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HUMAN MACHINE INTERACTION

AN INFINITE MIRROR BETWEEN VIRTUAL AND PHYSICAL SPACE

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ABSTRACT

This document researches the interaction between humans - machines, and the relationship between technology and human perception. Nowadays the evolution of technology reveals an aspiration to place the imaginary above the real world in order to create tools that are distracting people from their environment. Through the creation of mixed realities, we are presented with new forms of interactivity between humans, computers, the built environment and artworks. We are witnessing an era of a continuous use of computers; why it is important to take computation out of the offices and beyond the desktop? How an everyday object can become either an artwork itself through computing or a "controller" for an interactive installation*?* At this research we are going to explore physical computation and mixed reality installations as a synthesis of real and digital space through interactive projection-mapping.

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I / INTRODUCTION

Daniel Rozin interview by Marco Mancuso

> «*The physical world that surrounds us is the most unifying language that we have. We all spend our entire* lives *in the physical world and have an amazing intuition regarding its behavior, this is a type of intuition that I believe we will never have with the digital or virtual. Combining the physical with the digital or computational allows us to take the best of both worlds, on one hand to tap into this collective intuition and on the other, to take advantage of the flexibility of computation*»[1].

Computing has made en important evolution regarding the research in the forms of MR
Both augmented reality and augmented virtuality have made big steps concerning physical and digital objects that co-exist and interact in real time. Ubiquitous computing and systems that project computer generated visuals and information are projected on to physical surfaces transforming our experiences and perspective. *Our relationship with machines and technology must be examined in order to apply the theory and practice of art to the field of computing*.[2]
Within this research the dynamic of interactive systems that are extended beyond the computer screen are going to be questioned in order to capture the characteristics of what can be called interaction design and art or the design of the modes of interaction: a physical environment, in a space.

The Human-computer interaction is strictly connected to the topic of the digital art; it is a discipline whose aim is to give people the power of computers, using ways and forms that are both accessible in the creation of an artwork. Ben Laposky made the first attempt to combine art and science in the early 50s. He photographed thousands analog waveforms from an oscilloscope he had modified.(Figure 1) The importance of mathematics, in Laposky's case, cannot be ignored as a link between analog and digital devises. Laposky redirected a usable devise from the domain of science to art.

Today artists are experimenting with the physical world, as mad scientists and they are trying sometimes to escape from it by creating virtual universes. Fifteenth-century painter and architect Leon Battista Alberti was working in scientific content, on classical optics in determining perspective as a geometric instrument of artistic and architectural representation. (Figure 2) Nowadays we are playing with this perspective in order to create illusions. Alberti's paintings were open windows to the world, now we are creating projected worlds on windows. Today art is evolving more and more with technology and science; our interaction with machines/computers is changing our perspective to the world. So what can we learn from this new perspective? How we can express it through art, and how we as humans can keep up with the exponential development of computing and information.

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[1] As sited in an interview http://www.digicult.it/digimag/issue-014/daniel-rozin-mirror-of-the-soul/

[2] Paul A. Fishwick(2006) Aesthetic computing The MIT Press Cambridge Massachusetts p.380

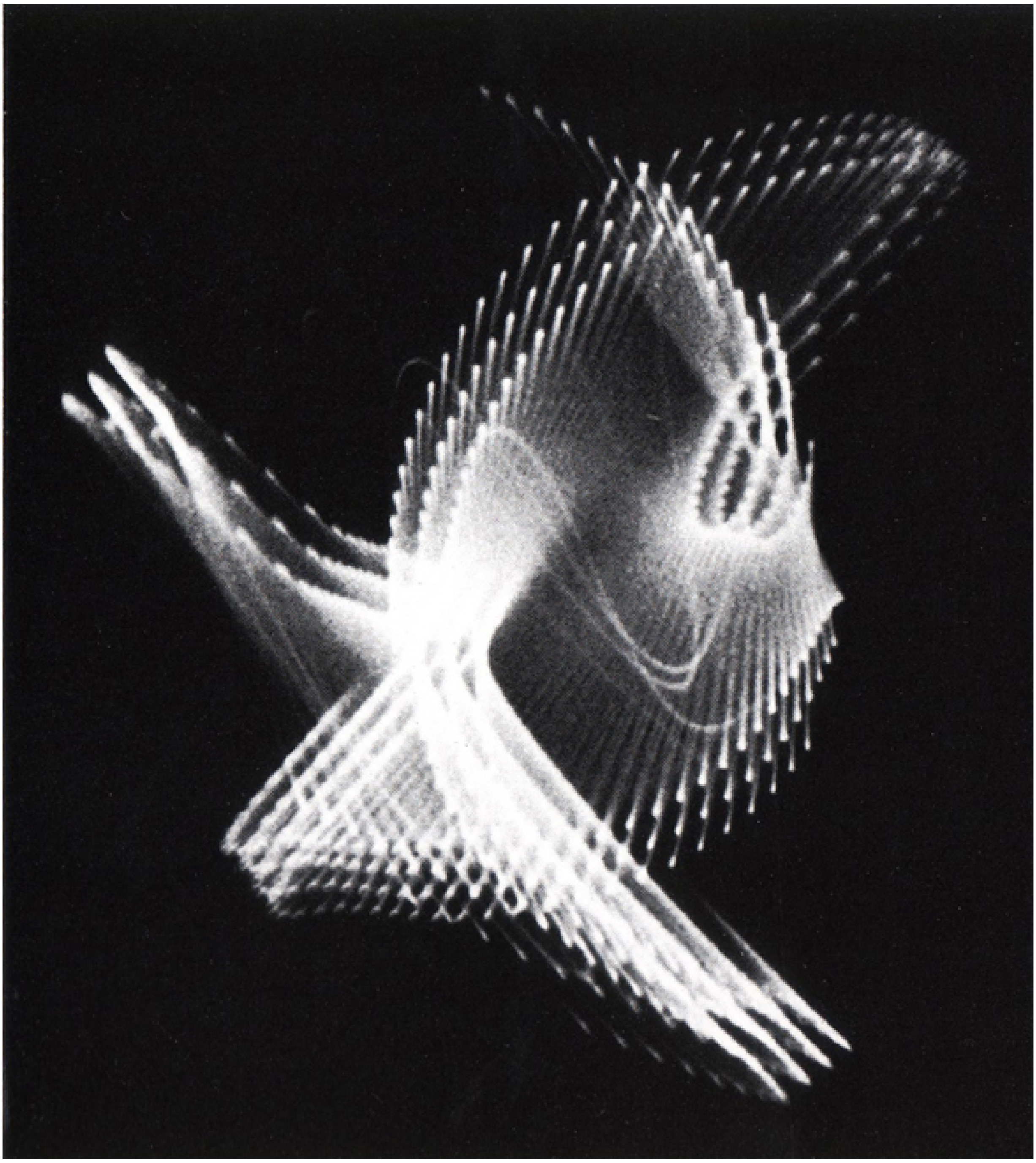

Figure 1 Ben Laposky-Oscillation 4-electronic abstraction 1950

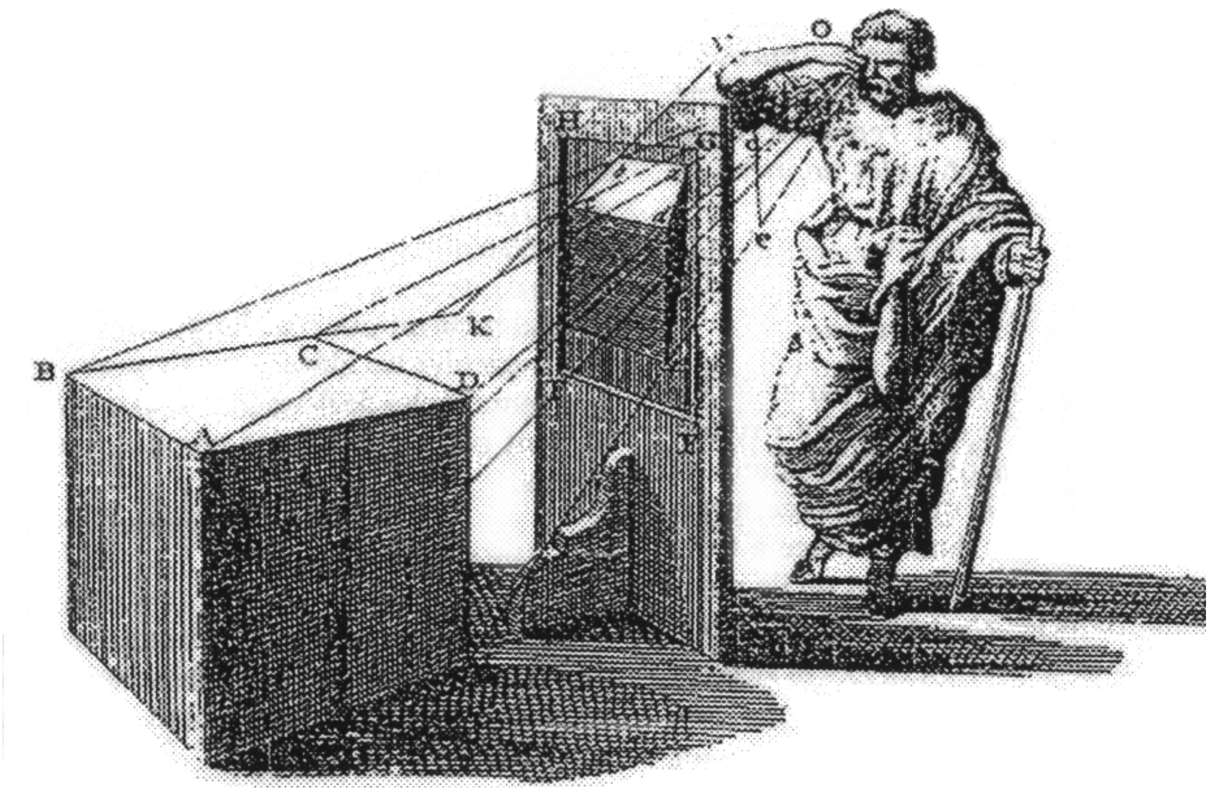

Figure 2. Illustration of Alberti's theory of images from Brooke Taylor: New principles of linear perspective, 1719

So is it a vice versa relationship between physical/virtual, real/artificial and digital and analog? How can the understanding of mathematical principles behind our physical world help us to create digital worlds? How can we learn about the way digital technology works in order to help us compute it physically?

II/ THE IMPACT OF MACHINES-FROM METROPOLIS TO MATRIX

The relationship between human and Machine, for the beginning, can be examined through the Camera lens; a technological instrument that has certainly changed our point of view.
The topic of the film *Metropolis* (1927) is a large automated industrial city with a society divided into two classes, the thinkers and the workers. The workers are behaving like robots, with stiff and controlled movements they are working beneath the city loosing track of time. Metropolis is ruled by the powerful industrialist Joh Fredersen, who orders Rotwang (crazy scientist) to give Maria's face (a woman admired by the workers) to the robot in order to send it to the underground city to deceive and stir up its inhabitants.

So, Joh Frederson

Isn't it worth the loss of a hand to have created the man of the future, the Machine - Man - ? Give me another 24 hours - and no one, Joh Fredersen, no one will be able to tell a Machine-Man from a mortal - - !

C. A. Rotwang (*Metropolis* Film 1927)

The reason that I am putting this dilemma is for pointing out, that machines, especially computers in now days, mustn't try to imitate the autonomy of human beings (Figure 3). The *Machine-Man* shouldn't have flesh, it should be like Rotwangs fully functioning metal prosthetic hand, work like it, and not as in Dr. Strangelove, whose gloved but uncontrollable right hand apparently has its own autonomy (doesn't work under his brain commands) and often tries to kill him. The science fiction Machine-Man of the film metaphorically embodies Jean Baudrillard's simulacra: a robot that acquires the destructive quality by imitating the appearance of a human being, or the real.

