Information Technology and Art: Concepts and State of the Practice

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INFORMATION TECHNOLOGY AND ART: CONCEPTS AND STATE OF THE PRACTICE

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Abstract
The intersection of information technology (IT) and art involves people from different disciplines with varying interests creating a milieu of interdisciplinary collaborations. In this context we explore the intersection of IT and art to understand different entities that are involved in the intersection. We do this by reviewing literature and reflecting and comparing our experiences from participation in five art projects. The objective is to develop a knowledge base at this interdisciplinary domain based on the interplay of the theoretical framework and our practical experience.

1 Introduction
The interaction between information technology (IT) and art is an increasing trend. Science, art and technology have been connected since the 60's, when scientists, artists, and inventors started to cooperate and use electronic instruments to create art. In 1960 Marshall McLuhan predicted the idea that the era of "machine-age" technology was next to close, and the electronic media were creating a new way to perform art [1].
The literature is full with examples of artists applying mathematics, robotic technology, and computing to the creation of art. The work in [2] is a good introduction to the merge of IT and art and introduces genetic art, algorithmic art, applications of complex systems and artificial intelligence. The intersection is drawing attention of people from diverse background and it is growing in size and scope. For these reasons, it is beneficiary for people interested in art and technology to know each other's background and interests well. In a multidisciplinary collaboration, the success depends on how well the different actors in the project collaborate and understand each other. See [3] for an introduction

about multidisciplinary issues. Meyer and others in [4] explains the collaboration process between artists and technologists.
The definitions of visual art have extended far beyond the canvas since the beginning of the twentieth century. The increased availability of computers has caused a burgeoning of computer based visual art, also known as digital art. This has developed into a broad range of computer graphics, animation, cybernetic sculptures, laser shows and Internet-gaming. While the aesthetic experience has always meant some interaction among the creator (artist), the creation (artwork), the viewer (spectator), the current "electronic age" allows a truly two-way involvement, with the possibility of input from both the creator and the viewer altering the creation.
The “new media art” is an umbrella term, which generically describes artwork that incorporates an element of new media technology. New media technologies are defined as technologies that were invented, or began integration into society from the mid 20th century. The most significant new technology, which has affected visual art is computer software, which enables individuals to digitally manipulate images. Traditional visual art is enriched through new way of expression: another art form, which has become prevalent in the digital age is “interactive art”. In this genre, the aim of the artist is to stimulate a two-way interaction between his works and the spectator. This process has become increasingly possible via new media technologies. It implicates creative activity in a context which now not only includes professionals such as graphic artists and composers, but the wider public as well. Spectators are no longer situated within a pure passive role: spectators today play an interactive role within the artist to create new media art.
The relationship between technology and visual art is well explained in [5] and [6]. In these works F. Popper introduces the concept of “synaesthesia” between art, human emotion and technology. The emphasis is on the visual aspects and their strict connection to emotions. Popper in his work “Art-Action and Participation” examines the interplay of art, craft, and technology in five major categories: laser and holographic art, video art, computer art, communication art, and installation demonstration and performance art [7]. At a time in which simulation and reality become interchangeable and humans and machines are intellectually connected, Popper began to study the new way of conceiving the visual arts through the experiences of other artists. Popper also looks at the social and political impact of the rapid communication of ideas, experience, and images. Popper in his works shows how the kinetics art influences all contemporary art expressions.
Cultural and social transformation from this age to nowadays elaborates a new method to reflect on art and technology. Nowadays, the number of artists participating in multimedia software games, interactive robotics and new electronic applications is continuously increasing in art projects like interactive art installations. As this intersection of art and technology grows, it involves people from different disciplines with different interests creating a milieu of interdisciplinary collaborations. At the Engineering Faculty of University of Catania and the Norwegian University of Science and Technology we explore the intersection of information technology and art to understand different entities that are involved in the intersection. In the general context of the intersection between IT and art we focus on three subsets of IT, which are software, electronics, and robotics. This choice is dictated by the nature of research and art projects we are working on.
The objective of this chapter is to provide a framework of the intersection between IT and art based on our theoretical (literature review) and practical work (participation to IT

intensive art projects). We have explored the intersection between technology and art through a deep investigation based on papers, articles and books, conferences, art projects, festivals and art centres, practical examples of interaction between information technology and art carried out in university of all over the world and in laboratories and research centres. We have explored this intersection through a detailed and systematic study of literature and we have also presented the criteria used to select the articles in order that the readers get an overview of the scope and the focus of the literature review. In [8] we have also identified the search strategies, including a list of searchable electronic database of scientific publications and a starting list of keywords. Relevant publications are those that address artist attitude towards technology, engineer attitude towards art, influence and usage of IT in art or of art in computing, and features of artistic software.
The rest the chapter is organized as follows. Section 2 provides the related literature organized in a framework. Section 3 uses the concepts described in the framework to describe our own research and art projects. Finally, section 4 discusses the differences and the similarities of these five projects and the advantages and the challenges of the provided framework.

2 The Conceptual Framework

The conceptual framework described in [8] is our attempt to clarify the intersection of IT and art by identifying the involved actors, their interests, place of interaction, and reasons behind collaboration. In this section we will present the conceptual framework. The study and our literature review is described by several entities such as "who", "where", "why" and "what" which stand, respectively, short for "who" are people involved, "where" the intersection take place, "why" the people are interested to the intersection and "what" tools or electronics or software are used in this intersection between IT and art.

