of landscapes, plants, animals, and people, or sculptors, who are famous for their skills of rendering what they observe, have created sculptures of the bodies of people and animals. On the other hand, such artistic illustrations and representations were also essential in advancing the biological sciences.

Biology promises to be a tremendous field of discovery in the twenty-first century. Analysts predict that this century will be 'biology's century', where the biological revolution will outshine the impact of the digital revolution. The effort and resources that are dedicated to biological research today have the potential to influence our everyday life as well as philosophical notions about life itself. For the arts, it will be, and already is, a common practice to become involved with such research, in order to comment on and to forge possible new research directions.[118]

This section concentrates on artists who use *living materials*, or incorporate concepts, capabilities, and contexts that are derived from *biological research*. It features projects in the areas of *human biology*, *molecular biology*, and *living systems*.

Ear on Arm (Stelarc, 2007)

Figure 15, 16: Stelarc with implanted ear; Surgery on Stelarc's forearm.

In this interdisciplinary art project, the renowned posthumanist *Stelarc* had a third ear surgically implanted into his left forearm. The ear was made of human cartilage and placed under the skin by a team of surgeons. In a second operation, a miniature microphone was positioned inside of the ear. Although the microphone was tested successfully, it had to be removed due to an infection. According to the artist, his intention was *"the engineering of a new organ for the body: an available, accessible and mobile organ for other bodies in other places, enabling people to locate and listen in to another body elsewhere."* [101]

This project seems controversial, but Stelarc's work is a speculative evolutionary prototype. It is a vision of what may exist after the anatomical body has run its course. The artist himself feels strongly that the human body is obsolete, and that humanity needs to free itself of its limitations in order to evolve further. His work is an example of the evolution of complex interactions between art and technological research. Moreover, this project is an outstanding example of a collaboration in the manner of the previously mentioned partnership model, since Stelarc was working together with a team of (medial) experts in order to achieve

his artistic vision. The artist's work, while intriguing, offended many who live with physical malformations, particularly those who were born without ears or had lost body parts due to unfortunate accidents. These protesters held the position that Stelarc should not be attaching extraneous extremities to himself while others had suffered the misfortune of being denied the normal amount. However, it can be argued that the artist's implementation of a microphone inside of his 'ear' may be a foundation upon which medical science can begin to research and develop, and eventually apply to individuals similar to those who originally disagreed with Stelarc's artistic experiment. In this manner in particular, the artist is not only appropriating technology in order to advance art, but quite possibly may also influence the course of medical development through his creativity and ingenuity.

Genesis (Eduardo Kac, 1999)

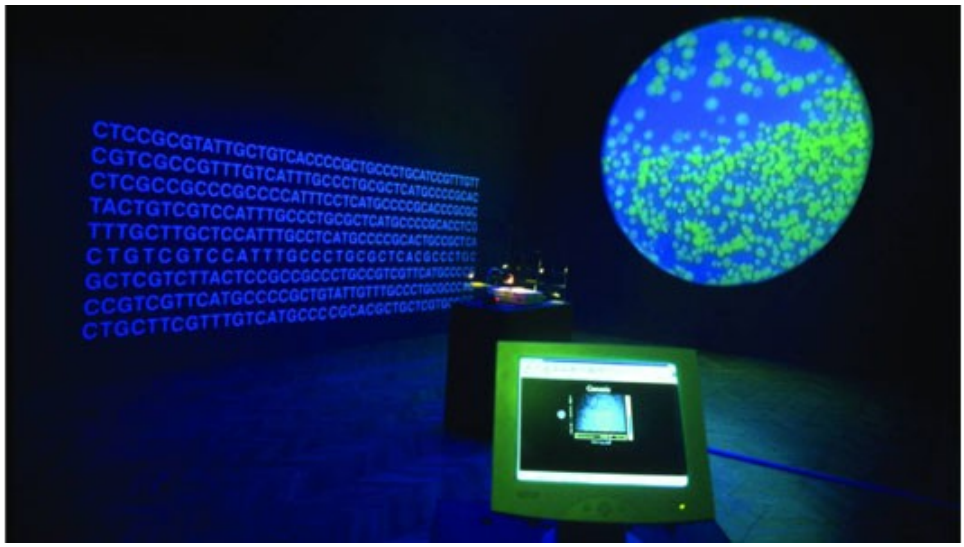


Figure 17: Genesis installation with a live microscope and projection of bacteria.

The center of this transgenic artwork is 'the artists' gene', which was created by translating a sentence from Genesis in the Hebrew Bible into Morse code, and then converting the code into DNA base pairs. *Kac* chose the text from Genesis because it implies the human being's divinely sanctioned supremacy over her natural environment. The gene was inserted into bacteria, and local as well as web viewers could manipulate it further by turning on an ultraviolet light that causes mutation

in bacteria. At the end of exhibitions, Kac translates the DNA of the bacteria back into Morse code, and then into the Bible verse to illustrate the changes in bacteria's DNA and the Genesis text.[102]

This artwork explores the intricate relationship between biology, belief systems, information technology, dialogical interaction, ethics, and the Internet. Moreover, Kac questions the assumptions of dominion represented by bioengineering. His artwork is a demonstration that in the age of biotechnology, art can not afford to neglect the new paradoxes of life. This particular work, however, embraces these anomalies, in that it demonstrates in a concrete and literal manner the way in which technology, bioengineering, and art can interact. Not only the translation of Morse code into a strand of DNA, but more so the insertion of a biblical verse into a living organism, which, in turn, affects the bacteria's very makeup, characterizes the essence of interactivity defining this artwork. This is further exemplified by the 'viewer's' control over the 'canvas' that displays the life forms through the utilization of technology, that is, the ultraviolet light. The artistic value may not only be attributed to the aesthetic beauty of the installation, but rather a critical statement of the artist towards the responsible use of bioengineering.

Augmented Fish Reality (Ken Rinaldo, 2004)

Figure 18, 19: Augmented Fish Reality installation; Fishtank closeup.

Augmented Fish Reality is an interactive installation including small robotic aquaria sculptures that are controlled by the movements of fish. They are tracked by sensors that send control impulses to the base of the robots, which allow the fish to move the construction. The sculptures enable the Siamese fighting fish, which have excellent eyesight that allow them to see even great distances outside the water, to interact with other fish and humans. The installation includes projections of fish-eye views from inside the tanks, in order to give viewers the feeling that they are immersed in the aquaria.[103]

This artwork is a vivid instance of the exploration of interspecies and transpecies communication. Additionally, it is the most recent research into fish intelligence, and offers a preview of future possibilities for technology-supported human-animal communication. The replication of a fish's movement as viewed by the spectator offers a unique experience, in which the human may have a sense of the inside of the aquaria, but, moreover, the individual can influence the action of the fish through her movements within the fish's line of vision, and hence may manipulate the exhibition as a whole. One may have a critical view of this artwork due to the use of live animals in order to pursue the scientific and artistic goals. Particularly in that the Siamese fighting fish must interact with the viewer and other fish, which would be their enemies in the wild, Augmented Fish Reality remains on the line between brilliant, interactive biology-inspired art and exploitation of animals for artistic purposes.