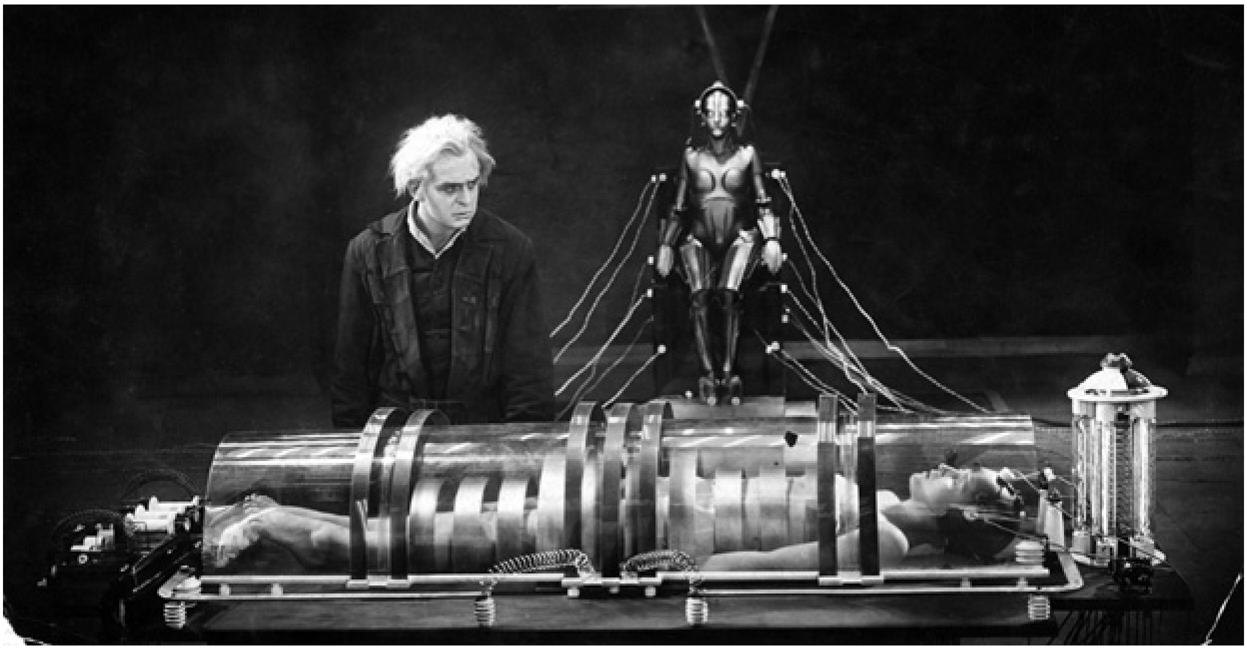

Figure 3 Scene of Metropolis (1927) Source http://www.ebertfest.com/thirteen/metropolis.html

All forms of technology, therefore, are also therapeutic and prosthetic technologies. Whether we view them as extensions of the body (McLuhan) or as extinctions of the body (Baudrillard), technologies always deal in artificial organs, which help to liberate us from the prison of space and time.[3]

Computers, as Vannevar Bush had envisioned, are supposed to assist or augment human intelligence; they were tools that they primarily extended the mind rather the muscles. In this frame of understanding, machines/computers were prosthetic, giving additional power as the Greek term "prosthetikos" as extension. Through the Memex[4] machine, Bush hoped to transform an information explosion into a knowledge explosion. His vision had to do with a machine that was manipulating

[3] Peter Weible (1994) Intelligent Ambient Environments of Artificial Intelligence, Intelligent Beings in an Intelligent Universe, Ars Electronica, http://90.146.8.18/en/archives/festival_archive/festival_catalogs/festival_artikel.asp?iProjectID=8669

[4] The memex is the name of the hypothetical proto-hypertext system that Vannevar Bush described in his article "As We May Think"(1945)

information in order to extend humans knowledge, and not a machine that was manipulating humans through false information as Maria at the Metropolis film.

In the *Metropolis* film the interaction with machines - which are inspired by clockwork-based mechanics, like the Antikythera mechanism an analog computer not a digital one - is depicted by machines enslaving and commanding the workers underground. In a classic scene (Figure 4) a man is shown straggling to adjust huge levers according to visual signals given by the machine. This distorted perspective - the human is working for the machine, not vice versa - shows how ambiguous the vision of future technology and its applications was at that time and expresses a concern that technology might surpass our humanity.

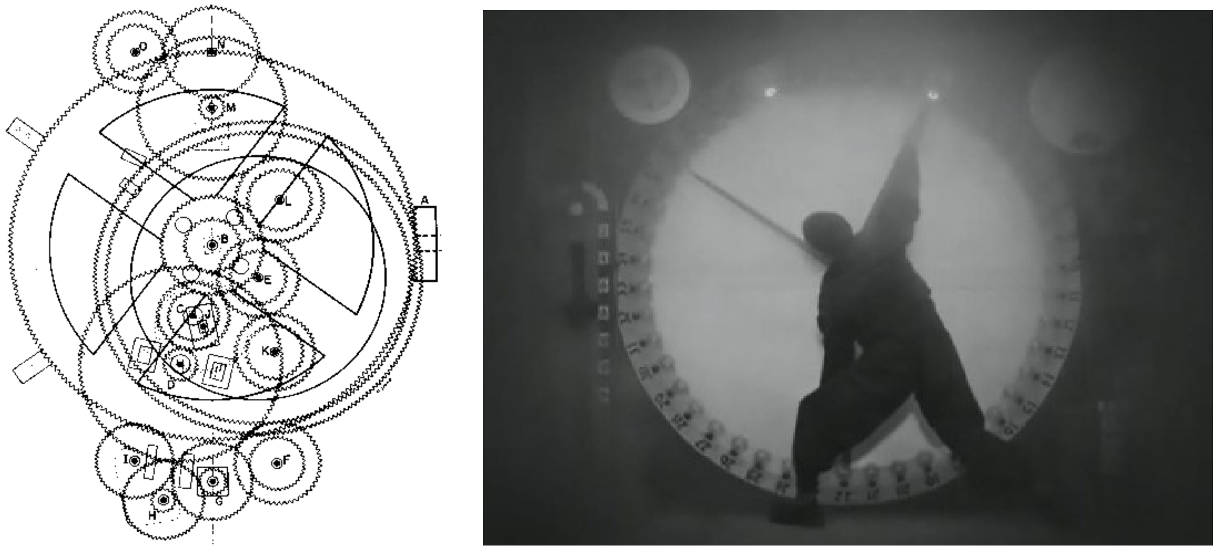

Figure 4. (left) complete mechanical schematic of the Antikythira device obtained by 3-d imaging
(right) scene of the Metropolis film (1927)

The concern still exists nowadays, in a slightly different context, as Donald A. Norman[5] says:

"*We are analog beings trapped in a digital world, and the worst part is, we did it to ourselves.*
We humans are biological animals. We have evolved over millions of years to function well in the environment, to survive. We are analog devices following biological modes of operation. We are compliant, flexible, tolerant. Yet we people have constructed a world of machines that requires us to be rigid, fixed, intolerant. We have devised a technology that requires considerable care and attention, a technology that demands to be treated on its own terms, not on ours. We live in a technology-centered world where the technology is not appropriate for people. No wonder we have such difficulties."
At exactly the same time as the *Metropolis* was filmed, in 1927, Bruno Munari an Italian artist and designer, in his Machinist's Manifesto, also concerns about machines that reproduce themselves faster than mankind; they already force us to busy ourselves with them, to spend a great deal of time taking care of them; we have to keep them clean, continually attend to them and meet their

[5] Donald A. Norman (1998)The Invisible Computer: Why Good Products Can Fail, the Personal Computer is So Complex and Information Appliances are the Solution, The MIT Press Cambridge Massachusetts p. 135

every need. In a few years we will become their little slaves. Munari finds the solution in the artistic world: “*The artists are the only one to save our civilization from that danger. The artists need to learn about machines, to abandon their romantic brushes, palettes, canvas, frames and start to understand mechanical anatomy, the machine language, to understand the nature of machines by making them function irregularly and using them to become artwork themselves, with their own means... We shall discover the art of machines!*”[6]

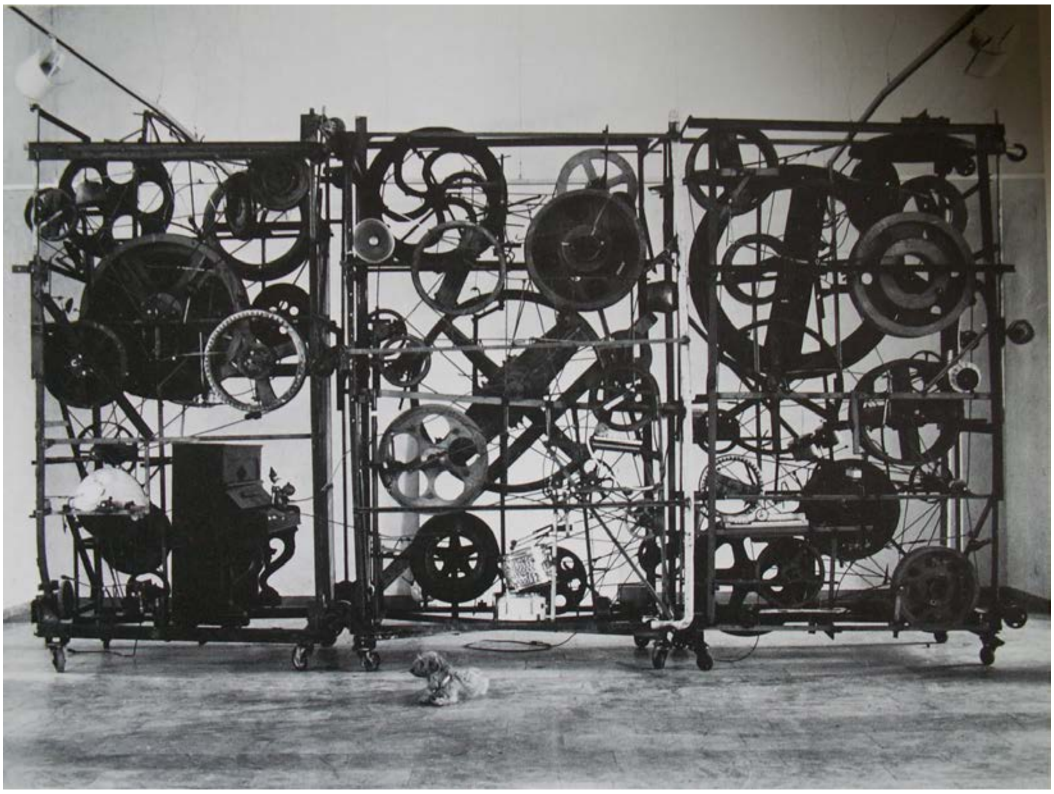

Figure 5. meta-harmony I, 1978, Jean Tinguely
Steel construction with mechanical elements, objects and musical instruments

This approach is about people that are trying to capture the inevitable, the evolution of things, and transform it in production processes; they are supplying their interest in machines and the machines are communicating a person’s expression. *Rather than trying to imitate the autonomy of human beings, we want to support it. Machines can be the medium of communication and expression*.[7]

So at the Machine Age while the fear of “robots” replacing humans or humans becoming robots was huge, there was also another machine that was extending human’s vision not the muscles, the camera that was changing more and more the world. Media technology was arising but there was a fear in that too. The confluence of media technologies are expanding our knowledge of the world, they transform it and helping us see from perspectives that we could not have seen otherwise.

[6] Bruno Munari (1938) Manifesto of Machinism
http://www.wired.com/2013/11/bruno-munaris-manifesto-del-macchinismo-1938/

[7] Dan O'Sullivan, Tom Igoe (2004) Physical Computing: Sensing and Controlling the Physical World with Computers, Thomson, Technology & Engineering Boston p. xviii

Vertov's films and writings were forehanded and inspire an interest in media technology of the past until now.

Vertov (1929) through Kino Eye explains the conquest of space, the visual linkage of people throughout the entire world based on the continuous exchange of visible fact… He writes: "*free of the limits of time and space, I put together any given points in the universe, no matter where I've recorded them. My Path leads to the creation of a fresh perception of the world. I decipher in a new way a world unknown to you*."[8]
With Kino eye Vertov was trying to show how a device such as motion camera could change the the life process, break it in points and pasting them in a new order; speed and time where taking a new form. Vertov develops a movement against the visual and virtual world that was arising.(Figure 6)

Figure 6. Dellusion Dwellers, Laurie Lipton Pencil Drawing, 2007.

Walter Benjamin's famous passage from "The Work of Art in the Age of Mechanical Reproduction" [9] seems particularly relevant here. He writes, "*Our taverns and our metropolitan streets, our offices and furnished rooms, our railroad stations and our factories appeared to have us locked up hopelessly. Then came the film and burst this prison-world asunder by the dynamite of the tenth of a second, so that now, in the midst of its far-flung ruins and debris, we calmly and adventurously go traveling*". However, as Manovich notes, "…*the cost of this virtual mobility was a new institutionalized immobility of the spectator. All around the world, large prisons were constructed,*

[8] Dziga Vertov (1984) Kino-eye: The Writings of Dziga Vertov , Annette Michelson , University of California Press California p.19
[9] Carola Moujan (2010) Learning from Baroque In Gianluca Mura (ed.), Metaplasticity in Virtual Worlds: Aesthetic and Semantic Concepts, Information Science Reference, Hersheyt:PA, p.175

that could hold hundreds of prisoners". [10] These prisons are what we call theaters. Video games break with this tradition of immobility and detainment only to the extent that players must twitch their hands. Like cinema, video games seemingly permit us to wander while it chains us to our seats.

Are we like the workers of Metropolis sitting in front of a computer working on tasks purely mechanical, being nothing more than an extension of the machine? Are we like Plato's prisoners in his Allegory of the Cave chained to a cave, facing a blank wall and watching shadows passing by? Or we are like "Neo" living in the Matrix?