2.1 Who

In the intersection between art and IT we find artists like cyber-artists, designers, software engineers [9,10], researchers, electronic and robotic engineers, theorists and critics [11] engineers and researchers [12,13,14]. The roles of artists, researchers, engineers and critics are neither exhaustive nor mutually exclusive. These roles have different backgrounds and viewpoints. One person can have many roles at the same time, for example, when the interactive filmmaker Florian Thalhofer creates the interactive documentary software Korsakov; he is both an artist and a software developer [15]. Technologists include people like software engineers and hardware engineers. But if we take the wider intersection of technology and art, technologists will include engineers from different disciplines like, mechanical, robotics and electrical engineers, just to cite some examples. In the following we will tend to refer to engineers and artists without trying to classify, each time, which kind of engineer and artist we are referring to.
Nowadays software, electronics, mathematics, robotic technology, genetic art, algorithmic art, led installations and artificial intelligence in union with music, dance, sculpture and painting expression are used to involve the audience as part of an interactive dialog with technology. Ref. [16] provides a good example of explanation about how these different technologies can be used to involve audience and create interactive dialog processes.

The role of software developer is explained for example by Machin in [17]. In order to build software tools for artists, pragmatics analysis of context and behaviour is crucial because art is heavily immersed in practice and action, and because art is valued on its ability to communicate [18].
At the same time other artists, such as Marco Cardini in his cyber art installation, want to create an immersive atmosphere in which the artist set an interactive dialog with audience involved [19]. In [20, 21, 22] a new way to create visual art is explored, through the research of strange attractors, patterns and shapes, through kinematics ad robotics. The importance of aesthetics in engineering is another topic discussed several times by various authors such as for example Adams [23].

2.2 Where

The dimension of the framework 'where' refers to the places or the context where IT and art meets each other. It is common that the intersection happens in the context of some institutional support. In the framework presented in [8], the following contexts are mentioned: educational institutes such as Art schools, computing schools, software industry, research institutes, art projects and art centres and festivals.
Another place of intersection between technology and art is Internet: in the recent years more and more artists are exploring the Internet as a medium to reach their audience and spectators [24], so Internet has became a new dimension where people can create different kind of web-art through special tool for artist [25, 26, 27, 28].
In art schools and computing schools interdisciplinary courses are conducted which include students from both art, computing discipline, robotic course, complex systems course [29]. Besides these interdisciplinary courses, there are also cases where the need of computing education is realized in the art discipline, and the need of art education in the computing discipline.
In addition to IT and entertainment industry, art and computing schools, there are research institutes where a research setting is intentionally created for artists and technologists to work closely together. These research institutes may be a part of a university or an industry. Often, this kind of collaboration is done through "Artist-in-residence" programs, for example, the Xerox PARC artist-in-residence program [30], COSTART project [31], "Robot Artist in Resident Project" [32]. The objectives of these programs are fostering of innovation and creativity. In an art project, the objective is to realize an artwork, whose main mission is to convey the artistic message that the artist wants to express.

2.3 Why

The 'Why' dimension refers to the reasons why artists and technologists want to interact. One of the main reasons artists seek help from the technologists is to get support with the tools that they need for the realizations of their artwork [33].
We make an attempt to classify the reasons for cooperation into six categories:

- **Learning about interdisciplinary cooperation**. The potential reciprocal interaction between artists and technologists is challenged by the demands of the user (artists). These demands stimulate engineers and researchers to extend technology with possibilities that go beyond its intended use [33].

– **Innovation of products and interfaces.** As an example we look into Human-Robot-Interaction (HRI), which aims at developing principles and algorithms to allow more natural and effective communication and interaction between humans and robots. Research ranges from how humans will work with remote, tele-operated unmanned vehicles to peer-to-peer collaboration with anthropomorphic robots. Many researchers in the field of HRI study how humans collaborate and interact and use those studies to motivate how robots should interact with humans [34].

– **Aesthetics in computing.** In [35] Fishwick reports the result of a survey on the usefulness of aesthetic methods on several areas of computer science. The result shows that data structure, algorithms, digital logic, computer architecture was chosen by the respondents as some of the fields where aesthetic computing can be used. Information visualization and software visualization are other fields that can contribute to bringing art/aesthetics inside of computing [36]. Paul Fishwick has coined the term "Aesthetic Computing" to refer to a new area of study, which is concerned with the impact and effects of aesthetics on the field of computing. As an example, the discrete models found in computing can be transformed into visual and interactive models, which might increase the understanding of the students. Fishwick represents a method for customizing discrete structures found in mathematics, programming and computer simulation. In [35] discrete models are transformed to geometric models. Moreover, Adams addresses the importance of teaching aesthetics in engineering education and the role of aesthetics in engineering [37].

– **Develop and exhibit IT based Artworks.** One main motivation for the cooperation between artists and engineers is that large artistic projects must rely on IT knowledge to be successful. For example, in [17] Machin underlines the importance of mature requirement elicitation techniques, which enable the capture of the artist's ideas without inhibiting the artistic process. Researchers are interested in comparing the software development methods in art projects and analyze which ones suit better an art project in a certain context. In [13] Candy and Edmonds investigate the most appropriate evaluation methods in software intensive art projects and if the evaluation should be done by artists or it should include software engineers as well. Where the artworks are implemented in limited time and budget and where artists lead the project, the maintenance and upgrading issues are often overlooked. Thus the maintenance and upgrade of these kinds of software supported artworks become one of the prime sectors where art projects need engineering help.

– **Reflection on society through art.** Erkki Huhtamo, Mathew Fuller, Florian Cramer, Jeffery Cox, Lev Manovich fall in this category. The people in this category are often called theorist or art critics whose main role is to besides other criticize artworks and social and cultural affects of art in our society. Many of the people mentioned here have several roles, varying from artist, teacher, theorist and programmer. For example Erkki Huhatamo is a lecturer, researcher, writer and curator all by the same time. Manovich is a lecturer and writer of many articles and books. His book, "The Language of New Media" is considered by many reviewers to be the first rigorous theorization of the subject. Even though there might not be a person who can be termed as only theorist, we mention them as a separate category here as we find a significant portion of research articles that we have reviewed are contributed by these theorists and art critics.