Additional artwork

Silvers Alter (2002) Gina Czarnecki and Keith Skene - Evolution of virtual humans

http://www.artscatalyst.org/projects/detail/silvers_alter/

Botanicalls (2006) Rob Faludi, Kate Hartman, and Kati London - Telephone-triggered humidity sensors for plants

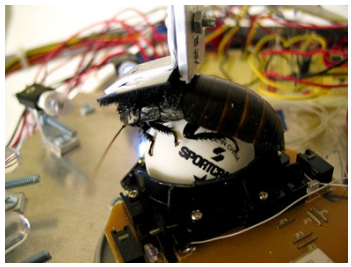
http://www.botanicalls.com/

Spore 1.1 (2004) Douglas Easterly and Matt Kenyon - Stock-controlled water supply for a plant

http://www.fundacion.telefonica.com/at/vida/vida10/paginas/v7/espore.html

Cockroach Controlled Mobile Robot (2004-5) Garnet Hertz

http://www.conceptlab.com/roachbot/



Family Portrait (2002) Marilene Oliver - Full-size 3-D structures of MRI scans

http://marileneoliver.com/portfolio/portfolio2003/2003family_port1.html

Physical Sciences

Artists have always had an intimate connection with the physical world by exploring the earth, the sky, and the seas. They attempted to represent natural forces as they can be experienced in the change of day and night, the flow of water, or the streaming winds. On top of that, they created buildings and objects that require an understanding of materials and respective forces through which they can be combined.

The physical sciences have opened up new ways of looking at and thinking about the world we believe we know so well. Physics, chemistry and the material sciences, geology, climatology and astronomy applied important knowledge and transformed our lives through the invention of novel materials and the discovery of energy in unprecedented manners, such as nuclear or solar energy. New disciplines like nanotechnolgy or materials science predict that humans will be able to create organic and inorganic substances atom by atom. Physical sciences provide new dimensions for the arts and challenge them to use information and processes of research to open up new doors and make relevant philosophical questions part of their discourse.[119]

For the artists that are featured in this section, scientific tools and concepts have become a central point of their practice. The presented works are engaged with scientific topics such as *atomic physics*, *astronomy*, *geology* and *earth science*.

TEMPEST (Erich Berger, 2004)

Figure 20: The picture shows digital images, created through electric radiation.

Drawing its name from a U.S. Government code word for limiting electric or electromagnetic radiation emanations from electronic equipment, the audiovisual installation / performance TEMPEST is based on the Van Eck Phreaking (VEP) phenomenon. VEP allows the decryption of electromagnetic fields of electronic devices, for example, computer monitors, and therefore offers potential for military surveillance technologies. Erich Berger's artwork is a combination of sound and images, whose relationship is precisely determined by electromagnetic emissions produced by a computer monitor. The graphics that appear on the screen produce radio waves that are captured from radios and result in vibrant sounds, which accompany the images.[104]

This piece is a critical analysis and demonstration of the omnipresent electric radiation that surrounds us. In the time of growing cellular telephone networks, wireless LAN connections, and television and radio waves, many artists make electronic pollution the focus of their works. Such pieces are important because it is difficult to determine the potential hazards of electronic emissions, and they therefore demand increased attention from the public. The intended result of this

installation is to raise constant awareness of the harm that modern technology may be inflicting upon the human body, in that these possibilities should remain in the viewer's consciousness and affect the decisions that she must make in her everyday life.

White Lives on Speaker (Yoshimasa Kato and Yuichi Ito, 2008)


Figure 21, 22: Closeup of a blob; White Lives on Speaker as an installation.

White Lives on Speaker transforms the brain waves of a participant into sculptures. This is realized through the conversion of brain waves into sound that is played through speakers. On top of the speaker's membrane is a liquid consisting of potato starch dissolved in water, which is stimulated by sound to create sculptures. Therefore, the participant can interact with this installation through her brain waves and experience changes in the sculptures that are shaped by them. In addition to this, touching the shaped liquid can create another experience of interaction.[105]

White Lives on Speaker is a playful contact with brainwave-modulation, which is useful for the representation of a person's mental state and health. Research in this field also aims to aid a variety of mental issues, and will gain significance in future

medical equipment. At the moment, there a several audio programs that make use of brainwave activity.

Gravicells (Seiko Mikami and Sota Ichikawa, 2004-7)

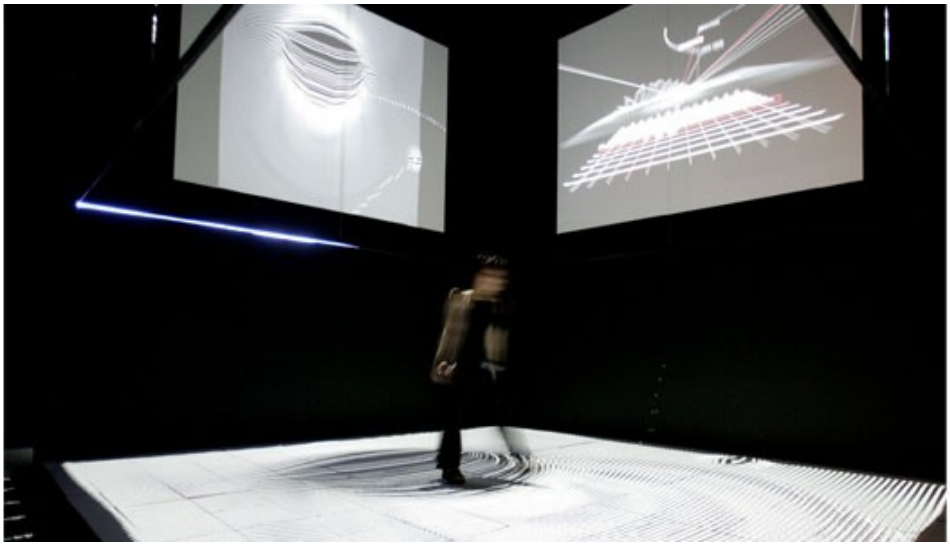


Figure 23: Gravicells' sensor floor and projections.

In this installation, the weight and movement of visitors is measured by a sensor-meshed floor, and transformed into sound, light and geometric topological images. Further, Gravicells illustrates interactive forces read by GPS systems, which are caused by the earth's movement. It is also theoretical proposed that the piece relates to gravitational attractions between people. According to the artists, Gravicells *"presents the dynamic processes of the interactions between gravity and resistance"*, *"where the interface itself exists inside of us"* in form of our body as a gravity sensor.[106]

Gravicells investigates gravity as an extended component of our consciousness, since our body keeps balance through an 'internal ear'. As something that is largely ignored by individuals, the experience of the body in relation to the pull of the earth is brought to the forefront in this artwork. Although humans take note of the other bodily senses, such as smell and vision, gravity is so deeply ingrained in the

individual that one must be notified by her other senses, as one is in this exhibition, that the experience of gravity is acting upon the body. The experiences and insights from this installation may be utilized as a basis for future developments in space travel and also contribute to rehabilitation therapy for balance disorders.