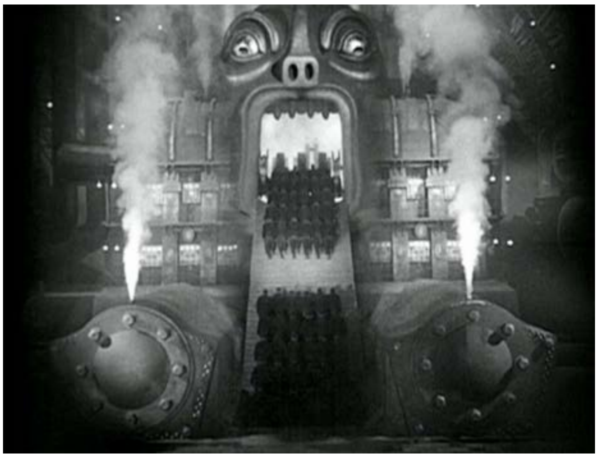

Figure 7. Scenes of Lang's.
Metropolis(1927)

Figure 8. Scenes of Vertov's
Man with the Moving Camera(1929)

As the Matrix is a computer program (Metropolis a huge machine) that humans are plugged into, the world they view as "real" is not what it appears to be. In reality, those living within the Matrix have never seen the real world that exists beyond their perception. Only those who have been "unplugged" or removed from the Matrix have ever truly seen the real world. And that is what art is all about. As Munari said in a way is that art is demanding to learn about Machines and it is art that finally forms them. The human engagement with the machine is depicted very well in Jean-Louis Baudry (1970) and other has referred to mechanistically as cinematic apparatus. From this perspective the audience within the cinematic apparatus is like watching themselves eaten by a machine, the camera. Both films Metropolis (Figure 7) and The Man with a moving Camera (Figure 8) are describing a labyrinth, which is their task; just to describe it not to show the way out. Their relationship works like an infinite mirror, like art and technology.

[10] Lev Manovich (1995) , An Archeology of a Computer Screen, Soros Center for Contemporary Art, Moscow http://manovich.net/TEXT/digital_nature.html

III/ SNAPPING OUT OF THE SCREEN

> *Personal computers have evolved in an office environment in which you sit on your butt, moving only your fingers, entering and receiving information censored by your conscious mind. That is not your whole life, and probably not even the best part. We need to think about computers that sense more of your body, serve you in more places, and convey physical expression in addition to information*.[11]

Today we have mobile computers and phones that, kind of, serve us in that way. But that is not enough because these devises are nothing more but a GUI with which we can actually have access to in almost everything and everywhere. And we can use it as a radio, as a TV even as a camera. (Figure 10) What we cannot do with our mobile devises is to produce art, yet. Artists need to explore deeply behind the Graphic User Interface.

Figures 10,. Screenshots of the advertisement for the Thirty Years of Mac - "1.24.14" Film

Steve Wozniak describes the operating system as a real-time display of current operation, a radio frequency converter to display the images from the microprocessor to your set output devise. Jobs is rephrasing "…you can see what you working on while you working on it. This is freedom, this is freedom to create, to do, to build as an artist". Friedrich Kittler[12] would disagree, he describes the structure of the computer a 'system of secrecy'. *This system of closure reaches its highest form, simulation first, with the emergence of GUIs, which, for Kittler 'hide a whole machine from its users' and second, with the accompanying implementation of protection software, which prevents '"untrusted programs" or "untrusted users" from any access to the operating system's kernel and input/output channels'».*[13]

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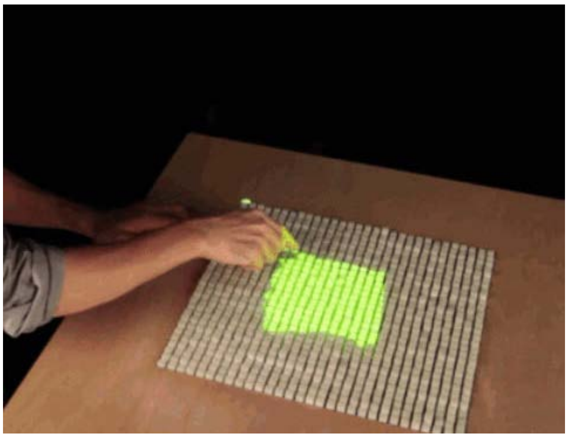
[11] Dan O'Sullivan, Tom Igoe (2004) Physical Computing: Sensing and Controlling the Physical World with Computers, Thomson, Technology & Engineering Boston p. xvii

[12] Friedrich Kittler (1943 –2011) was a media theorist who admired Linus Torvalds, the developer of Linux open-source operating system, and was himself a product of an open and free university system.

[13] Nicholas Gane and David Beer (2008) New Media: The Key Concepts Berg London p.108

a) The decline of GUI

What was Wozniak using as a display at the time was a television. Now the display can be almost everything; they take a wider view of displaying than the common GUI, making use of the entire physical environment as an interface to computer generated information. Instead of closing information in tiny boxes they taking advantage of of the physical environment (Figure 11)



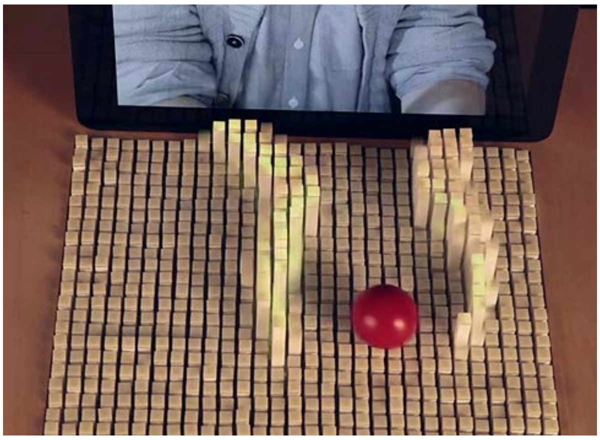


Figure 11 inFORM - Interacting With a Dynamic Shape Display

Steve Jobs set out to build "computers for the rest of us." The idea was to enable people who were not computer experts—like artists, educators, and children—to take advantage of the power of computing. Thanks to the graphical user interface (GUI) that Apple invented everyone is now able to use a comuter. GUI technology allows you to drag and drop, but it won't notice if you twist and shout.[14]

It allows you to cut and paste. This process, as Manovich explains, is made simple with the advent of the networked computer and has similarities with what Vertov was trying to do with his Camera:

> "*The practice of putting together a media object from already existing commercially distributed media elements existed with old media, but new media technology made it much easier to perform. What before involved scissors and glue now involves clicking on 'cut' and 'paste'…[] Pulling elements from databases and libraries becomes the default; creating them from scratch becomes the exception. The Web acts as a perfect materialization of this logic. It is one gigantic library of graphics, photographs, video, audio, design layouts, software code, and texts; and every element is free because it can be saved to the user's computer with a single mouse click*".[15]

It allows you to point and click (Figure 12)!! As Richard Harris point out at DouglasAdams.com:

> *When graphics came along and the computer using portion of the human race forgot all about 500,000 years of language evolution and went straight back to the electronic*

[14] Dan O'Sullivan, Tom Igoe (2004) Physical Computing: Sensing and Controlling the Physical World with Computers, Thomson, Technology & Engineering Boston p. xvii

[15] Manovich L, (2001) The language of New Media. Cambridge, MA: MIT Press p.130

equivalent of banging rocks together - the point'n'click game. Infocom and most of its competitors went to the wall - signalling the arrival of the post-literate society. But something strange has now happened. The Net, and particularly e-mail, has become an integral part of millions of lives. People have learned to type again and are taking an interest in interacting, via their computers, with other people and with content."

Figure 12. http://www.olaladirectory.com.au/why-2d-and-3d-video-projection-mapping-technology-became-popular/

Except of their language evolution, people also forgot to interact with their physical environment. Current GUI-based HCI displays all information as "painted bits" on rectangular screens in the foreground.[16] GUIs cannot enfold the plethora of human senses and their skills interaction with the physical world.

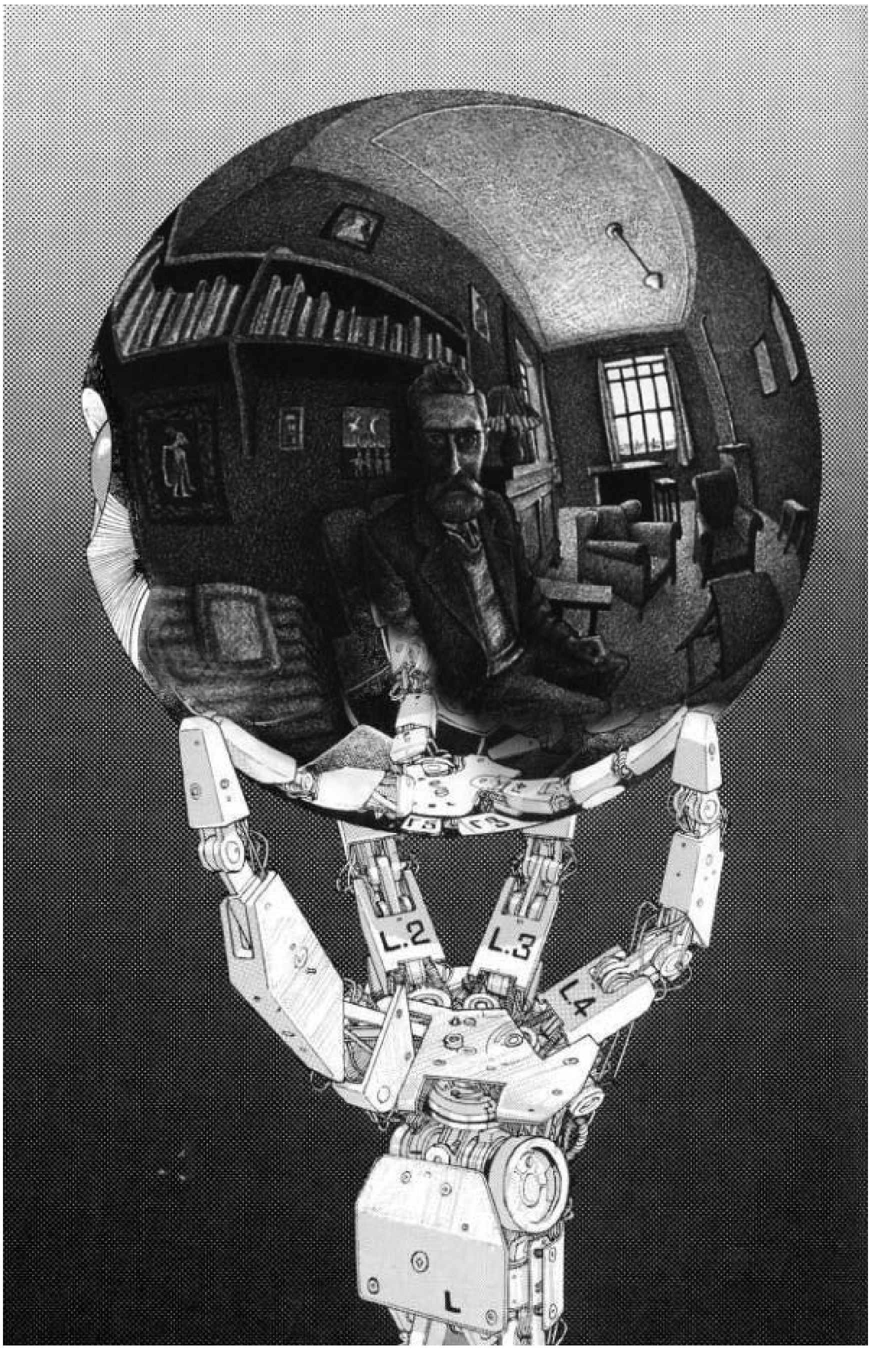
"We live between two realms: our physical environment and cyberspace. Despite our dual citizenship, the absence of seamless couplings between these parallel existences leaves a great divide between the worlds of bits and atoms. At the present, we are torn between these parallel but disjoint spaces.
The interactions between people and cyberspace are now largely confined to traditional GUI (Graphical User Interface)-based boxes sitting on desktops or laptops. The interactions with these GUIs are separated from the ordinary physical environment within which we live and interact."[17]

b) The rise of new HMI

We usually interact with machines through an interface, so in this research we can assume that HMI stands for Human Machine Interaction as well as Human Machine Interface and in general for any definition that describes an interface for between Human and Machine. Human Machine Interaction

[16] Hiroshi Ishii and Brygg Ullmer (1997)Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms, , MIT Media Laboratory, Cambridge MA p.7
[17] Ibid p.1

(HMI) describes how we as humans interact with machines, and we define a machine as 'any mechanical or electrical device containing one or more parts that uses energy to perform an intended action.(Wikipedia)



M.C. Escher x Otomo Katsuhiro "Hand with Reflecting Sphere" amended By Nefeli Georgakopoulou

Existing HMI Technologies

The fundamental task of human-computer interaction is to shuttle information between the brain of the user and the silicon world of the computer. [18] Input and output researcher are focusing on the end of this communication.; what devices are used by computer in order to communicate with people and which organs people use for the reversed procedure.