- **Dissemination of research results**. In recent years emergent scientists create interactive installations that allow for immersive relationships to develop between the spectator and the artwork. For examples one of the five presented projects in the Section 3 is “Chaotic Robots for Art”: the realization of this, takes inspiration from the theory of strange attractors of Chua’s circuit [38] and from the innovative conception of visual art developed by Frank Popper. The gallery of strange attractors of the Chua’s circuit [39, 40] is widely known in the literature. The wide variety of patterns based on strange attractors achieved an aesthetic level such that more people worked in order to emphasize in art the impressive features of strange attractors considering chaos as bridge between Art and Science. Many engineers such as Moura L., and Reichardt J., also start in their work a new way to create cyber paint through robotics [41], [42]. The role played by simple mechanical systems that generates complex strange attractors has been remarked in different works and with different strategy, and the emergence concepts in generating new patterns has been emphasized in researches with the final objective to demonstrate the new paradigm of shapes and complexity [43, 44]. There is a growing tendency to develop new kind of robots for art [45] and the research of new modelling methods with a biological approach applied to entertainment robotics and bio-robotics [46]. In this sense for example bio-robotics for art is ever closer to the mechanism that ensure that a robot can have a brain similar to the man’s brain. For example a new class of visual-motor neurons, recently discovered in the monkey’s brain, the so called “Mirror neurons” are used in robotics and they represent today the key element in the understanding of phenomena like imitation, evolution of language, autism, knowledge of the behaviour of others [47]. In [48] Wolpert studied practical examples and models for the motor commands inside the brain through the concepts of mirror neurons and with the background of the Simulation theory of Mind-Reading of Gallese and Goldman, [49]. All the concepts and the theories studied by Wolpert and Gallese are often used in robotics because of the increasing trend to combine art and bio-inspired robotics.

In Table 1 we give a visual representation of the where, who, and why dimension.

Table1: Who, where, and why dimension of the intersection of software and art.

Who Where	Artists	IT Engineers	Researchers	Theorists
Education Institutes	Learning, Develop	Learning	Learning, Innovation	
Research Institutes	Innovation, Disseminate	Innovation, Aesthetics, Disseminate	Learning, Innovation, Disseminate	
IT Industry	Innovation	Innovation	Innovation	
Public Art projects	Develop	Develop, Innovation	Learning	Reflection
Festivals	Learning, Develop	Innovation, Learning	Disseminate	Reflection

2.4 What

The 'what' dimension of the framework refers to the tools and technologies used in the intersection of art and IT. After identifying people (who), reasons behind their interest at the intersection (why) and the places/sectors (where) art intersects with software, here we present some practical examples of what (tools and technologies) binds the relationship between software and art. In the framework presented in [8] different categories of tools and software are identified, for example, graphics manipulation software, multimedia authoring, 3D graphics manipulation software, sound manipulation software, video manipulation software, and other applications.

Here we take a wider perspective by looking at kinetic art in addition to software art. The term kinetic art refers to a particular class of artistic sculpture made primarily at the end of years 1950s. Kinetics art contains moving parts or depends on motion for its effect: for example wind, a motor, or the observer generally powers the moving parts.

Jean Tinguely is another artist that with his works realises an infinity of constructivist images by means of constructions whose elements rotate with different, incommensurable speeds. The Meta Matics of Tinguely at CAMeC (Centro Arte Moderna e Contemporanea at La Spezia) are machines, which automatically create infinite sequences of drawings. The principle of these machines is that of Lissajous figures, i.e: the superposition of different harmonic oscillations [50]. Carried out in a precise way, such movements result in stark geometric images with pretty Moiré-pattern-effects: this is what we see in many early computer-generated graphics. But the mechanical imperfections of Tinguely's machines create an abundance of irregularities, deviations and interruptions, which result in a suggestion of expressive human gesture. The Meta

Matics presented a pastiche of the abstract-expressive painting of the 1950's. Their position in art history may be compared with Jackson Pollock's all-over's.

Pontus Hultèn organized a futuristic exhibition on art and mechanical technology at the Museum of Modern Art in New York (MOMA) in 1968 with the title "The Machine: As Seen at the End of the Mechanical Age". Today this art sculpture of P. Hulten is shown at MOMA gallery of New York [51]. Pontus Hultèn understood such transformation to make an impact on the audience visually, but often on the exhibition space as well via sound, smell, taste, image and light effects.

For visual artists the computer is a design tool. Utilising the available techniques of pasting, erasing, displacement, and multiplication, artists are able to develop their own 'electronic palette' to assist them with their creations. Researchers, like Oates, look at computer art as an information system and propose to extend IS research agenda to include computer art [52].

The technologies used for creating visual art can enable collaboration, lending themselves to sharing and augmenting by creative effort similar to the open source movement, in which users can collaborate to create unique pieces of art.

Artists tend to use software for different purposes. Quite often they use commercial software; often they are interested in open source software as a cheap alternative. In few cases, artists develop their own software. Most of the time they use the software as it was intended to be used by the creator of the software but sometimes they can be creative and use it in a different way which was not intended. For example the artist Jen Grey used the proprietary software Surface Drawing in a unique way to draw live models, a purpose which was not intended [53]. Some software is used as a tool to develop artwork; some as a media to support artists' activities indirectly (for example collaboration) while others are general purpose programming languages used to build applications. Besides these, there is also customized software i.e., software that is built for a specific artistic purpose. Several papers mention this kind of software which was developed by either artists alone, or with the help of programmers as part of an art project. These tools provide the reader an overview of what type of software and tools are used or required by the artists.

Artwork support tools, i.e. tools used to develop artworks, are mainly special purpose artistic software which specializes on some tasks such as visualization, sound manipulation or animation.

Apart from the artwork support tools there are other tools and software that artists use for supporting other activities such as communication, publicity, sharing works, ideas etc. Internet and Web tools have become not only a medium for the artist to publish and present their work and activities, but also a medium for communicating and collaborating with other artists. "The digital arts site Rhizome is recognized for the crucial role it plays enabling exchange and collaboration among artists through the network" states Walden in his review on the book Net_Condition: Art and Global Media [54]. The other purposes of website include, publishing artworks, selling art products, virtual tour of museums and creating online communities, discussion groups or forums, and blogging.