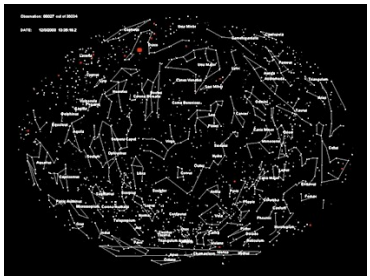
Additional artwork

The weather project (2003) Olafur Eliasson – Artificial weather environment inside of a museum

http://www.olafureliasson.net/works/the_weather_project.html

"We Are Stardust" (2008) George Legrady – Projections of NASA sky observations

http://www.mat.ucsb.edu/res_proj2.php

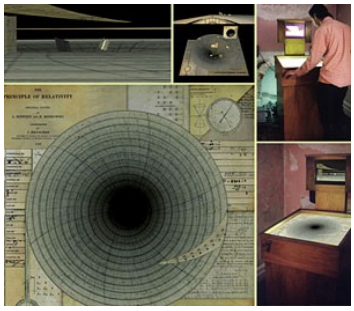


Eon (2003) Shawn Brixey – Voice translated into sonoluminescence at atomic level

http://www.washington.edu/dxarts/profile_research.php?who=brixey&project=eon

HyperCollider(2004) Chris Henschke – Pinball-like simulation sending particles into blackholes

http://www.topologies.com.au/collidertext.htm



Weather Songs (2002) Tom Dukich – Weather converted into sound

http://www.tomdukich.com/weather%20songs.html

Kinetics & Robotics

"That which moves, moves the imagination in many directions."
(Dore Ashton)

The history of the pre-industrial age is filled with attempts to create and describe moving and autonomous objects, and lifelike automata. Today, researchers are engaged with the control of light and motion, the transformation of everyday items, robotics, and the mixing of realities to link the physical and virtual worlds. Furthermore, research into smart objects and robotics results in radical changes of the defintion of sculpture.

Researchers aim to create objects and robots that intelligently adjust to their environment, operate without human intervention, and learn to accomplish tasks independently. Many of them are convinced that sensing, computing and communication functions will become invisible and integrated into everyday objects and spaces. Artists are especially interested in the narratives that shape the physical worlds we are inventing, and the limits and type of intelligence we can design into machines. They are exploring new types of control over motion, light and sound, the integration of the mechanical and the organic, and merging the physical and electronic worlds.[120]

The works featured in this section deal with *robotics*, *machine autonomy*, *haptics*, *mixed realities*, and *conceptual kinetics*.

Exoskeleton (Stelarc, 1998)

Figure 24: Stelarc performing with his Exoskeleton.

Like the previously presented artwork by Stelarc, Ear on Arm, this project is also an extension of the human body. Rather than enhancing the body in a biological manner, Exoskeleton is a mechanical six-legged device resembling a metal skeleton that amplifies the power of human muscles. Standing on top of the walking machine, Stelarc can move in non-human ways and has performed multiple times with his construction. The body actuates the device, that is, different gestures cause various motions through a translation of limb to leg movements, enabling the Exoskeleton to move forwards, backwards, sideways and to turn on the spot. [107]

Like most of Stelarc's works that have a futuristic and ominous appearance, this hybrid piece compels viewers confront their notions of what the human body may become. Unlike his previously mentioned project, Ear on Arm, this work of art demonstrates little practical applicability to the present-day human situation. Rather, the Exoskeleton portrays an intimidating vision of the future human form, in which the body depends solely upon technology for its required performance. This may manifest itself in a future in which humanity must utilize the aid of such

an apparatus in order to function in an acceptable manner. Possible examples of this may be the installation of technologically developed chips in order to enhance brain activity beyond its natural capacity, or the necessity of mechanized limbs in to be competetive in athletics. Additionally, military researchers have already begun to construct similar devices that allow soldiers to run at superhuman speeds or carry tremendous loads.

Autotelematic Spider Bots (Ken Rinaldo and Matt Howard, 2006)

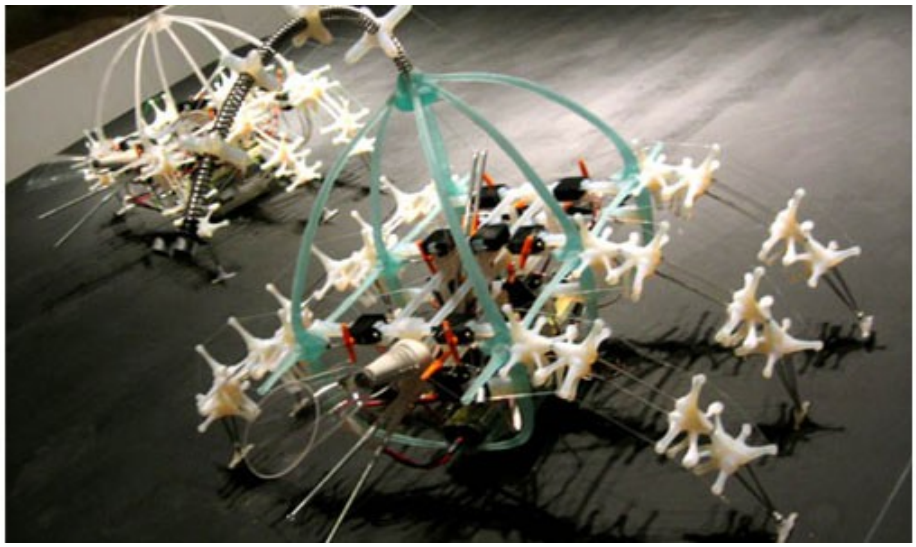


Figure 25: Two Spider Bots interacting.

Ken Rinaldo created a community of robots that can mimic the behavior of ants and spiders. His Autotelematic Spider Bots are able to interact with visitors through infrared eyes, tell each other about food supplies and manage their own 'metabolism'. The 'food' is provided in form of electrical recharge ports, which can be detected by the robots. Rinaldo sought to create a quasi-ecosystem in which the robots communicate with each other and learn from their interactions in order to develop emergent, artificial-life behaviors. Aside from these facts, sensors control the robots' unique movement, which adds an undeniable aesthetic grace to this work.[108]

Rinaldo stated that the control mechanisms used in this project could have a wide practical application in future robotics technologies. Furthermore, this work demonstrates contemporary possibilities of how technological creations can mimic living organisms. The use of highly sophisticated control mechanisms combined with machine learning will undoubtedly be the future of the development of autonomous robots. This can already be seen with the existence of simple robots, such as automated vacuum cleaners and lawn mowers, which can execute their task largely without instruction from their human 'owners.' Although this is a primitive manifestation of the available technology, more advanced robots that perform more advanced tasks are beginning to appear. One such example is *Robocup*, in which autonomous machines play soccer collaboratively, depending not only upon their programmed skills, but also improving their performance through 'learning' by experience.

Reactable (Music Technology Group, 2004)

Figure 26: Reactable's multi-touch interface.