The existing physical technologies/input devices for HCI basically can be categorized (a) Acoustic (Sound) (b) Optics (Light) (c) Bionics (d) Motion (e) Tactile (Touch). [19]

<u>Optic technology</u>

In Optic based technology the primary hardware/input used is usually a camera; HMI utilizes this hardware for Computer Vision. In optic HMI the user doesn't need to physically touch anything; the interaction with the device is done by gestures and hand motions.

<u>Acoustic technology</u>

In Acoustic or sound based technology the main device/input a microphone and it focuses on speech recognition. It is used to convert spoken words to text, manipulate a device, or communicate with a machine.

<u>Bionic technology</u>

In order to use biological signals we need to gather useful information from our bodies; this is done via electrodes. There are several HMI techniques that use electrodes/inputs to gather electrical data.

- Brain Computer Interfacing(BCI)
- Myoelectric Interaction (EMG)
- Electrocardiogram(ECG or EKG)
- Electrooculography (EOG)

<u>Tactile(touch) technology</u>

Tactile based technology is the only technology that physically requires you to touch something; all the others in some sense can operate hands free. The most classically touch technology/input is the button, as used on the keyboard, which is the most popular HMI device ever created, we use it in an incredible amount of applications ranging from the computer keyboard, mobile phones, to personal entertainment devices. One quite impressive piece of tactile technology is the textural interface, Super Cilia Skin (SCS) which has potential as an artificial skin with sensory feedback.

<u>Motion technology</u>

Motion technology includes all HMI that in some way can detect motion, gyroscopes and accelerometer's are the main technologies/inputs used. However they are not often used alone, but mostly combined with other sensors. Some of the most notable motion sensing technology is in the wii controller, which a good example of sensor fusion, infra red sensors are used together with an

[18] Hinckley, K., Jacob, R., Ware, C., (2004**),** Input/Output Devices and Interaction Techniques. Chapter 20 in *The Computer Science Handbook, Second Edition*, ed. by A.B. Tucker, Chapman and Hall / CRC Press, Boca Raton, FL, , pp. 20.2 – 20.3.

[19] James Cannan and Huosheng Hu , Human-Machine Interaction (HMI):A Survey, Technical Report:, CES-508 University of Essex p.2

accelerometer to detect motion. Another popular example of a motion sensitive device is the iphone which can use both gyro's and accelerometer's.

We are not going to analyze the categories of HMI further, what I wanted to point out was the breaking of all kinds of Interactions to their inputs technologies/devises. We can cause a variety of different output actions to happen based on various input actions. It has to be noticed that the designation of a device as either input or output depends on the perspective. For example mouse takes as an input the movement of our hand that for us is an output.
The output from these devises is input for the computer. What relies between input and output is the processing. The third part requires a computer to read the input, make decisions based on the changes it reads, and activate outputs or send messages to other computers. This is where programming comes in. [20]We are going to analyze the output devices in a next Chapter, not in a wide range though, only the large-format/projection.

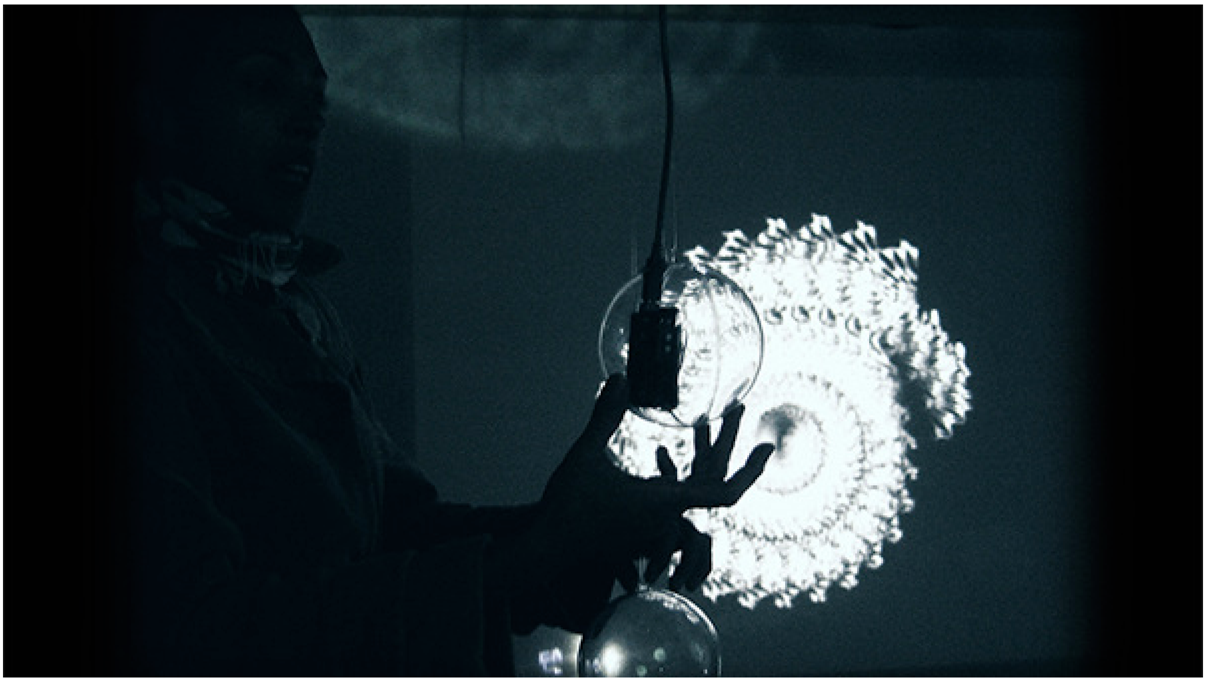


Figure 13 Vesna Krebs, Interactive Installation-Arduino, http://www.vjmisstake.org/About

Author and game programmer Chris Crawford has a great definition for interaction: *Interaction is an iterative process of listening, thinking, and speaking between two or more actors." Most physical computing projects (and most computer applications in general) can be broken down into these same three stages: listening, thinking, and speaking—or, in computer terms: input, processing, and output.*[21] So how can we take these cycles of events to create interactions that balance them in a satisfying way, like a good conversation? How can we make our physical environment sensitive, neither fully material nor totally virtual?(Figure 13)

[20] Dan O'Sullivan, Tom Igoe (2004) Physical Computing: Sensing and Controlling the Physical World with Computers, Thomson, Technology & Engineering Boston p. xx

[21] Ibid p.1

c) Ubiquitous computing

Ubiquitous computing (ubicomp) is an advanced computing concept where computing is made to appear everywhere and anywhere. In contrast to desktop computing, ubiquitous computing can occur using any device, in any location, and in any format. A user interacts with the computer, which can exist in many different forms, including laptop computers, tablets and terminals in everyday objects such as a fridge or a pair of glasses. (Wikipedia)

Ubiquitous computing follows the vision of moving computing from the desktop and integrating it into the "fabric of everyday live". Everyday objects in the physical environment are equipped with networked sensors and actuators, hence able to compute and respond to particular context situations accordingly[22]. (Figure 14)

Some subdomains of ubiquitous computing research are the following:

- *embodied interaction*
- *Tangible User Interfaces*
- *Mobile Physical Interaction*
- *Wearable Computing*

Figure14. Oikonomic Threads installation, 2013 Afroditi Psarra, Maria Varela,Marinos Koutsomichalis

[22] Mark Bilandzic (2003) The Embodied Hybrid Space–Designing Social and Digital Interventions to Facilitate Connected Learning in Coworking Spaces, Urban Informatics Research LAb, Creative Industries Facult School of Design, Queensland University of Technology , Brisbane, Australia

Umbiquitous computing is also referred as pervasive computing or ambient intelligence. Each term has slight variations and different aspects. When it has to do with the objects that are involved in this “fabric of everyday live” computing, it is also known as physical computing. (Figure 15).

Figure 15, Mécaniques Discursives”, Fred Penelle & Yannik Jacquet (2012)

<u>d) Physical Computing</u>

Physical computing, in the broadest sense, means building interactive physical systems by the use of software and hardware that can sense and respond to the analogue world. Physical computing is about creating a conversation between the physical world and the virtual world of the computer. The process of *transduction*, or the conversion of one form of energy into another, is what enables this flow.[23]

From the TV display that Wozniak used we are now witnessing an environment in which every corner, every object and everything that someone can put in his mind can be used as a display. This creates a strange relation between the computer generated and the physical space. The physical environment that has become a labyrinth since the industrial age, where the metropolis notion was born, it is now giving life to new tools in order to manage its expanded dimensions.

[23] Dan O'Sullivan, Tom Igoe (2004) Physical Computing: Sensing and Controlling the Physical World with Computers, Thomson, Technology & Engineering Boston p. xix

Memorsion

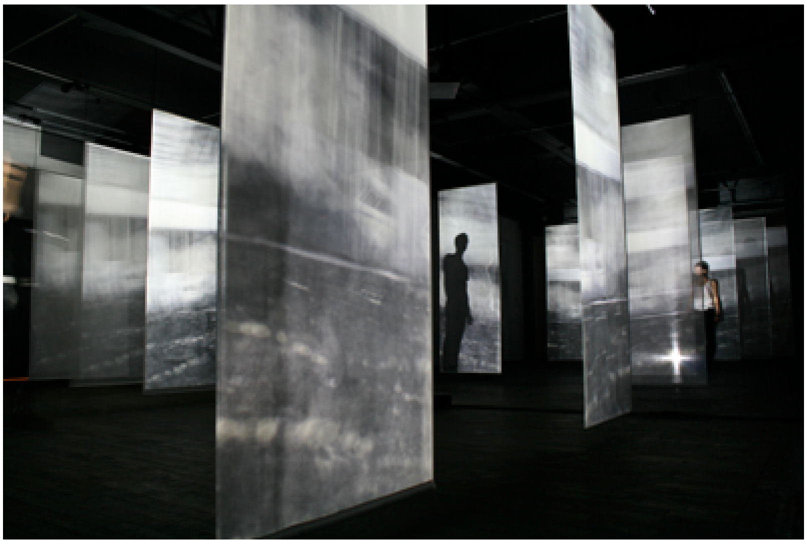


Figure 16 *Marsh 1st 2014 : Society for arts and technology, Nuit Blanche, Montreal. [Installation]*

Memorsion (Figure 16) is a three-dimensional audiovisual experience. This installation made up of 22 semi-transparent screens where a unique urban environment is constructed through the audiences interactions. Video footage of fragments — concrete expanses, tunnels, graffiti-covered walls, human bodies — are used to reconfigure familiar urban settings and sculpt a novel space. The result is a meditation on urban architecture and cultural memory—traces left on forgotten, abandoned and obsolete structures. Visitors are invited to immerse themselves in this dramatic environment, and to experience the personal associations evoked by imagery fluctuating between abstraction and strong cultural references. Videos are also used to sculpt the exhibition space. The use of multiple screens and it's resulting effects, is somewhat akin to the 2D multilayer technique, however these moving images are projected and perceived in a three-dimensional environment, allowing them to be seen and felt from different vanishing points. The work is a mix of digital art, film and immersive sculpture, Memorsion uses the luminosity of video to explore a new form of audiovisual and sensory expression.[24] Imaging the experience if these semi-transparent screens where moving.......

Concerning the objects and physical computation at this research we are going to focus on how the "objects involved" (Figure 17) can become artworks themselves. Each one should be a unique device and not a mass product. How the output can be combined with a visual representation? So for this research we are going to examine the interactive/animated spaces combined with virtual ones, because it's not only the field of HMI that is rapidly developing but also the impact of computer graphics, 3d modeling software and the machines for fabrication. It is not all about how we communicate with the physical world via computers but also how computers re-present and re-construct the physical world.

[24] As sited in http://manuelchantre.com/art/memorsion.

Figure 17 Book as installation art - Breathing books by Edith Kollath 2008

IV/ THE OUTPUT OF HMI (re-present and re-construct the physical world)

a) Transforming the physical to virtual (Projection Mapping)

Plato's "*Allegory of the Cave*" is probably the first inquiry into the possible effects of cinema and the illusion of reality. Shadows projected on a wall, distorted moving figures from the light of fire, were maybe the first allusion of virtual reality. Siegfried Zielinski is comparing spectators of cinema with the prisoners of Plato's cave and describing the cinema room as following:

" *Cinema as an environment for the enjoyment of art, for immersion in traumatic experiences, for hallucination, for irritation of real experience; and, what is more, with films constructed in deliberate opposition to the experiences of those who pay to enter the dark womb and be at the mercy of the play of light and sounds*." [25]

Before cinema, though, we had the wall painting that put people in front of an illusion, with the difference that the figures and scene were still. Wall paintings of Pompeii include illusionary elements. They extend the walls mirroring worlds and humans that didn't existed capturing the dwellers gaze between real and virtual. Creating windows and doors that the observer could pass in order to travel through time in an another world and wonder through the movements of his mind and fantasy. (Figure 18) *The most effective examples of these frescoes use motifs that address the observer from all sides in a unity of time and place, enclosing him or her hermetically. This creates an illusion of being in the picture, inside an image space and its illusionary events*.[26] Hundreds years after we had the Quadratura, a seventeenth century technique which became popular between Baroque artists. It refers to the idea of opening up physical spaces and boundaries. It was also associated with the Italian ceiling painting. Quadratura had to deal with the theories of perspective and the representation of architectural space. And as taking these established theories in practice along with painting and sculpture it managed to give a more immersive illusion than earlier examples.
In 1860s, 360-degree art through panoramic murals began to appear. An example of this would be Baldassare Peruzzi's piece titled, *Sala delle Prospettive*, and in 1992 we have the first CAVE from the University of Illinois at Chicago.