Domain specific programming language are preferred by artists compared to the general purpose programming languages unless the artist does not aspire to be a professional programmer. This is because general languages can be daunting due to the steep learning curve associated with learning programming. Besides, artists often prefer to work with intermediate tools where the need for programming is reduced. But that does not make any limitation for artists to learn the general purpose programming languages. Some of the papers that we have reviewed mention a number of general purpose languages which were used to realize artworks or some artistic software, for example, C++, ActionScript, UML, 2D OpenGL.

Moreover the role of open source software has to be mentioned as an important factor for making artists more interested to software. Artists tend to move towards using open source technology not only because they are cheap, even free of charge, but also because many artists believe in the open source ideology. In [55] Halonen mentions that new media art is based on cooperation to a greater degree than many art forms that can be created alone. He identified four groups with diverse motives: i) using open source network as an important reference for professional image, ii) using open source projects as a platform for learning, iii) an opportunity to seek jobs and iv) enrich professional networks. From our project experience, we identified that some artists want to have open source projects so that they can build an interested community around the project which might assist in the further development, upgrade and maintenance of the project at a low cost. Open source and free software usage in artists community is also encouraged by different art festivals such as piksel (http://www.piksel.org), makeart (http://makeart.goto10.org/). The interest is also visible by the activities of different art organizations/institutes such as APO33 (http://apo33.org) ap/xxxxx (http://1010.co.uk/) Piet Zwart Institute (http://pzwart.wdka.hro.nl/).

3 Description of the Projects

In this section we use the framework introduced to present five of our projects. Each project is described by a short introduction, followed by the who (and when), where, why, and what perspectives. In the introduction we try to reconstruct the artistic idea or the research motivation for the artwork. This partly overlaps with the why dimension.

3.1 Flyndre

Flyndre [56] is an interactive art installation. It has an interactive sound system that has the artistic goal to reflect the nature around the sculpture. To implement this goal the produced sound changes depending on parameters like the local time, light level, temperature, water level, etc. Flyndre relies on Improsculpt, a software tool for live sampling and manipulation, algorithmic composition and improvised audio manipulation in real time.

Figure 1. Flyndre.

Who

The sculpture was built by Nils Aas. Then work of adding sound features was initiated in 2003 by composer, musician and programmer Øyvind Brandtsegg. Brandtsegg used a customized version of his music composition tool Improsculpt. Brandsegg had started the development of Improsculpt in 2000 and the first version of the software was completed in 2001. Brandtsegg collaborated with engineers regarding the development, testing and deployment of the sound system. A group of software engineering students and researchers at NTNU has re-factored the software modular architecture.

The first version of the software was a single script file that was hard to modify, maintain and upgrade. Students from NTNU were involved to develop and improve aspects of Improsculpt from the software engineering point of view. The software architecture has been re-designed to make it modular, easy to extend and modify. Another group of students with multidisciplinary background has improved the Internet based communication between the sculpture and the servers at NTNU that process sounds. The students developed the technical framework for the networking and the sensors systems (i.e. for capturing parameters by the sensors and for transferring them via the Internet to the sound processing station). A third group has developed an open source version of Improscuplt and published it as open source by uploading a project in Sourceforge. Besides, utilization of wiki and Concurrent Versioning System (CVS) introduced by the software engineers was found to be very useful by the artist. A summary of these activities is published in [56].

Where

The intersection between IT and art in this case is in the context of a real life art project. It is a public art project meaning that the artwork is placed in a public place. According to the presented framework, it falls in the category of public art. The student work falls in the category of educational institutes. The sculpture is located in Inderøy, Norway. Visitors can walk around the sculpture or sit nearby to watch it and listen to its music.

Why

In case of Flyndre the collaboration is between artists, IT engineers, and researchers. The project involves many students as mentioned in the 'who' part of the description. The main reason behind the intersection is technological help to the artist who wants to develop and exhibit an IT based artwork. The artist needed technological support to improve the architecture of Improsculpt. For installing the sound on Flyndre, the artist collaborated with the sound engineers. From the artist point of view cooperation is motivated by his desire to use technology in the artwork and learn about tools and technology. Researchers and engineers were motivated by learning goals.

What

The sound installation Flyndre makes use of a loudspeaker technique in which the sound is transferred to the metal in the sculpture. The music is influenced by parameters such as high tide and low tide, the time of year, light and temperature, and thus reflects the nature around the sculpture. The computer that calculates the sound from the sensor data using the Improsculpt software is located in Trondheim. The sensor data and the sound signals are streamed via the Internet between Inderøy and Trondheim.
There is a website of the project which provides a live streaming of the sound that is played by the sculpture. The web site includes on-the-fly animated Flash application that displays the current parameters of the environment and the current music played by the sculpture. The archive of the previously played music by the sculpture is also accessible through the web site. At the controlling core of the sound installation there is a custom version of the software Improsculpt. It is software for live sampling and manipulation, algorithmic composition and improvised audio manipulation in real time. The main tools and technologies used in the project are Csound, Python, Wiki, Sourceforge, and CVS.

3.2 Sonic Onyx

Sonic Onyx is an interactive sculpture that enables people to send files and plays them back. Anyone located inside the space of the sculpture can send text, image or sound files from Bluetooth enabled handheld devices such as mobile phones or laptops. The received files are converted into sound and mixed with other sound files. The converted sound file is then played back by the sculpture. The project is an example of artists, engineers, and researchers working together. There are many actors involved in the project making it a multidisciplinary project and collaboration.

Figure 2. Sonic Onyx.

Who

The actors involved in the project come from different backgrounds. The project includes the people involved from the development phase of the project to the users of the artwork. The actors of the project are namely the artist, software engineers, and researchers. Besides these actors there are the users which include students and teachers of the school. Samir M'Kadmi is the artist of the project. There are five software engineering students and their supervisor, two IT consultants, three researchers (from NTNU). The physical structure was build by a mechanical company. The users, or visitors of the sculpture are mainly students and teachers of the school but anyone can visit the sculpture.