The Reactable is both a piece of art as well as a successful commercial musical instrument. The multi-user environment consists of an 'active table' where *"several performers share complete control over the instrument by moving physical*

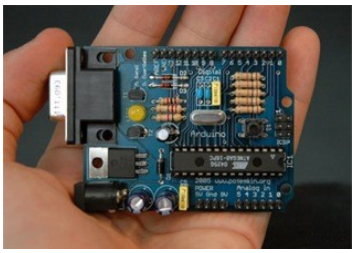
artifacts on a table surface." Through the movement of objects, which represent components such as filters and modulators, the user can configure a music synthesizer. A camera tracks the placement of these physical entities, and the computer system to which it is linked activates the corresponding sound generators that then connect the objects via projected lines. The Reactable appears in several museums, where *"it provides visitors with a new, instantly responsive, visually compelling and socially interactive music-making experience."* Likewise, the instrument is also used by several musicians.[109]

This project illustrates the topicality of the art and research worlds' interest in 'mixed realities'. It also incorporates state-of-the-art multi-touch technology, and is an outstanding example of the application of tangible user interfaces within a collaborative multi-user environment. Moreover, the Reactable represents the future of digital musical instruments due to its approachability and variety of possible synthetic sounds. The tangibility of this 'instrument' enables interaction and involves individuals in a creative process, which, by virtue of the table environment, functions ideally in a collaborative setting. The visual qualities of the Reactable are integral to the success of the table in engaging the user, which enables it to act as a musical instrument and a constantly fluctuating work of art simultaneously.

Additional artwork

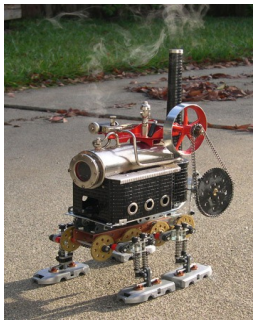
Arduino (2005) – Microcontroller electronics platform

http://www.arduino.cc/



Steam Walker (2006) I-Wei Huang – Steam-driven robot

http://www.craftsmanshipmuseum.com/Iwei.htm

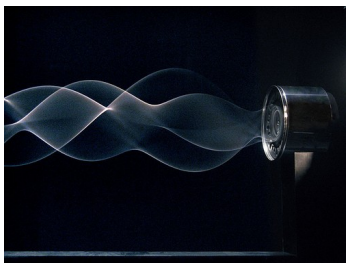


Graffiti Writer(1998) Institute for Applied Autonomy – robot writing street graffiti

http://www.appliedautonomy.com/gw.html

Waves (2006) Daniel Palacios Jiménez – Rotating rope creating sounds and visuals

http://danielpalacios.info/



PainStation (2001) Fur – A painful arcade game

http://www.painstation.de

Mathematics / Algorithms

> *"Mathematics is the majestic structure conceived by man to grant him the comprehension of the universe."* (Le Corbusier)

In the late nineteenth and early twentieth century, abstraction became a major cultural force. Scientists began to incorporate practices that are based on theories specifying entities that are opaque or can not be directly sensed. Using tools such as mathematics or theoretical physics, scientists conceptualized worlds that defy 'common sense'. Today, computers and electronic devices rely on sets of detailed instructions to guide their actions, which makes mathematics or algorithms part of everyday life.

Artists are interested in algorithms and code, including the intellectual change caused by working with symbols that represent complex, dynamic processes. They have explored code and its cultural implications and used algorithms to create images, sounds, animations and interactions, as well as increased the 'intelligence' of code in order to simulate artificial life and artificial intelligence.[121]

This section includes works of artists that make use of contemporary mathematical concepts, as well as algorithmic artists who develop abstract sets of computer rules. It incorporates projects in areas such as *algorithmic art*, *artificial intelligence* and *artificial life*, and *evolutionary art systems*.

A-Volve (Christa Sommerer and Laurent Mignonneau, 1994-97)

Figure 27: Artificial life forms of A-Volve.

A-Volve is an interactive computer installation that allows users to create and observe virtual creatures in the space of a water-filled glass pool. The fish-like artificial life forms are products of evolutionary rules, but can be influenced by human decision. Users can design new creatures on a touch screen by selecting a variety of anatomical and behavioral characteristics. The audience can further influence evolution by protecting the life forms from predators in the pool. If two creatures meet, they can produce offspring, which carries the artificial genetic code of its parents. There are an unlimited variety of forms possible, which represent evolutionary and human rules.[110]

The work of Sommerer and Mignonneau examines the potentials for algorithm-based simulation of evolutionary principles. The necessary interaction of the users with not only the rules regarding a creature's behavior and appearance, but also the life and death of the creature itself attributes to the value of the installation as that based upon generative evolution. The human manipulation of the algorithmn, and therefore, the qualities exhibited in the life forms contribute to the simulation's success as a technologically controlled work of art. A-Volve can be

described as an influential project in the field of generative art that shaped several future artworks. Additionally, A-Volve bridges real and virtual worlds, and is according to the artists *"a further step (after 'Interactive Plant Growing') in the search of 'Natural Interfaces' and 'Real-Time" Interaction'."* [110]

Electric Sheep (Scott Draves, 2006)

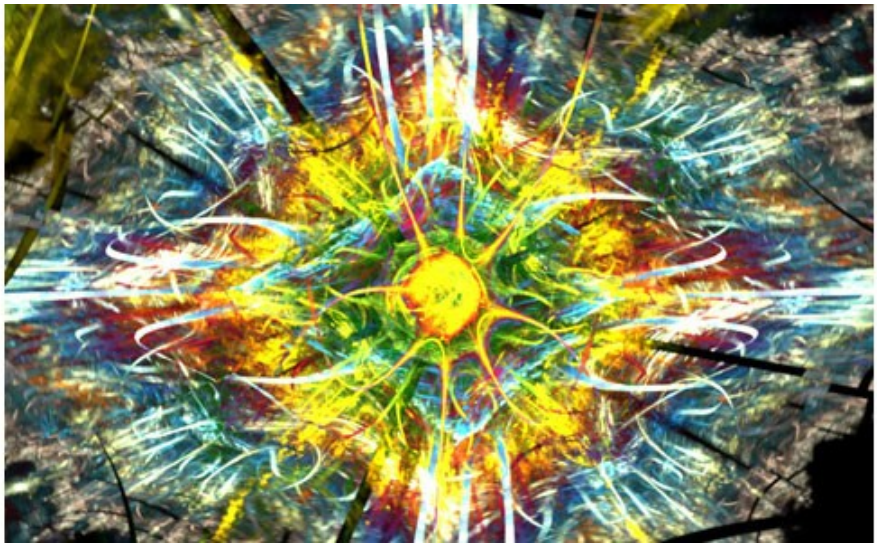


Figure 28: An Electric Sheep designed by a user.

Electric Sheep is an evolutionary art program that enables people to vote on which images in a set should serve as parents from which a new generation of images derives. The project makes use of the Internet to involve an international community in the distributed evolutionary process. While a host computer 'sleeps', the Electric Sheep program communicates with others *"to share the work of creating morphing abstract animations". The more popular creations live longer and reproduce according to a genetic algorithm with mutation and cross-over."*[111]

Draves states that his work is primarily intended *"to create beauty, it validates the premise of a-life: that beauty and life can spring from iteration of simple mechanical rules. That you can get out more than what you put in."* [112] This artwork shows that technology, rather than limiting the creativity of the artist, can augment the visual

concept of the artist. In creating these works, the artist relies upon the program to mutate her original work. In doing so, the originator of the artwork engages in a creative process with the technology, therefore accepting that the program will contribute to the final product in the same manner as the human artist. The interactive quality of this project is further reinforced by the availability of completed artworks to the international community, upon which individuals may add new aesthetic aspects or manipulate the older works in order to enable an infinite collaborative creative process.