[25] Zielinski Siegfried (1999) and Gloria Custance (Translator). Audiovisions: Cinema and Television as Entr'actes in History (Amsterdam University Press) p.92
[26] Oliver Grau (2003) *Virtual Art: From Illusion to Immersion ,MIT Press, Cambridge MA p.25*

Figure 18. **Above** Pablo Valbuena, para-site, Projection Mapping 2011 **Below** Fresco in Pompiie

Before the CAVE, though, we can find an example of a total transformation of space, an immaterial one; back at 1990 in the context of TED2 conference that happened in February 1990 in Monterey of California, Marty Sklar President of WDI (Walt Disney Imagineering)[27] invited a group of professionals to the Steinbeck Auditorium. "*Imagineers? Give me a castle*!" he announced, and the Steinbeck Auditorium turned into the inside of a castle. The Disney group managed to create the perfect illusion at that time, through projecting everywhere in the auditorium. They had achieved an immaterial transformation of space, a virtual reality, but without their senses being controlled by a computer and their actions influence the produced outcome.

Another technique for adding extra dimensions, optical illusions, and notions of movement onto previously static objects or buildings (interior or exterior) is called projection mapping. Projection Mapping is a new creative medium where video projectors are used to bring everyday objects to life. Projection mapping is the transformation of a still object into a notion that represents the

[27] Imagineers is the design and development arm of The Walt Disney Company, responsible for the creation and construction of Disney theme parks worldwide, source from Wikipedia http://brianstorms.com/2012/08/the-ted2-conference-writeup----22-years-later.html

movement of light and time. It is the opposite, but in a vice versa relation, of what Chris Marker achieved in his masterpiece science fiction, photo-roman movie, “La jetée” *(1962). (Figure 19)*

Figure 19 Snapshot of the movie “La jetée” *(1962).*

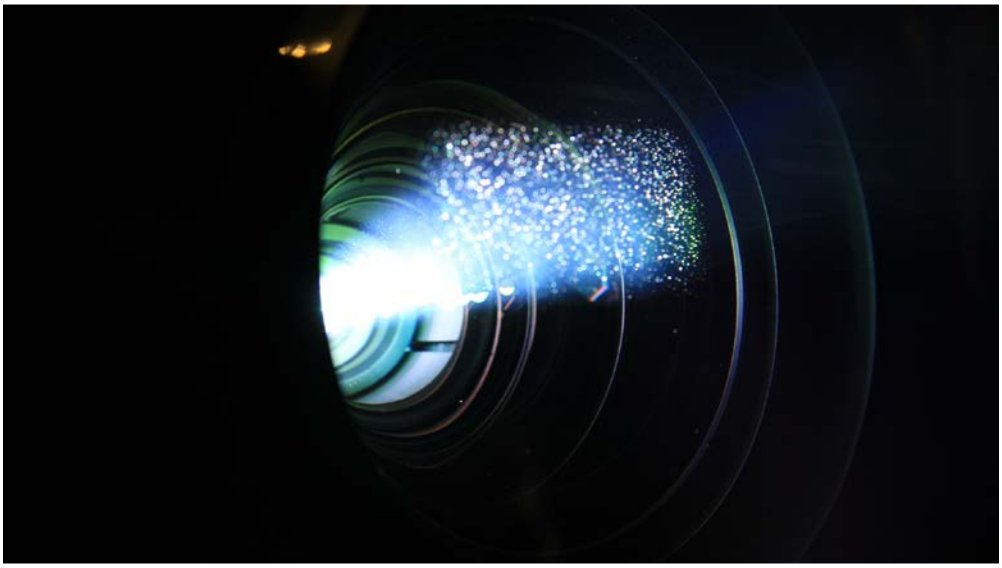


Figure 20 from http://www.ktbg.bg/#/en/services/4

In “La jetée*”* Chris Marker uses still photos in order to represent a travel through time. The protagonist is being thrown from the past to the future, ending through this movement in seeing his own death when he was a child. It this relationship that these machines (from the camera that captures, to the projector that represents) are magnifying; the infinite loop between watching and acting, of passive and active spectator or user.

In her essay “Gilles Deleuze and a Future Cinema”, Barbara Filser posits a theory of a third cinema, one that would develop from Deleuze’s theory of the time-image[28] into a cinema of the 21st

[28] Gilles Deleuze, (1989), Cinema 2: The Time-Image, Hugh Tomlinson & Robert Galeta, Minneapolis: University of Minnesota Press,p.xii.

century. This third cinema is a virtual reality, embedded in Deleuze's time-image theory to create a cinema of the mind, directly from the thoughts of the spectator/character.

The fact is that virtual reality today is more close to the immersion of the body on not the mind through body attached devices. In contrast to traditional VR, in projection mapping or Augmented Reality the real environment is not completely suppressed; instead it plays a dominant role. Rather than immersing a person into a completely synthetic world, it attempts to embed synthetic supplements into the real environment.(Figure 21)

Figure 21 *Perspective Lyrique was projected on the facade of former Lyrical theater the "Celestins". The building deformations and figures were controlled by the audience, using a microphone and an audio analysis algorythm.*

Projection mapping is being used a lot the last decades from artist and advertisers. What is in the focus of this research is the interactive projection mapping, but before we continue further we are going to see an example of this technique made in 1980 in order to discuss about the visual feedback of the computer, the output, the display. Especially, spatial displays which takes off the body-attached displays and integrate them into the environment.

Displacements

“Displacements” (1980-1984) is an immersive film installation by Michael Naimark. The idea was to set up a typical Americana-style living room on-site, then to film with a motion picture camera on a slowly rotating turntable from the center of the space.

Figure 22 Michael Naimark ,Displacements, 1980

After filming, a matched projector would replace the camera on the same turntable and the entire contents of the room would be secured in place and spray-painted white (Figure 22), to act as its own projection screen. What is interesting here is that the projection of the virtual world was exact as the real use to be. The technique reminded us the one that we use today at 3D computer graphics software for UV mapping. A physical room/scene, painted white, transformed in a 3d model-like scene, and the materials were projected on it live. They had their replica in a 1:1 scale and they could transform it, not in their computer, but in the physical world and they could navigate in there at the same time. Michael Naimark was exploring the representation of space, how new media can represent sense of place. He was researching how to "map" a place for experiencing it virtual and he actually achieved to map/capture how we experience space in time. He created, in a very inspiring way, the "perfect" ghost.

b) Transforming the virtual to physical (Movement Mapping)

Another work that mapped time into space (in contrary with Naimark's) and introduced a method of finding an architectural or sculptural form based not on manual modelling but on generative processes was *The Invisible Shapes of Things Past (1995) (Figure 23)*

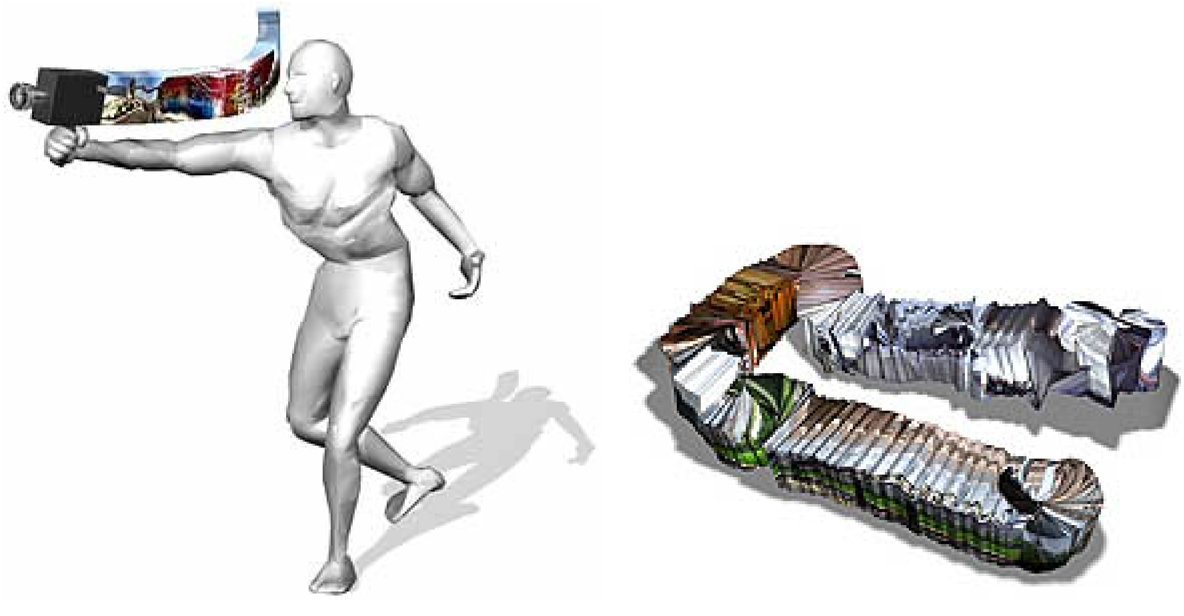


Figure 23 Joachim Sauter, ART+COM: The Invisible Shape of Things Past

The Invisible Shapes of Things Past

Here the mapping goes from 2D to 3D -- from the flat surface of a movie screen into a 3D virtual computer space. *The Invisible Shape of Things Past* is an exploration of the representation of time in virtual space and the navigation through time in VR. The project enables users to transform film sequences into interactive virtual objects. The movement of the camera is been divided in frames which in turn modulate the skeleton of a new form. First this object existed only in a virtual world.

After years with the advent of 3D printers, this captured movement is able to unfold in physical space, like an accordion, allowing air to flow inside and produce unusual volumes. (Mass elements) That which existed only in a virtual world now takes a place in the physical one. Joachim Sauter was sculptured immaterial film into material. (Figure 24)

Figure 24 Joachim Sauter, ART+COM: The Invisible Shape of Things Past

So while the projection mapping is a technique that transforms physical space virtually, digital fabrication translate immaterial processes into physical designs. These techniques combined with physical computing can transform space physically and create new aesthetics and experiences of space and time. By studying nature we have created algorithmic worlds in which until recently we could only visit them virtually; and now with the help of technology we can create them physically. When these two blend virtual and physical we are dealing with Mixed Realities installations.

V) MIXED REALITIES

a) The mediation of material and immaterial

Architecture is the art and science of the built environment; it's a field that illustrates the evolution of technology as they share the same vision, they are trying to surpass the limits of nature. Architecture tries to archive it through "materiality" and technology through "virtuality". The fear of replacing material by the virtual that existed previously is now has been exceeded.

> *According to Bullivant architecture in the information age faces two challenges: the need to reconcile materiality with the image and practices of a digital culture; and overcoming the limitations of the built environment through flexible digital technologies. New evolving design technology promises the possibility of transforming space and modes of representations to meet changing needs and desires..*[29]

A great example in which we can understand this «third space», which is not interactive in the sense of an external intervention though, is Kinetic Art – Dynamic Structure 29117 (Figure 25), made by Dutch artist Willem van Weeghel, who is known for his absolutely hypnotic works of art. The whole work is made from 32 independently moving lines which are controlled by a computer system. The forms that he uses are the medium for making the movement visible. He chooses simple forms as it is possible for creating constantly changing structure. The studies of these structural versions are being more specialized through designing programs. His work focuses in motion and current of time. Watching these movements and their shadows from a distance we can't tell if what we are looking at is real or virtual. They wiggling so natural, pointing out the intuition of the physical world that Weggel has in order to compute them.

In mixed realities installations, time and space are bound together in a very tight way, with time existing only dependently through space. Taking in mind this, we can examine these installations as space-time events.