Why

The artist needed help from the software engineers and developers to develop the artwork. Technology consultants had an important role here as software developers were still students and had lack of experience. Researchers were interested to observe and analyze different characteristics of the project. For the students (developers of the project), it is also a reason to learn to work in a multidisciplinary project apart from the main objective of realizing the artwork and providing technology and tools support for the project. The technology consultant worked also in providing technology and tool support both to the artists and software developers.

Where

According to the framework the intersection of art and technology comes here in the form of an art project. The final objective of the project has been to create a piece of artwork which will is open for public and mounted in a public space. It falls in the category of public art and art project.

What

The software tools and technologies that are used in the project are mainly open source. Linux has been used as the operating system of the server. Pure Data has been used for sound processing and Python has been used for the application.

3.3 The Open Wall

The Open Wall is a 80 × 30 pixels resolution 201 inch LED screen. The Open Wall is a wall-mounted LED installation. One goal of the Open Wall project is to inspire reflection about Information and Communication Technology with focus on openness, copyrights, and authorship [57].

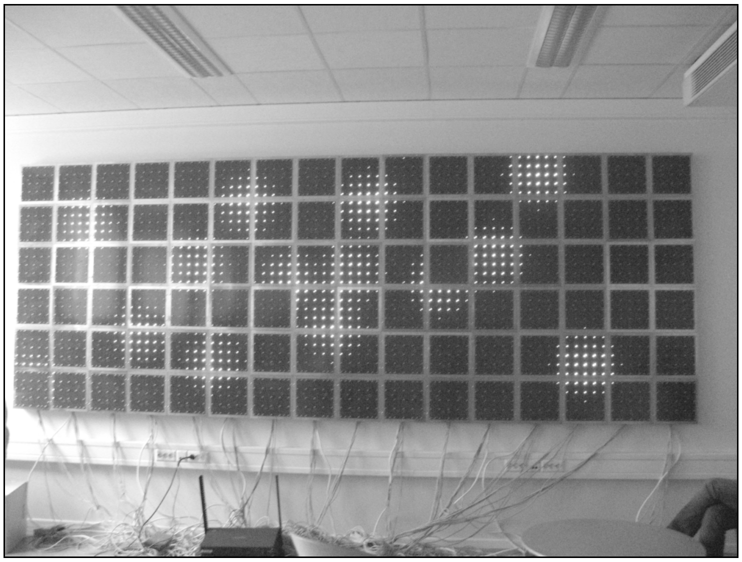

Figure 3. The Open Wall.

Who

In 2005 architect Åsmund Gamlesæter initiates this project as he wanted to build a LED facade for an experimental house. The house was built by a group of students and was supposed to stay for one year. The architect asked CIS (Computer and Information Science) department for help and cooperation. Hardware design was the most important task when the installation was built for the first time.

When the experimental house was removed, the boards were taken over by CIS. In 2007, as a result of a master thesis, the Open Wall software goes open source with BSD license. In January 2008 three groups of students re-build the installation during a three weeks intensive course. The students reuse the existent hardware and software and develop the missing pieces of the software and the content.

Why

The projects has many actors, each having different point of views. Engineers and researchers see the cooperation with artists as a source of inspiration and a possibility to reflect about technology and find inspiration for innovations. In particular, the SArt perspective is to inspire reflection about Information and Communication Technology with focus on openness, copyrights, and authorship. Artists want to engage in projects like this to explore the possibility of technology and interaction with technical people and researchers. Students choose this project as part of their curriculum because they like to co-operate with other students with different background. Technology gets old quickly.

Technologists experience this inevitable assumption as a source of both frustration and motivation to learn all the time about new technology. An important lesson we learn in this project is that visitors criticize our work as the technology, which was developed 3 years ago (at time of writing this paper). An important question that arise is therefore: "how important is the type and novelty of technology in a cooperation project between artists and technologists? ".

Where

The installation is first installed on the façade of an experimental house in the town of Trondheim. A sister installation is build and installed in a discothèque in town. The current Open Wall is in a meeting room at the Department of CIS. The installation is available through a WEB interface, which allows its users to both upload and see pictures on the Open Wall. The software of the installation is available at sourceforge.net.

What

The Open Wall is a wall mounted LED piece consisting of 96 circuits boards (16 x 6 boards) containing 2400 orange LED lights with 5 cm distance in all directions to the next light. The wall is 480 cm long and 180 cm high. Each board has 25 LED lights on its surface, emitting light with 99 possible intensities. Each board has its own microprocessor, power connection, and Ethernet. Connection to the main controller device is established through a set of switches or hubs. In short, this is a massive parallel network of boards. The software governing the installation is written in Java and available at http://sart.svn.sourceforge.net. In the context of a multidisciplinary project work, three groups have developed 3 projects based on The Open Wall, and one of the groups, inspired by living art which would 'die' if nobody cares about it, presents a bunny that changes its state (i.e. sleep, awake, excited) according to activities in the room. The second group brings the discussion to political and social themes by reflecting about the wall and its open source and creative possibilities. They use the wall to display texts from "Steal This Book" by Hoffman '70. The idea of the third group is to display an ECG wave propagating along the wall screen as on an ECG monitor. All three groups discuss the possibilities to include interactivity through sensors (e.g. movement in "Lux Vitae", people position "Bull devil 7", sound level in "Heart and software"). With the installation in place, the employees of CIS start to play with it and develop a web based interface which enables users to upload and see the content of the wall with an Internet browser.

3.4 Chaotic Robots For Art

This research begins from the study of the cooperative behaviour of inspection robots by combining the concept of art and complex systems. The role of chaotic synchronization in the generation of the kinematic trajectory shows the discovering of new aesthetic features of the motion in mechanical control systems.