DrawBots (Paul Brown and Phil Husbands, 2005-8)

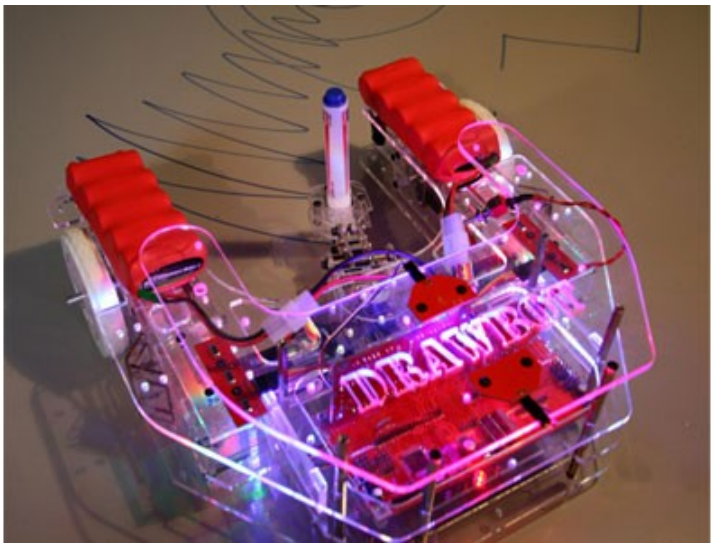


Figure 29: A DrawBot performing.

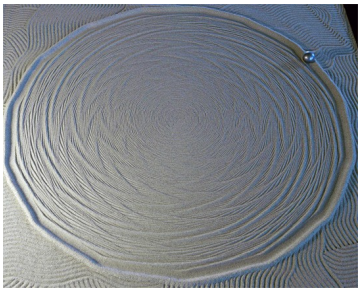
DrawBots is part of a larger research project, in which an interdisciplinary team consisting of artists, engineers, AI researchers, cognitive scientists, philosophers, and art theorists applied evolutionary robotics methods in order to understand the nature of creativity. The goal was to develop an embodied robot that manifests autonomous creative behavior by having the ability to make marks or draw. The application of contemporary evolutionary and adaptive systems methodology to the field of creative behavior and the visual arts intended to create a series of 'artworks'.[113]

The DrawBots project generated valuable results through its investigation of the theoretical bases of artificial intelligence, artificial life, philosophy, and creativity and congnition. The project also succeded in stimulating dialogue in the respective areas.[113]Additionally, the collaborative nature of this project, aside from its speculative artistic intention, is beneficial to numerous scientific domains, and therefore presents itself as an example of a fruitful partnership between experts from diverse intellectual backgrounds. Equipped to simulate adaptive behavior, DrawBots succeed in providing a research basis to a plethora of disciplines, which are searching for not only the tangible, but also the abstract foundation of creativity.

Additional artwork

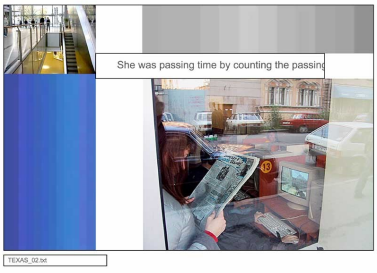
Sand Tracings (1990s -) Jean- Pierre Hébert – A magnetically dragged ball forms algorithmic patterns

http://hebert.kitp.ucsb.edu/index.html



Soft Cinema (2000-5) Lev Manovich – Algorithmically generated cinema

http://www.craftsmanshipmuseum.com/Iwei.htm



E-Volver(2006) Erwin Driessens and Maria Verstappen – Evolutionary art system breeding digital organisms

http://www.xs4all.nl/~notnot/E-volverLUMC/E-volverLUMC.html

TI (2004) C.E.B. Reas – Images generated through interactions between autonomous computer image generating agents

http://reas.com/

Biowall (?) Christof Teuscher – Artificial life self-configuring wall

http://lslwww.epfl.ch/biowall/

Information

In recent years we have come to depend on efficient storage, management, retrieval and analysis of data in various areas of life. This process was amplified by the Internet, because online activities crucially contribute to the growth of information. Data-mining, analysis and visualization create unprecedented information from the tremendous amounts of this data. Such developments may increase efficiency and enrich our lives, but they are also a threat to an individual's privacy and can be exploited.

Artists encounter the masses of information and respective developments with mixed feelings. They both comment on their dangers and explore the potential that derives from the accumulation and analysis of information. Their artistic practice ranges from creating visualization methods, reflecting on surveillance, and inventing methods to undermine and question information systems. In the future, they will address the endeavor of how to make reasonable use of data and the implied negative aspects. Ultimately, they will indicate possibilites to move beyond utility in order to transform data-derived information into innovative aesthetic forms.[122]

The following projects address topics such as *surveillance*, *telepresence*, *Internet and game art*, *location-aware technologies*, and *information visualization.*

Uncle Roy All Around You (Blast Theory, 2004)

Figure 30: A street player with handheld device.

Uncle Roy All Around You is a game where street players in an actual city and online players collaborate. It incorporates real and virtual forms of street theater with interactive storytelling. The players in the 'real world' are equipped with handheld devices that display a map, and can send and receive messages. Uncle Roy messages the street players in order for them to meet him at a location that has been marked on the hand-held map. Online players can assist the participants searching for Uncle Roy by sending them private messages. Once street players have arrived at the meeting point, they are directed to Uncle Roy's office and online players are invited to join them in a virtual office. The entire experience has no definite end, since the users can choose to chat further with the street players. [114]

This pervasive game investigates various social changes brought about by ubiquitous mobile devices, continous network connectivity, location-aware technologies, and telepresence. The blending of a real environment and the virtual world result in an abstraction of reality, through which both worlds become mutated. This project may also be interpreted as a critique of the overuse of

connectivity within modern life. For example, devises such as Smartphones change the everday reality of the individual, in that one is constantly connected to the virtual world, which may cause a shift in human behavior and interaction. Conversely, pervasive gaming, such as this project, provides a new form of entertainment and excitement in the digital modern world, while creating an interactive forum, which ultimately contributes to the success and confirms the future proliferation of such technologically enhanced games.