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[29] Rahaman, H & Tan, BK (2009),'Interactive space : Searching for a dual physical-virtual world', in T-W Chang, E Champion, S-F Chien & S-C Chiou (eds), 14th International Conference on Computer-Aided Architecture Design Research in Asia (CAADRIA 2009), Yunlin, Taiwan, pp. 670

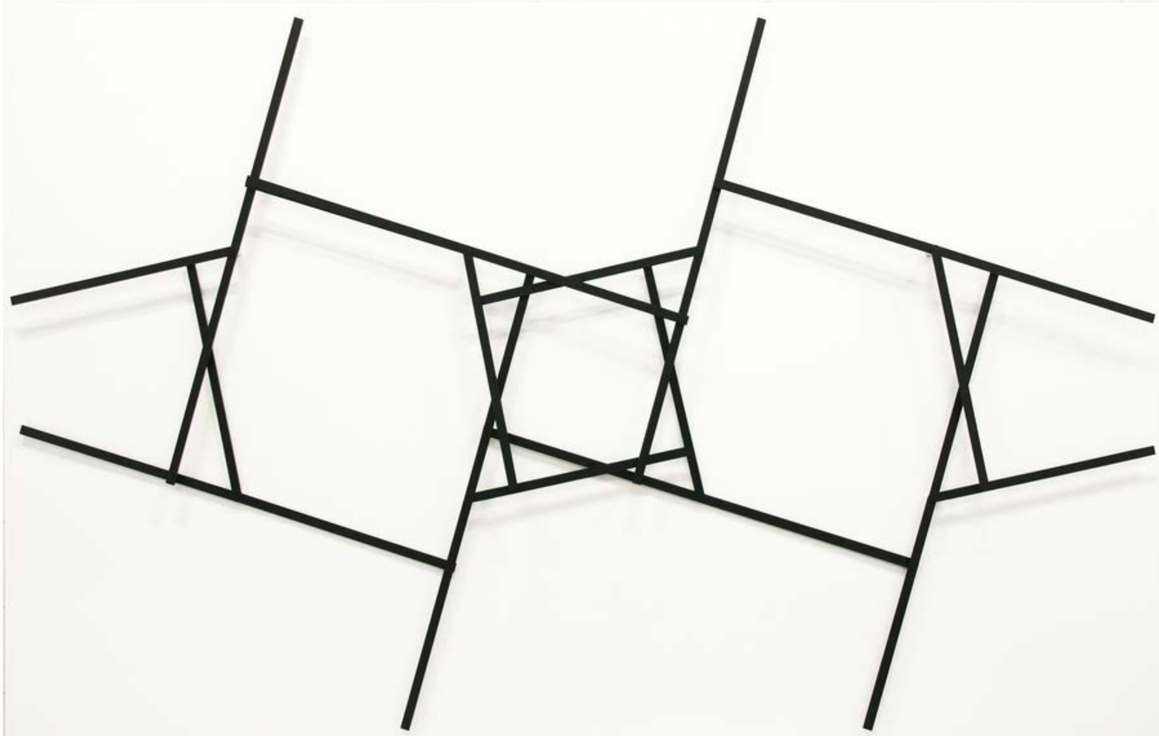

Figure 25 Willem van Weeghel, Kinetic Art – Dynamic Structure 29117

> «*In these works flow, not shape, is the key. Similarly, in the Baroque architecture, illusions of movement in built masses are conveyed through the use of perspective. They are an invitation to movement, making flow a central element and transformation, the only constant».* [30]

At this chapter (10) Carola Moujan explains how mixed reality installations share an aesthetics of baroque architecture and how an artist manage to create a radical shift from vision to touch in order to create different experiences. This as Usman Haque has pointed out, would lead to a deep transformation of the concept of space design[31]. The period of the baroque (late sixteenth to mid-eighteenth centuries) saw extensive reconfiguration of European cities and their public spaces. Yet, this transformation cannot be limited merely to signifying a style of art, architecture, and decor. Rather, the dynamism, emotionality, and potential for grandeur that were inherent in the baroque style developed in close interaction with the need and desire of post-Reformation Europeans to find visual expression for the new political, confessional, and societal realities.[32] So as a future research directions she express her interest to start thinking about mixed reality installations and their capacity to enable fluid transitions through perception instead of material, as alternatives to bold destruction. Not demolition and rebuild but transform.

[30] Carola Moujan (2010) Learning from Baroque In Gianluca Mura (ed.), Metaplasticity in Virtual Worlds: Aesthetic and Semantic Concepts, Information Science Reference, Hersheyt:PA, p.171

[31] Ibid

[32] Gary B. Cohen and Franz A. J. Szabo (2008) Embodiments of Power: Building Baroque Cities in Europe, *Berghahn books 2008 p.284*

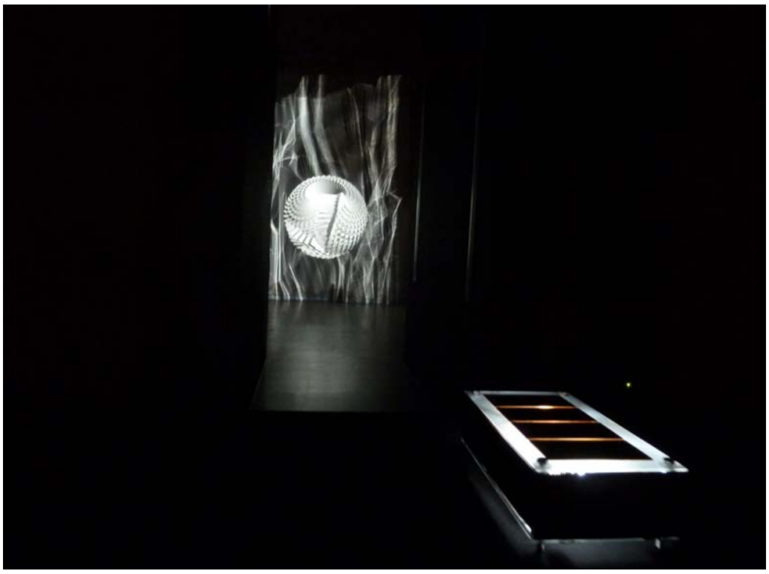

Figure 26 Non Human Device #001 from visiophone.

b) Examples

--"NON HUMAN DEVICE #01"

> "NON HUMAN DEVICE #01" Figure(26,27,28) *is an audiovisual installation based on Boris Chimp 504's audiovisual live performances. During a recent exploration to Kepler22b, an exoplanet from the Kepler-16 binary star system, Boris Chimp 504 found some metallic objects on its surface. Though the origin of this object is totally unknown, it's probably a piece of technology from an extraterrestrial civilization. Boris has sent this object in an hyperspace capsule to the Vladivostok Space Center, on Earth. It is believed that it's a part of a machine, a mechanism or a device of some kind. Recent investigations on the object lead to believe that it is an interface to control the position and orientation in space and time of something bigger, a spaceship maybe. The device responds to touch, and generates an electric magnetic field that interferes with audiovisual signals and causes space-time distortions. In this public installation, the audience will have the opportunity to interact with this "Non Human-Machine Device", and experience the effects that it causes to audiovisual signals and space-time orientation.*[33]

The reason that I am putting this installation as an example is because it is raising the question of how we can interact with a *Non Human-Machine Device.* Rodrigo Carvalho and Miguel Neto for this work had "invented" a new object, a machine from outer space and with their futuristic sci-fi aesthetic had created an artwork in order to interact not with our environment but with another plabet.....

[33] As sited from the artist http://www.borischimp504.com/nonhumandevice/index.html

 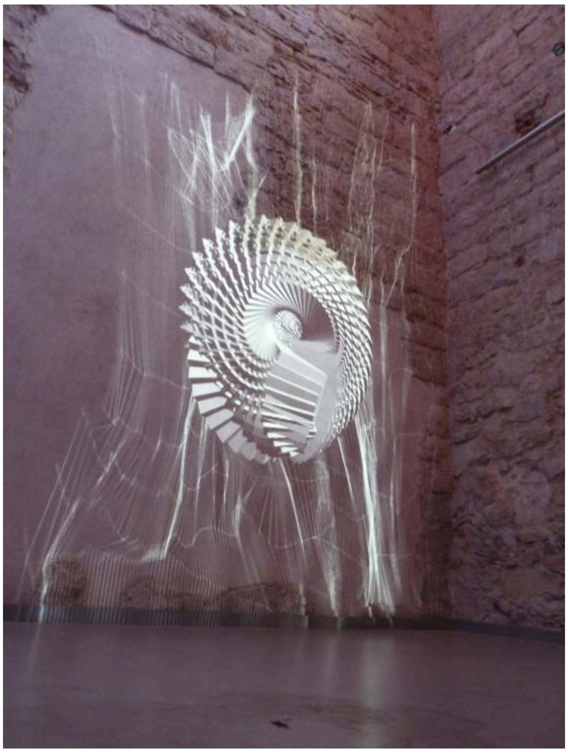

Figure 27,28. Non Human Device #001 from visiophone at microMutek Festival, Barcelona,2013.

--Wooden Mirror

Figure 29 Wooden Mirror by Daniel Rozin, 2000 SIGGRAPH

Wooden Mirror is an octagonal shaped and composed of hundreds of wooden tiles. Each tile is set on an individual electric motor. In the center of the structure, a tiny video camera records the image of anyone who comes to view the piece. A computer processes the image from the digital camera and sends appropriate signals to the motors. The tiles are moving and create the image of the person standing in front of the mirror. This installation is responding to its environment creating a live-mosaic. This work explores in a very interesting way the dialogue between virtual and physical. As it creates a reflected duplication of what stands in front of it, makes natural sound. This mirror works like a "live" low resolution display.

As Rozin explains:

> "*the non-reflective surfaces of the wood are able to reflect an image because the computer manipulates them to cast back different amounts of light as they tilt toward or away from the light source... The image reflected in the mirror is a very minimal one. It is, I believe, the least amount of information that is required to convey a picture... It is amazing how little information this is for a computer and yet how much character it can have (and what an endeavor it is to create it in the physical world*)".[34]

--Trace 2013

The installation (*Trace 2013*) by HC Gilje consist of moving lights on LED strips that continuously illuminate space from different angles creating an intersections of form, perspective and shadow. In almost pure darkness the visitor is invited to explore the derelict space as details are illuminated and space is constantly reshaped (Figure 30).

The curators asked works to ´question the current human predicament of being stuck in a continuous loop, where the predominant ideas that shape our world are unsustainable and unimaginative when it comes to solving everyday problems.

Figure 30 Trace by HC Gilje, 2013

[34] Paul A. Fishwick(2006) Aesthetic computing The MIT Press Cambridge Massachusetts p.373
This source is taken from Siggraph 2000. Electronic Art and Animation Catalog. ACM Siggraph, 2000

In an earlier (Light Space Modulators, 2011) installation he had also experimented with sound. Sound was projected into the empty space, using the physical structure and texture of the space to transform it. At the same time the slow movements in light and sound is transforming the physical space into a contemplative environment. The circular discs are freestanding sound modules (Arduino with a wave Shield) placed on the floor, thus becoming a central part also of the visual experience.[35] With his work he comments out the need to realize that the digital world drags us away from the physical.

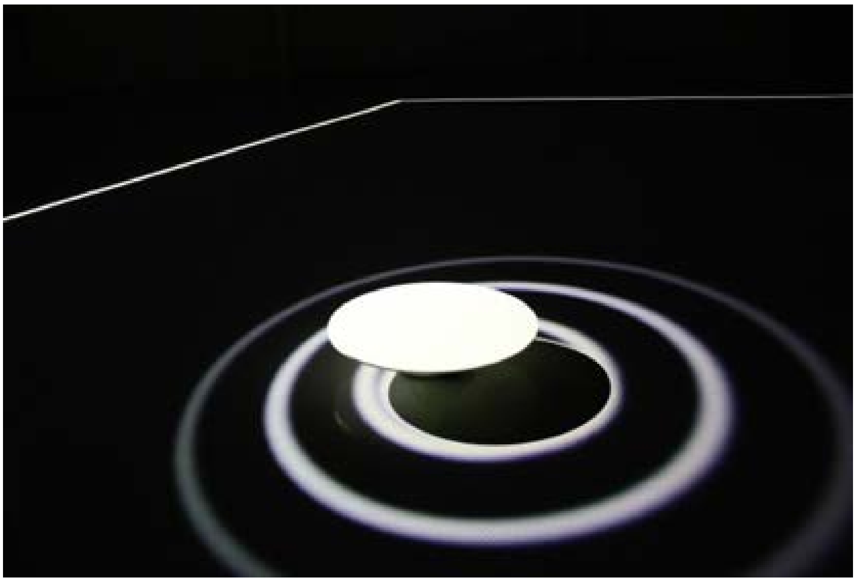

Figure 31 Light Space Modulators by HC Gilje, 2011

> *« HC Gilje has developed his own software (VPT), as is typical in this digital world when one wants to freely explore and do research. His art is deeply rooted in experience in and with the physical world, in the particular and singular act performed in a particular place at a particular time and with particular people. He designs his real-time digital tools to maximise his freedom in a live situation, to feel and experience the specific context and its materiality, and to elaborate audiovisual dialogues using the power of simulation and computer generated illusions* that *intensify our sense of being in the world..»*[36]

--**The Fractoid**

Fractoid is an example of mixed reality installation that includes almost everything that we have discussed so far and going to see below; a parametrical figure, kinetic sculpture that is being constantly transformed virtually and physically. Enclosing the notion of a game where the players actually are taking the roll of sculptures carving a rock with light. For this work has been used an Arduino controlled step motors and a control schema utilizing TouchDesigner. (Figure 32)

[35] As the artist sited in an interview https://www.youtube.com/watch?v=rMenxHWqpVc

[36] As sited in iMAL (interactive Media Art Laboratory) regarding his work http://www.imal.org/en/activity/light-space-modulators