The target of the project is to show emergent spatial attractors generated by clusters of robots called "Chaotic Robots for Art". The project idea takes inspiration from our studies on groups of robots to working together, with different skills. We use dynamical chaos instead of classical random algorithms to drive robots in a given arena, and we use typical chaotic laws to drive our robots. The use in engineering-entertainment area of interactive technologies suggests the idea to establish new ways and new methods to create art with the intent to satisfy an increasing need to bring new technologies to users.

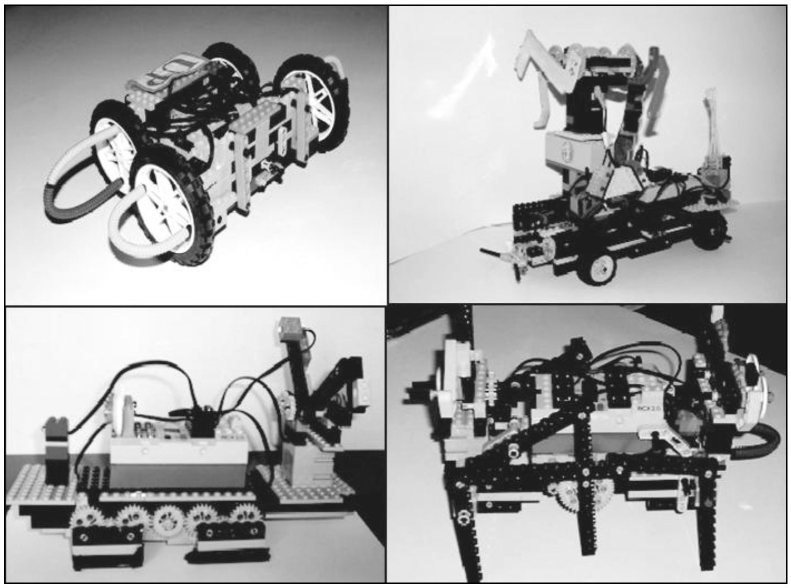

Figure 4. The four Chaotic Robots for Art.

Who

The actors involved in the project are three engineers (two electronic engineers and one software engineer) that take inspiration from different artists, researchers and robotic engineers, cyber-artist, theorists and critics.
From the late of 2005 at laboratories of University of Catania Luigi Fortuna, Mattia Frasca and Cristoforo Camerano began to apply on entertainment robotics their previous results of nonlinear dynamics theory for the generation of patterns and strange attractors [20].
These three artists engineers try to create an immersive relationships between the spectator and the artwork: these relationships are controlled by complex sensor-triggered interfaces which incorporate movement, speech, touch and light information on entertainment robotics.

Where

The final objective of this art project is to create a piece of artwork mounted in a public space like museums, art schools and researcher centres. Up to now people can manage the "Chaotic Robots" to create art at the DIEES laboratories of the Engineering Faculty at the University of Catania.

Why

This research and art project includes cooperative robots, strange attractors synchronization, and led trajectories analysis. It is inspired by the Popper theories [6], and aims at integrating robots in virtual arts. The key element is the spectator interaction

and participation. The reflection in a 3D space of the shapes and patterns of cooperative robots generate the artwork.
Another important key-element in the background of the presented research is the idea to find similarities through a real dancer and a dancer robot.
For this reason in the middle part of our experiments, we tried to compare the trajectories of our chaotic dancer robot with the trajectories of a real dancer that plays in the same room in the given arena. The research revealed the discovery of a class of strange trajectories and patterns that are shown in Fig.5.
The hypothesis is that the possibilities to reveal the beauty and the charm of typical chaotic forms of strange attractors can suggest a possible interesting alternative for future development of entertainment robots applications for art and this new way of establishing interactive dialogs between audience and the used technology can became a new way to create immersive Cybernetic-Painting-Art.

What

HRI (introduce in the framework in the previous section) is implemented through a SCADA-System (Supervisory Control And Data Acquisition-System) that is a simple GUI (Graphical User Interface) that is able to control the chaotic robots. The target of the project is to show emergent spatial attractors for art generated by clusters of robots. The research revealed the generation of emerging sets of strange attractors, spatially distributed, and the generation of a gallery of strange attractors in a 3D space. We realized mobile robots by using different kinematic structures and the Lego Mindstorms system allowed us to easily implement them.
The task of each robot in the cluster is to provide specific functions and to explore the environment in different points in order to get complete specific information.
The scenario where the measurements must be taken is a three-dimensional space with spatial coordinates (x; y; z) where equipments must be dynamically located in order to perform different types of investigations and where the kinematism assures the realization of a congruent set of detections. Randomized trajectories are generated for each robot and a random search algorithm is used to improve the detection performance of the clusters. In particular, instead of using randomized positions a strategy based on chaotic trajectories has been conceived. In this way, even if a randomized motion is performed, the robots in the cluster can be synchronized each other to coordinate their behaviour.
The use of synchronized clusters of robots is adopted in this work in order to implement coordination of robot trajectories both inside each cluster and among the various clusters and at the same time this mechanism of synchronization should be adopted in order to have symmetries in the trajectories.
The trajectories that are shown in the Fig.5 represent a strange attractor gallery of experimental routes generated by using mechanical device synchronization. In particular, the control strategy adopted consists in emphasizing the cooperation and the randomized motion avoiding collisions among robots. In order to trace the trajectories, the robots were equipped with markers (different led were equipped on each robot) and the whole environment was totally obscured. Then, photos with long exposure times or videos of the robot motions were taken. In the latter case the video is then post-processed in order to have the complete trajectory of the robot. In all experiments shown the size of the arena was fixed to 3,5m X 4m and the height of the arena walls was 40cm. The control laws used for all robots is a typical logistic function or other chaotic laws. Actually, in

spite of each robot being fed with the same set of rules, its detailed behaviour over time is unpredictable, and each instance of the outcome produced under similar conditions is always a singular event, dissimilar from any other.
The robots controlled by chaotic laws perform interesting chaotic dynamics such as "Multi Scroll" Attractor .