Listening Post (Ben Rubin and Mark Hansen, 2002-5)

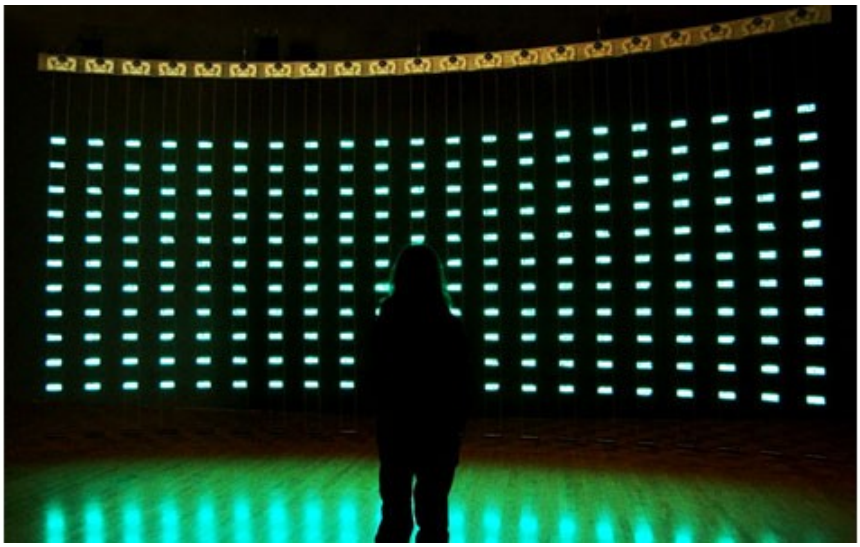


Figure 31: Listening Post installation showing the digital-text displays.

The sculptural installation Listening Post culls conversations from Internet chat rooms and displays them on more than two hundred minute screens suspended from the ceiling. In addition to this, a synthesized voice reads randomly selected words or phrases. The snippets on the screens are determined by a variety of algorithms, for example, most infrequently used words or first-person statements such as 'I am', 'I like', or 'I love'. The multimedia installation, which has won many international awards, consists of six different movement cycles, each of which generates different content, visual unfolding, and soundscapes.[115]

Listening Post can be seen as a critical reference to data-mining programs, which include profiling practices and monitoring. This is an important aspect concerning the privacy of communication that happens every day in telecommunication systems. This project calls the viewer's attention to the accessibility of personal information in what may seem to be an anonymous environment. One may be forced to confront that that which they associate with their private life could be easily accessed through specific programs. The Listening Post, while aesthetically pleasing to the viewer, also creates an environment in which the participant unintentionally takes on a voyeuristic role through the observation of personal Internet communication.

Newsmap (Marcos Weskamp and Dan Albritton, 2003)

Figure 32: The dynamic 'news collage' of the Newsmap.

The Newsmap system visualizes enormous amounts of information that are automatically collected from *Google's* news site. The dynamic collage of rectangles symbolizes relationships between news items, in that the size of the boxes indicate the number of articles that focus on various topics. This representation reveals *"underlying patterns in news reporting across cultures and within news segments in constant change around the globe."* The Newsmap provides the possibility to

compare the news landscape of many countries. Therefore, it is possible to see *"which countries give more coverage to, for example, more national news than international or sports rather than business."* [116]

Today, the Internet contains tremendous amounts of disorganized information. The Newsmap refers to this information overload and is a first step towards the development of new interfaces that allow us to deal with the overwhelming quantity of knowledge. Through its categorization of articles into color-coded sections, the Newsmap provides the viewer with an approachable and easily comprehensible visualization. Moreover, due to the endless flow of information, the collage undergoes constant alterations, which sets it apart from other works of art, in that it is not only visually appealing, but is also influenced by unknown collaborators throughout the digital media landscape.

Additional artwork

Zone*Interdite (2006) Christoph Wachter and Mathias Jud – A website collecting information about restricted military areas

http://www.zone-interdite.net

Velvet Strike (2002) Anne-Marie Schleiner – A game patch for Counerstrike with counter military graffiti

http://www.opensorcery.net/velvet-strike/

Worldprocessor (1988-) Ingo Günther –
Globes visualizing various political, economic, and sociological information

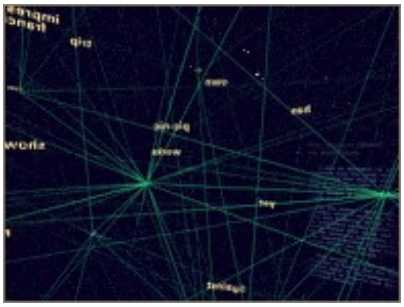
http://worldprocessor.com

Police State (2003) Jonah Brucker-Cohen –
Internet data referring to terrorism is used to controll toy police cars

http://www.mee.tcd.ie/~bruckerj/projects/policestate.html

Valence (1999-2002) Ben Fry –
A system that puts words from a book into structural relationships

http://benfry.com/valence/



After having presented and discussed various projects of new media artists working within or even across the scientific disciplines of biology, physics, kinetics and robotics, mathematics and information (technology), this section concentrates on the approaches and potentialities that distinguish or connect artworks in their respective fields.

Artistic work that deals with the topic of biology is frequently created with the intention to advance biological sciences and present a new field of discovery for this scientific domain. Aside from that, artworks also aim to comment and scrutinize possibilities that are created through biological research. Since biology is a sophisticated and rich area of research, artists depend on collaboration with experts in order to achieve their artistic goals. These partnerships are common approaches in new media artworks and can be seen in the work *"Ear on Arm"* by *Stelarc*, who had to cooperate with specialists within an interdisciplinary research environment to realize his artistic vision. As mentioned before, Stelarc's work represents an evolutionary prototype, which shows a prospect of future biological developments. In the same fashion, *Ken Rinaldo's "Augmented Fish Reality"* offers new insights and possibilities in human-animal communication. Equally important as new paths in biological research, which are created through artistic projects, is raising awareness and questioning the possible implications that accompany biotechnology. The artwork *"Genesis"* by *Eduardo Kac* can be understood as a critical statement against the negative side effects of bioengineering.

The physical sciences have always helped humanity to describe and understand natural phenomena. Works of art within this discipline follow the same principle of explaining the physical world with the addition of providing different views of it and revealing underlying, opaque processes. Similar to biology inspired art, artists are also critically engaged with the physical sciences to raise our awareness of technology. An example of different views of physical forces are epitomized in the envisioning of brainwaves in *"White Lives on Speaker"* by *Yoshimasa Kato* and *Yuichi Ito* or the unusual experience of gravity in *"Gravicells"* by *Seiko Mikami* and

Sota Ichikawa. Further, *Erich Berger's "TEMPEST"* demonstrates the effects of electric radiation, while commenting upon its potential harmful aspects.

Scientists, as well as artists, who are engaged with kinetics and robotics are highly interested in shaping the physical world. Artworks such as *Stelarc's "Exoskeleton"* are futuristic attempts to enhance the physical abilities of the human body with the help of machines. Numerous other artistic projects are dedicated to a similar approach, with a concentration on autonomous machines that mimic the movement, behavior and appearance of humans or animals. For example, *Ken Rinaldo's "Autotelematic Spider Bots"* are inspired by the movement of ants and spiders, and are able to learn from their interactions. Another goal of kinetic artworks is to invent new ways of interacting with multimedia systems, as it can be experienced in the 'musical instrument' *"Reactable"*.

Artworks based upon algorithms that utilize mathematical methods are largely created to simulate artificial life and artificial intelligence, or to execute sets of computer rules in order to create evolutionary visual or sonic output. Examples of the first mentioned goal are found in *Christa Sommerer's* and *Laurent Mignonneau's "A-Volve,"* which deals with artificial life forms that evolve over a certain time period, and *"DrawBots"* by *Paul Brown* and *Phil Husbands.* This work exemplifies an interdisciplinary research project committed to evolutionary robotics and exploration of the nature of creativity. Next, similar to *Scott Draves' "Electric sheep"*, which mutates pictures in an evolutionary process, a plethora of new media artworks are of a generative nature and utilize algorithms or automata to create music, movies, or images. The essential factor in such projects is an algorithm that contributes to the outcome of an artwork in the same manner as a human artist.