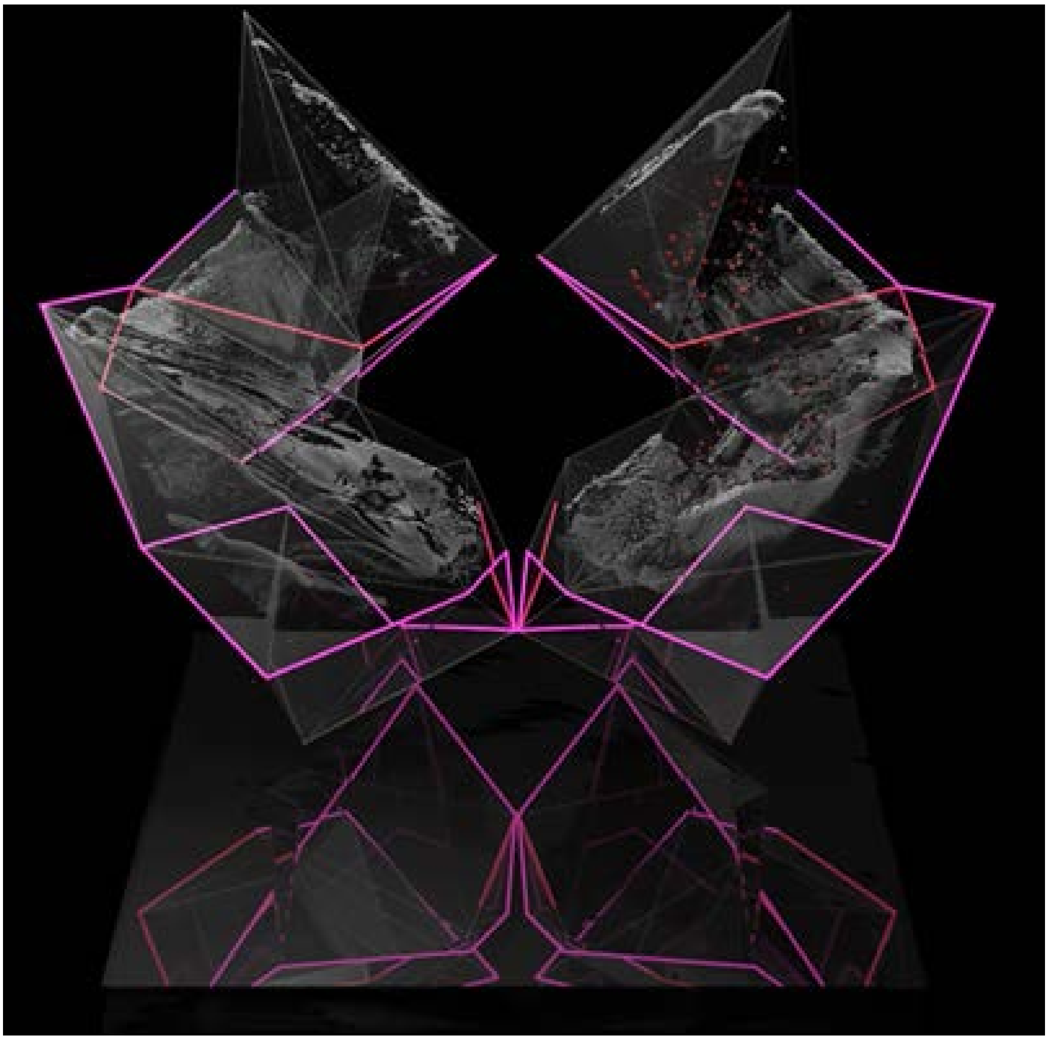

Figure 32 Fractoid by artists Gabriel Pulecio and Mike Russek.
Sound design by Sam Pool 2013

VI) THE ARDUINO AS TOOL FOR ANIMATING THE PHYSICAL WORLD

> *«Arduino is a tool for making computers that can sense and control more of the physical world than your desktop computer. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board. Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs..»*[37]

There are people who are trying to write interesting software, and for whom computers are just a medium of expression, as concrete is for architects or paint for painters. It's as if mathematicians, physicists, and architects all had to be in the same department. Sometimes what the hackers do is called "software engineering," but this term is just as misleading. Good software designers are no more engineers than architects are. The border between architecture and engineering is not sharply defined, but it's there. It falls between what and how: architects decide what to do, and engineers figure out how to do it. What and how should not be kept too separate. [38]
Microcontrollers, traditionally used by engineers, are now in the hands of artists and designers working with the Arduino, and vice versa. Engineers are also creating artwork and design pieces. It is like we are going back to the late 1400 until late 1800 where the art of mechanical toys flourished. Another flashback that Arduino give us is its path into museums like photographs in the 1800 were seen as a new technology belonging to science.

There were artists like Dziga Vertov at that time who took this "new technology", a camera and used it to explicitly call attention to the tools of his trade by inviting viewers to share in his wonder and amazement at how those tools could record and transform reality. In his film Man with a Movie Camera (1929) Soviet citizens are shown at work and at play, and interacting with the machinery of modern life. As Manovich describes:

> "*Vertov stands half-way between Baudelaire's flâneur and computer user: no longer just a pedestrian walking through a street, but not yet Gibson's data cowboy who zooms through pure data armed with data mining algorithms. In his research on what can be called "kino-eye interface," Vertov systematically tried different ways to overcome what he thought were the limits of human vision. He mounted cameras on the roof of a building and a moving automobile; he slowed and speed up film speed; he superimposed a number of images together in time and space (temporal montage and montage within a shot). A Man with a Movie Camera is not only a database of city life in the 1920s, a database of film techniques, and a database of new operations of visual epistemology, but it is also a database of new interface operations which together aim to go beyond a simple human navigation through a physical space*."[39]

[37] As sited in Arduino's website Arduino. http://arduino.cc/

[38] Graham Paul (2004) Hackers & Painters, O"Reilly Cambridge p. 18.

[39] Lev Manovich (2002) The Language of New Media MIT Press, Cambridge MA p.236

Vertov uses a lot the collision editing technique; individual shots in juxtaposition against one another, implying that the life of a person is analogous the life of the city. For example, a woman cleans her face and starts blinking her eyes in one scene, and to the other the blinds on the windows start opening and closing in unison to her eyes. I believe Vertov couldn't imagine at that time that someday the city itself could react at an external stimulus, like the woman's eyes do. He could see though, the daily cycles and processes of both humans and their environment as a mechanism, *the "crystallization of time", the invention of another type of machine which is capable to encounter the mechanic and thermodynamic machines; a machine capable to reproduce the time of perception, of sensibility and of thought.* [40]He believed that he could make peace between man and machine. He developed the idea of cinema as a machine that releases the temporal and spatial chains imposed to human perception.

The interesting thing about Vertov is that between 1914 and 1916 he had attended Betcherev Institute of Psychoneurology in Petrograd. And maybe that's why he had this obsession with the process in which we encounter our relation to the world. Almost 90 years after Vertov was trying to reconstruct and rethink time and space and the relation of what see and what we experience through his experiments with the moving camera, nowadays it's getting easier to tap into these signals of attention, stress, and our processing of the world. The research in neuroscience is revealing fascinating things about human perception. Also this research (brain-computer interfaces (BCI) is lately followed by a dialogue among designers, technologists, biomedical engineers, neuroscientists, and environmental psychologists explores what brain data tells us about our experience of the city. Can new technologies deepen our understanding of how people relate to place and improve how we design cities?

A brain-computer interface is a direct communication pathway between the brain and an external device. BCIs are often directed at assisting, augmenting, or repairing human cognitive or sensory-motor functions. Today, OpenBCI is a low-cost (240 euro), programmable, open-source EEG platform gives anybody with a computer access to their brainwaves. It is fully accessible and powered by an open-source community of hardware and software builders, making it easy for creators of any skill level and ideal for researchers who haven't yet settled on the perfect system design. The OpenBCI platform is intended to serve as a malleable starting point in the rapidly growing field of brain-computer interfacing.

The decision to make these initial prototypes fit the form factor of Arduino was based on the emergence of numerous hardware platforms that are embracing the Arduino pinout. We wanted to be able to quickly move between different microcontrollers for testing and prototyping.[41]

There is also another way for monitoring brainwaves, a kind of DIY. With the Mind Flex game which has two headsets for DIY brainwave monitoring. Through hacking these headsets and connecting them with an Arduino board it is possible to take as an input the brainwaves. This is the cheapest brain interface (35 euro) but there is some job to be done in order to make it work via the Arduino.

[40] As site in Ulus Baker collective website http://www.korotonomedya.net/kor/index.php?id=21,181,0,0,1,0 under the title A Comment on Dziga Vertov: The Cine-Eye

[41] As sited in http://www.openbci.com/.

The headset uses the NeuroSky chipset just like the commercial units. Some hacks are even available to open up the full communication of the chipset. There are videos on you tube showing how to do that.

I believe that it is fascinating that within almost a century the evolution of the medium, that artists use for the creation of their work, has changed radically but their concern about our “being in the world” not. Today artist have in their hands very powerful tools and it is time to use them right. What Vertov has trying to do with a camera, now it can be done with just 35 euros and some electrodes on our head. Are we living in the third cinema era? And if we live in it or getting there is close, what about the physical world that surround us and stimulates our minds?

VII) – Time Cube Project

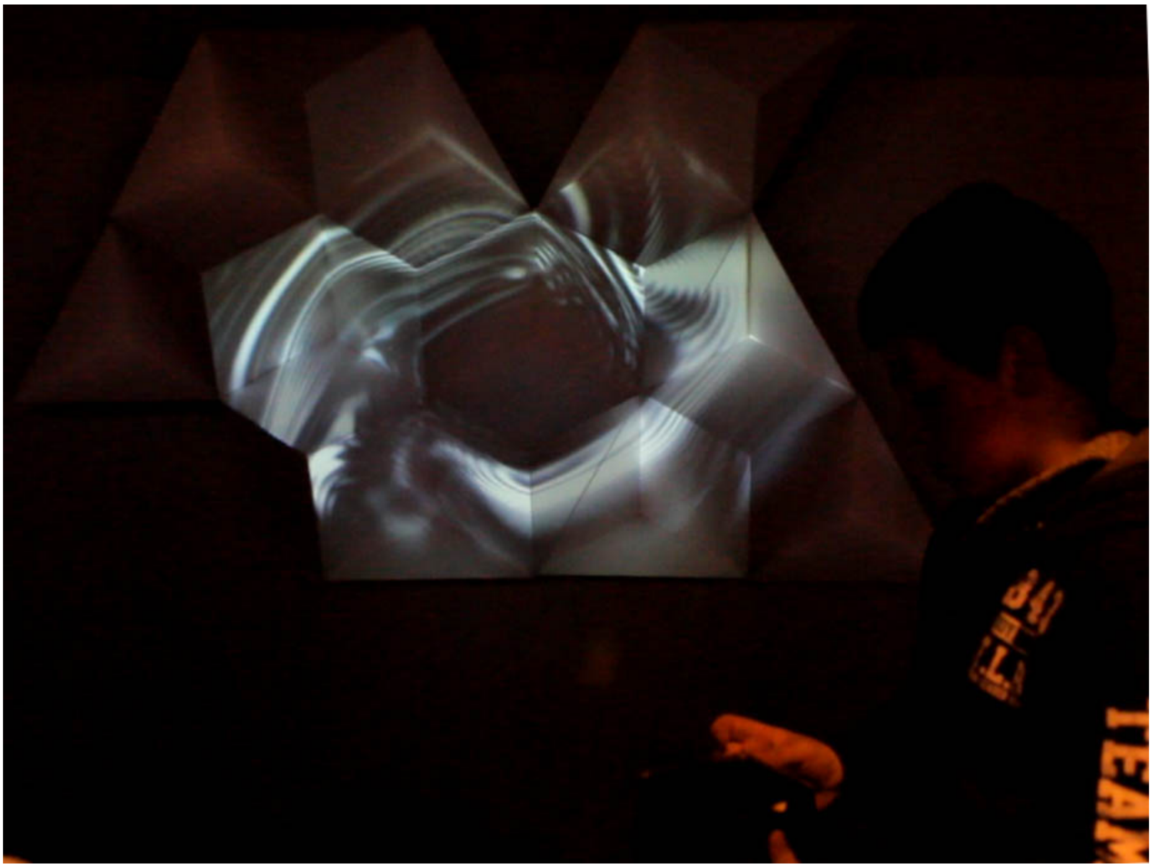

Figure 33 TimeCube, SpaceContinium Laval irtual 2014

After reviewing all these theoretical aspects, it is time to confront the practice I had in order to create a virtual world with which the interaction reveals new aspects of physical space/objects. I will first briefly introduce the project on which we worked, and then I will analyze the techniques that were used. Also I will explain the experiments that I did in order to improve the interaction that the player could achieve between the virtual and the physical world.

a) Presentation of Time Cube

TimeCube (Figure 33) is a project we made with Zamplaras Dionisis, Kourkoulakou Sophia and Theodorou Ino which combines the Unity software, Arduino and VPT to create an interactive projection mapping. TimeCube invites visitors to a journey through the flow of time in a digital world. It combines combines the exploration of a virtual world, with the manipulation of physical/tactile object (Figure 34), using the technique of projection mapping. The installation includes an Arduino sensor and a polyhedron structure (h = 150cm, l = 200cm, d = 96cm) made of cardboard. Part game, part visual experimentation, visitors are invited to play with the "space-time continuum" of this abstract universe, through the manipulation of a single object, a cube -shaped clock.