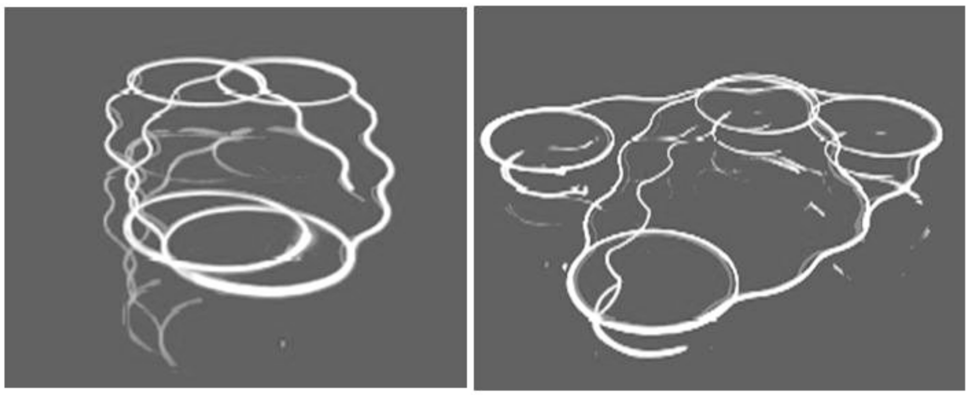

Figure 5. The robots perform typical Chaotic Attractors.

By analysing the above described course of action of the set of four robots, we note that from initial random steps of the procedure, a progressive arrangement of patterns emerges, covering the shown trajectories. These autocatalytic patterns are definitively non-random structures that are mainly composed of clusters of ink traces and patches: this shows the artistic emergence of complexity in real time and space.

3.5 Interactive Bubble Robots For Art

This project takes inspiration from the study of the interactive processes between human and robot defined as HRI and from the study of Mirror Neurons (as described in the framework in section 2) to study elements of imitation and learning of the movement sequences.
The target of the project is to show artistic emergent spatial patterns that reflect the processes of learning through imitation and the processes of understanding the behaviour of others. The study reveals the opportunity to implement through two identical Bubble Robots the concepts of the "Mirror Neurons" to study the applications in art of the 3D spatial shapes described by the trajectories of the robots.

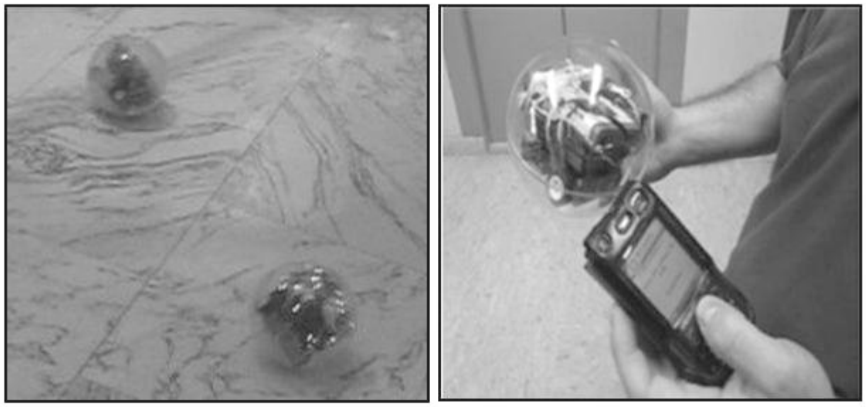

Figure 6. The two Interactive Bubble Robots for Art.

Who
HRI is a multidisciplinary field with contributions from the fields of human-computer interaction, artificial intelligence, robotics, robotics art, bio-robotics, natural language understanding and social science. In this context, DIEES researchers are currently exploring different applications areas for HRI systems. Application-oriented research is used to help bring current robotics technologies to bear against problems that exist in today society.

Where
Public space like museums, art schools and research centres can benefit from this research art project. This art project has the final scope to create a piece of artwork opened to the public. At moment people can work with the "Interactive Bubble Robots for Art" to create art at DIEES laboratories at the University of Catania.

Why
The mechanism of Mirror Neurons in the brain of the macaque is able to show the congruence between the observed action and the executed action. The Simulation theory of Mind-Reading (Gallese and Goldman, 1998) requires two different kinds of simulation: "Predictive" simulation that, under the hypothesis that the observer has the same final goal of the observed one, after the simulation process results in an action, and a "Retrodictive" simulation that represents a "Postdictive" simulation that produces the same observed action by predicting it.
Motor control theory, studied by Wolpert [48], requires two different kinds of motor commands. The ″Action-to-Goal″ model receives information about an action and then makes a goal for it, while in the ″Goal-to-Action″ model one system generates a specific action for the goal that is shown as input. At the same time, the ″Forward Model″ (still proposed by Wolpert) represents a ″predictor″ receiving a replica of the motor command and generating the expected action for it. On the contrary, the ″Inverse Model″ represents a ″controller″ and produces motor commands that are specific to realize a desired final goal. Researchers used this biology models to perform a simulation model for Art applications through two identical rolling robots that implemented the mechanism of mirror neurons.

What

The two rolling robots are equipped with special sensors to detect light and sound. In the upper side of robot structure there are 21 leds used for the implementation of the mechanism of imitation of mirror neurons. The sphere that surrounds the robot is in plastic, and consists of two matching halves. The first Bubble Robot performs his chaotic trajectory in the given arena according to a chaotic control law based on logistic map. The second Bubble Robot has a special control unit that contains the Mirror Neurons "neural net" software implementing the imitation mechanism. With this procedure, the two Bubble Robots can be distinguished as an "Observer Robot" and an "Observed Robot".