Perhaps the most promising present and future topic for artists, as well as scientists from multiple disciplines, is information and its associated systems. Today, we are faced with tremendous amounts of data that need to be structured, organized and visualized, in order to maintain control over it and enable efficient searching. Similar to the aforementioned scientific disciplines, artists attemp to

open up new ways and possibilities for dealing with information, while simultaneously critiquing its related implications. For example, *Ben Rubin's* and *Mark Hansen's "Listening Post"* can be understood as a critical reference to data-mining and surveillance in that it reveals personal information found on the Internet. Similarly, *Marcos Weskamp* and *Dan Albritton* present an attempt to organize information and reveal underlying connections with their artwork *"Newsmap"*. A playful example of the artistic use of information can be found in *Blast Theory's "Uncle Roy All Around You,"* which harnesses the phenomenon of telepresence in a game, and illustrates social changes caused by ubiquitous computing in everyday life.

In summation, it can be said that artists working within these disciplines show a great respect for and interest in the respective scientific fields and do not hesitate to consult experts within the corresponding areas in order to achieve a greater understanding and feeling for a specific topic. Depending on the complexity and scope of an art project, collaborations between artists and scientists are an essential prerequisite in simultaneously creating useful scientific and valuable artistic works. Thus, science related artworks present new insights for multiple research domains and address critical thinking in connection with scientific progress of the twenty-first century.

Summary / Conclusion

The first chapter of this thesis provided essential definitions of science, technology and art, which are necessary for the understanding of inquiries in the respective disciplines. In addition to this, characteristics of art and science were depicted that reveal a close connection between both professions and are the basis for art-based scientific research, as well as artists working with technology. A section was dedicated to a specific, contemporary branch of art – new media art - which is highly influenced by technology and therefore acts as the primary subject in analyzing research activities that are related to art. A historical discourse of the last century illustrated the roots of new media art and led to the intentions, approaches, and themes that characterize this art form.

Historical aspects, beginning with accomplishments of the Paleolithic Era, leading into the Renaissance, as a time of flourishing artistic and scientific activities, and culminating in Modern Art as an era of major scientific developments and a plethora of art movements that rediscovered the connection between art and science, were used as arguments for art/science cross-fertilization.

A chapter was dedicated to the urgency of collaboration and integration of art and science into modern society, in order to stimulate mutual interest in both. It delivered ideas on how artists and scientists can work together and benefit from the characteristics of both disciplines.

The subsequent chapter exemplified institutions, organizations, and university programs that provide nurturing environments for artists and scientists to collaborate, with the aim of pursuing experimental art practice and creative research.

The last part of this thesis concentrated on the works of artists who engage with the worlds of technology and research in profound ways. Categories such as biology, physics and mathematics were chosen to illustrate the wide range of scientific fields that are the subjects of several contemporary artists' works.

This thesis has focused on the mutual influence between art, science, and research. The implications of this relationship reach beyond artists and scientists, and have become a major public topic. The twenty-first century is undoubtedly the century of research and innovation, promising a remarkable future. Unfortunately, efforts to integrate research and art are still very immature and face a long path ahead of them.

However, the artists presented in this thesis have begun to engage the world of research. They are reclaiming art as a zone of innovation and questioning, and create works diverse in approaches, goals, and ideologies. Ultimately, they have joined scientific inquiry in order to help shape its future.

Finally, an integration of art and science will be more approachable and appealing to our society than one discipline on its own. Together, they must shape a future of new forms of art and a truly hybrid culture where scientists and artists are vitally inspired by each other.

Appendix

Exhibitions/Institutions/Communities/Collaborations

Leonardo/ISAST: http://www.leonardo.info/

YLEM - Artists Using Science & Technology: http://www.ylem.org/

Ars Electronica: http://www.aec.at/

Zentrum für Kunst und Medientechnologie (ZKM): http://www.zkm.de

V2_ - Institute for the Unstable Media: http://www.v2.nl/

The Kitchen: http://www.thekitchen.org/

Rhizome.org: http://rhizome.org/

International Symposium on Electronic Art (ISEA): http://www.isea-web.org

NTT InterCommunication Center [ICC]: http://www.ntticc.or.jp/

PARC PAIR: http://www.parc.com/

SymbioticA: http://www.symbiotica.uwa.edu.au/

ART+COM: http://www.artcom.de

The Arts Catalyst: http://www.artscatalyst.org/

DXARTS -Center for Digital Arts and Experimental Media:
http://www.washington.edu/dxarts/

Artworks

Ear on Arm (Stelarc, 2007)

http://www.stelarc.va.com.au/projects/earonarm/index.html

Genesis (Eduardo Kac, 1999)

http://www.ekac.org/geninfo2.html

Augmented Fish Reality (Ken Rinaldo, 2004)

http://accad.osu.edu/~rinaldo/works/augmented/augmented.html

TEMPEST (Erich Berger, 2004)

http://randomseed.org/tempest/

White Lives on Speaker (Yoshimasa Kato and Yuichi Ito, 2008)

http://www.wlos.jp

Gravicells (Seiko Mikami and Sota Ichikawa, 2004-7)

http://g--r.com

Exoskeleton (Stelarc, 1998)

http://www.stelarc.va.com.au/projects/exoskeleton/index.html

Autotelematic Spider Bots (Ken Rinaldo and Matt Howard, 2006)

http://www.osu.edu/features/2006/rinaldo/

Reactable (Music Technology Group, 2004)
http://www.reactable.com/products/reactable_experience

A-Volve (Christa Sommerer and Laurent Mignonneau, 1994-97)
http://www.interface.ufg.ac.at/christa-laurent/WORKS/CONCEPTS/A-VolveConcept.html

Electric Sheep (Scott Draves, 2006)

http://electricsheep.org/

DrawBots (Paul Brown and Phil Husbands, 2005-8)

http://www.arts-humanities.net/casestudy/drawbots_project_computational_intelligence_creativity_cognition_multidisciplinary_investi

Uncle Roy All Around You (Blast Theory, 2004)

http://www.blasttheory.co.uk/bt/work_uncleroy.html

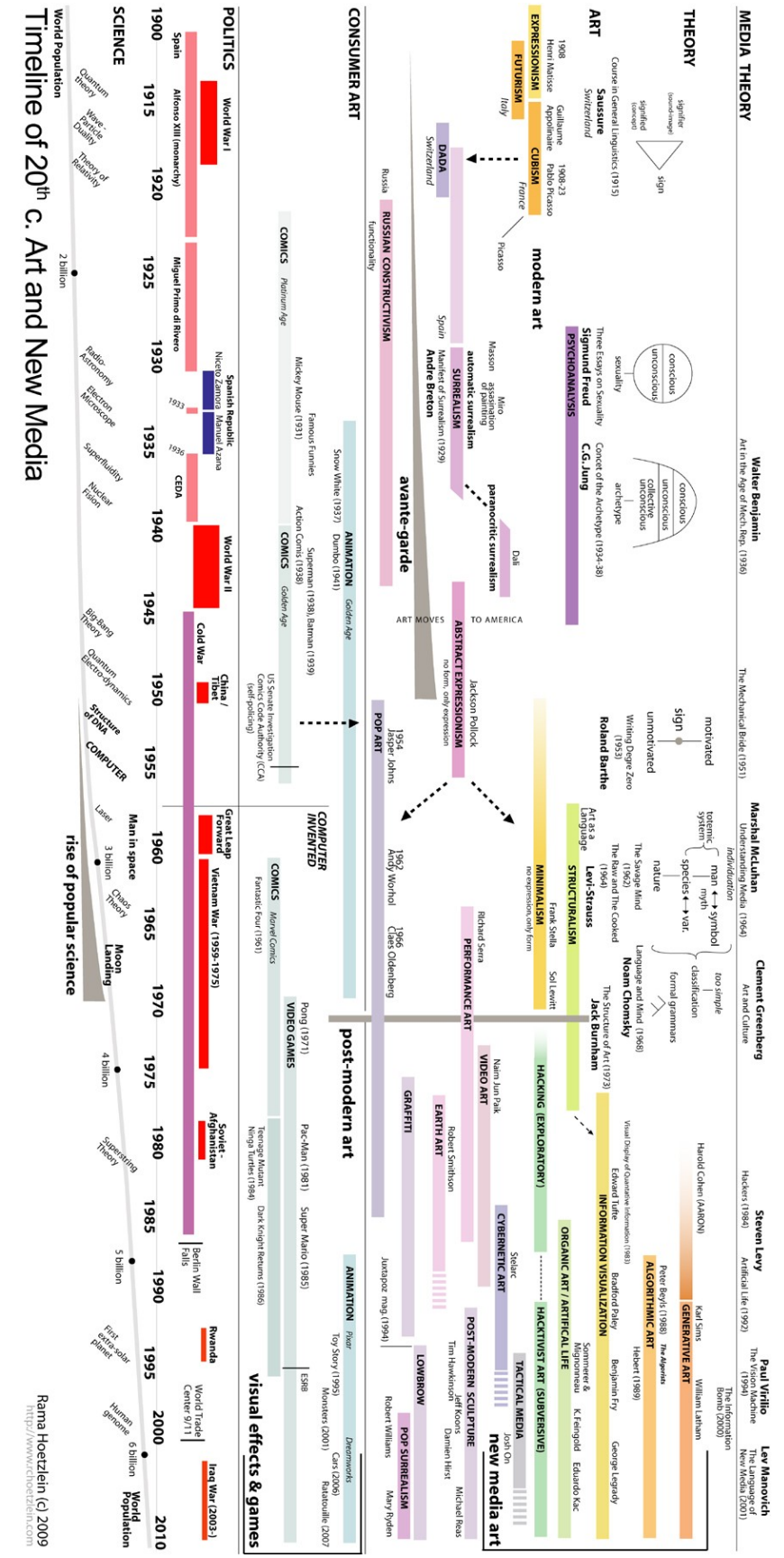
Listening Post (Ben Rubin and Mark Hansen, 2002-5)

http://www.earstudio.com/projects/listeningpost.html

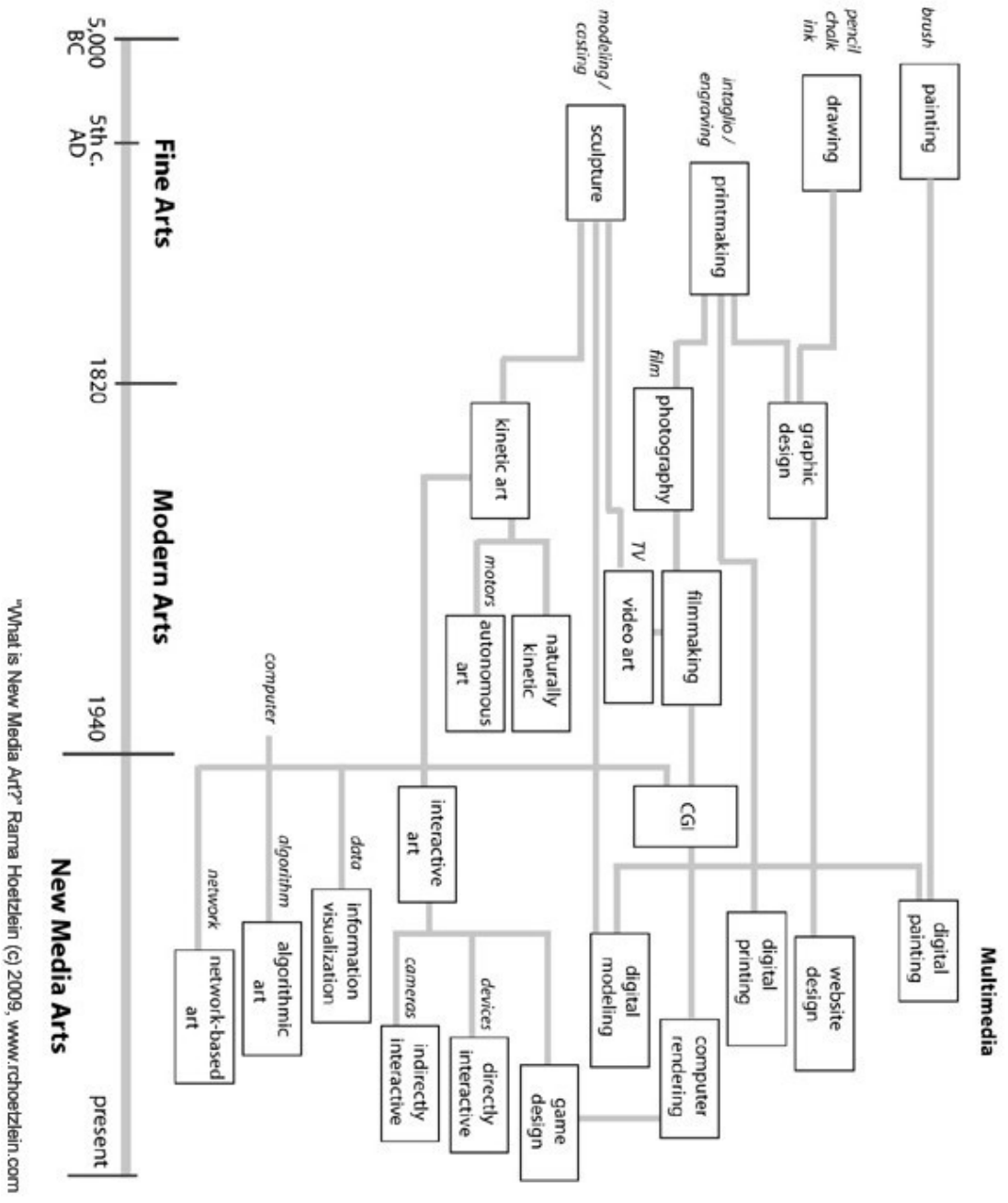
Newsmap (Marcos Weskamp and Dan Albritton, 2003)

http://marumushi.com/projects/newsmap

Timeline of 20th century art and new media



New Media Arts



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