When one robot moves in the arena, the trajectories are mapped through the flash lights of the leds. The "Observer Robot" is able to understand and learn through imitation. In fact the led system of the first robot activates the mirror neurons of the second robot. In our model, the vision (visual neuron) is represented by the sensors of the "Observer Robot" which detect variation of the light emitted by the first robot. The "Observer" Bubble Robot reacts as a monkey when it sees another monkey that performs a behavior similar to its personal behaviour and initiates to imitate the first monkey.

Through the described research, a model of the mirror neurons system has been applied to robotics. The model implements at each stage an unsupervised learning mechanism, and the experiment seems to confirm that the model applied to the Chaotic Bubble Robots provides a direct support for the simulation theories of Mind-Reading and the interpretation of the inverse model of the control loop [48, 49].

The robots are able to understand and learn through imitation: a robot comes in harmony with each other through these neurons. A robot can create art and the other is able to imitate his gesture of art.

4 Discussion and Conclusion

In this chapter we have given an introduction to the multidisciplinary field of IT and art by giving some hints of the historical perspective (in the introduction) and by providing four categories (who, where, why, what) that can be used to reflect about existing literature. We have used these four viewpoints to describe five projects we currently work with. Our literature classification is unavoidably incomplete. First, even if we have used a systematic review to collect papers at the intersection of IT and art, we are aware that we have covered a limited part of the extensive literature in the field. This depends from the fact that all the authors have a background as IT researchers. This happens even if, as shown by the description of our projects, we are used to work with artists and to listen to their perspective. In the future we have to continue and intensify this cooperation with artists. Moreover we aim at working together with art theorists to enrich our horizon concerning literature sources.

Table 2: Summary of the five projects according to the framework.

Project	Who	Where	Why	What
Flyndre	Programming artist & researchers & engineers	Public (sculpture park) and Internet (flyndresang.no)	& Learning	Sound Python C-Sound Improsculpt Flash
Sonic Onyx	Artist & researchers & engineers	Public (school)	Develop & Learning	Sound & Light Linux Pure Data Python
The Open Wall	Architect & researchers (hw and sw)	1. Public (house facade) 2. Research (meeting room) & Internet (theopenwall.no)	1. Develop 2. Learning & Aestetics & reflection & Disseminate	Led Art Linux Java Wiki
Chaotic Robots for Art	Researchers & artists (dancers)	Research	Develop & Learning & Aestetics & Disseminate	Kinematics, Chaos Theory, C-language, Trajectories Led Art
Interactive Bubble Robots for Art	Researchers	Research	Aestetics & Disseminate	Kinematics, Java, Mirror Neurons, Trajectories Led Art

As shown in Table 2, the framework makes possible the comparison of different art projects. We have used the framework to compare three Norwegian projects with two Italian projects and we claim that the framework enables us to understand the similarities and to reflect over the differences. On the "who" dimension we notice that all the five projects encompass researchers. Concerning the "why" dimension, our framework focus on the motivation of the cooperation. At the same time an artwork is always driven by an artistic idea and the cooperation between the actors aiming at realizing the artwork is strongly related to the artistic idea even if it does not necessarily coincide with it.

From the five projects we can observe few trends. In project "Sonic Onyx" and "Flyndre", the artists are the driving force and they first came up with the ideas to create artworks using technology. In these two projects, artists came into contacts with the technologists to seek help for the development of the artworks. In projects "Chaotic Robots for Art" and "Interactive Bubble Robots for Art", technologists developed ideas to create artwork using robotics. The resulted works represents the urge/ desire of technologists to create artistic or aesthetic applications using technology. In the project "Chaotic Robots for Art" the technologists collaborated with artists to explore the artistic possibilities of application of chaotic laws into robotics. In the project "The Open Wall" the initiation in the project and the collaboration between artists and technologists is multifaceted. An architect initiated the project. The artistic possibilities are kept open and addressed by both technologists and artists who challenge the technical limitations of the wall to express novel applications as well as enhancing the capabilities of "The Open Wall".

In the projects “Chaotic Robots for Art” and “Interactive Bubble Robots for Art”, kinematics is an important tool to create three-dimensional artwork: this connects IT based art with kinetic art. The kinematics aspects of Chaotic Robots and Bubble Robots give inspiration to two dimensional artworks, like “The Open Wall” and open up for possibilities of transforming static two dimensional led systems as the Open Wall into tree-dimensional artworks.
Presenting the projects over the framework shows us that the “who, why, where, what” characteristics can be matched properly with framework. The concepts of the framework are present in our projects.
On the “what” column, devoted to tools and techniques, we give the main functionalities of the artworks, being sound for “Flyndre”, sound and light for “Sonic Onyx”, led art for “The Open Wall”, and Kinematics and led art for the two projects “Chaotic Robots for Art” and “Interactive Bubble Robots for Art”.
The framework allows us to reflect about art projects and to pose questions that can generate research questions and inspiration for further work. We conclude our work with a set of questions that are important for us. Here we list the questions that we have developed by looking at the combination of the theoretical framework and our practical projects and that will drive our work in the future years.

- **Who**: Given an artwork. Who is the author? Who is the responsible? Which roles are driving the project? Why do we miss one role, like for example theorists in our five projects?
- **Where**: Which effect has the “where” dimension on an artwork? If we look at the Open Wall, taking the installation from the public space into a meeting room in a University department has consequences in this respect. If the installation could be regarded as a piece of art when it was the public space, it has become a technological prototype or tool when taken into a private space in a University. Which is the role of the web interface with respect to the artwork?
- **Why**: How can we attract and facilitate multidisciplinary participation in the development of projects like this? How can we convince Industry and Public Funding Agencies to found these projects?
- **What**: Which are the tools that make each project successful and which are those that hinder the success of our project? Can we facilitate good software evolution by publishing it as Open Source? Which software license should an artwork that is published as open source should have? Which is the role of the source code? Is this product, like for example “The Open Wall”, a piece of art or is it a tool for artist expression? How can theories from fields such as kinematics, dynamical nonlinear systems, neurobiology, and chaotic trajectories challenge the now main stream computer based digital art?

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