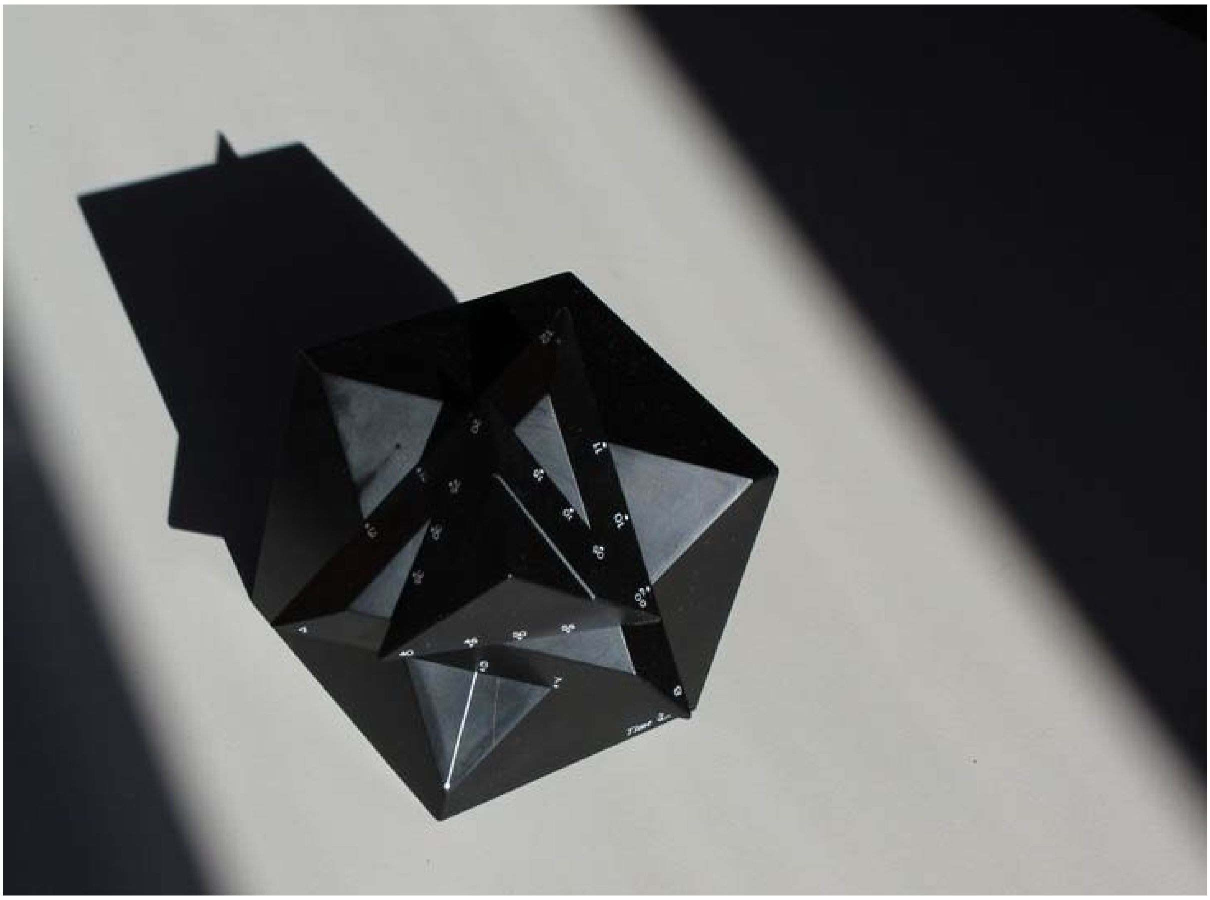

Figure 34 TimeCube ,the object founded in Flea Market at Porte de Clignancourt

The player is trapped in an infinite loop in the virtual world and the only way out is the exploration of the physical structure through its transformations. The environment is designated in Unity 3d, some elements are modeled in 3d Maya through computational generative systems, while all interactions are made possible with the Arduino microcontroller, placed inside and connected with the clock via Unity3d Uniduino. Projections are calibrated with the use of VPT, open-source software, which is able to communicate with various applications, for example Unity3d via the Syphon framework. Syphon allows sharing imagery between applications, so in our case we are sending to VPT frames from the Unity camera. Equipped with a tactile object, the player can intervene and change the forces of the virtual universe, as well as its inner “clock”.

More specifically, the movement of the cube around x and y axes changes the values of the accelerometer attached. Each universe has its own rules which the player can manipulate through the changing values of the accelerometer. In addition, the rotation of the hands of the clock changes the values of the potentiometer, giving the player the freedom to navigate forward or backward in time to the narration.

b) **The concept/About the object**

We decided to create a "game" that was going to be strongly relevant to the physical environment, a virtual world which was going to be discovered through the interaction with the physical.
In order to achieve that we had to make a hybrid/mixed reality installation, an interactive projection mapping.
So we had to invent a mechanism that will connect the virtual with the physical world and that mechanism we decided to be an everyday device.So we went to the Flea Market at Porte de Clignancourt. And then we found a futuristic designed clock.

> "*Time is a child playing at dice. The kingdom is a child's*." *So said Heraclitus some 2500 years ago. Heraclitus was the philosopher of perpetual motion and change. He gives us an imagery of time, of eternity, of how it precedes, a notion of the larger meaning of play and game". Heraclitus uses the notion of the game within a metaphor, a literary device. We read at dictionary.com that a literary device is "a literary or linguistic technique that produces a specific effect, esp. a figure of speech, narrative style, or plot mechanism*."[42]

So what we needed was an object that could work as a literary device, an object that would make the difference between game and play to stand out.
Let's have a look to the difference between game and play.
Play is an open-ended territory in which make-believe and world-building are crucial factors. Games are confined areas that challenge the interpretation and optimizing of rules and tactics - not to mention time and space[43]……
While playing we explore a world. Playing implies the notion wonder and relaxation in contrary game an anxiety for wining. When we are playing we are driven by stories that we can invent in that respect. When we play it is like we are in a labyrinth, not a maze. Labyrinth isn't a maze where you must choose which of several paths to follow and try to remember where you've been and wonder how to get where you want to be. There are no wrong ways, dead ends, or blind alleys, no decisions to make or puzzles to solve. It's a self correcting lesson in concentration. As I mention before "The labyrinth represents the ultimate figure of a space subject to time....".

That's what we needed, a game playing with time. So we decided to use a clock.
We wanted to create a play within a game engine, and it was going to be difficult to keep the player attention if there wasn't a task for him. Maybe giving to the player a clock it was going to be like we were giving him the kingdom. And someone must be concentrated in order not to lose his kingdom.
The clock that we choose to hack was an analogue one and there was a reason for it.
We didn't want a discrete state machine which uses buttons for setting the time, like digital clocks are; we wanted a devise with which someone could control time through a number of values, because time is measurable not a state.

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[42] Videogames and Art, Andy Clarke and Grethe Mitchell, Intellect Books, The University of Chicago Press, 2007 p.54

[43] Bo Kampmann Walthe, (2003) Playing and Gaming, Reflections and Classifications, Game Studies volume 3, issue 1 http://www.gamestudies.org/0301/walther/#_edn1

c) The scenario/ About the universe

So we had an analog clock with which the player could interact and navigate into the visual world. We decided that the total space available to the player was going to be four «levels», four worlds that were connected linear.
At this work levels weren't used in order to represent a difficulty phase or define a section of a given game as in most of games, but divisions of a continuous universe.

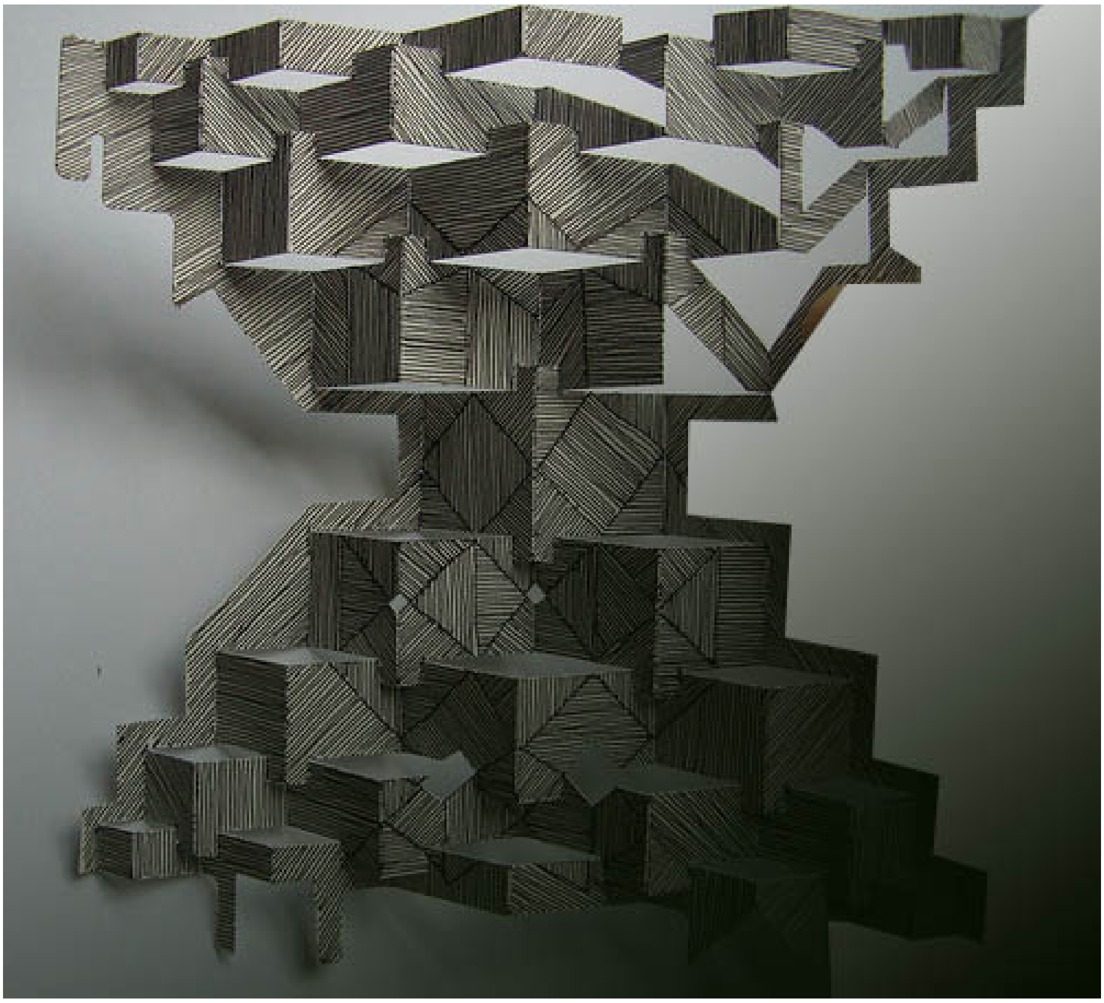


Figure 35 from Conviviality Studio - folding architecture

Once again I am going to do the parallelism with a labyrinth. Leibniz explains that a continuous labyrinth is not a line dissolving into independent points, as flowing sand might dissolve into grains, but resembles a sheet of paper divided into infinite folds or separated into bending movements, each one determined by the consistent or conspiring surroundings. 'The division of the continuous must not be taken as of sand dividing into grains, but as that of a sheet of paper or of a tunic in folds, in such a way that an infinite number of folds can be produced, some smaller than others, but without the body ever dissolving into points. [44] (Figure 35)

[44] Gilles Deleuze, (2006) THE FOLD: Leibniz and the Baroque, Foreword and translation by Tom Conley, Continuum, p.6

Each world as I mentioned had its inner time, an animation that was lasting about 30 seconds. When that time has passed the player was automatically transferred to next world. The only way to stop this infinite loop was to turn the hands of the clock. When the hands were moved backwards the inner clock of the universe was changed accordingly while some videos were playing, revealing the real structure on which the projection took place.
Thus, turning the clock was a link between the virtual and the physical world, and escape from the universe that the player was trapped.
In order to achieve this we needed a sensor that could determine how the object is oriented with respect to something else.

d) The controlller

The simplest rotation sensor that we could use is the ordinary potentiometer. But most pots do not turn 360 degrees infinitely and second, it is difficult to find a way to attach them to the object that the user is supposed to rotate. We deled with the first challenge by using a rotary encoder. An encoder can continuously move 360 degrees around a circle. But we still had to find a way to attach it with the hands. An encoder is an interesting sensor because was common in older computer mice. Encoders combine a rotating wheel and a light sensor to sense rotation. The heart of a common encoder is a wheel with slits cut in it. Generally, encoders are more effective for measuring speed than position. Encoders are common in older computer mice. An Encoder has 3 pins as a potentiometer but the circuit is different. With the potentiometer we connect one side of the pot to ground, the other to 5 volts, and the center to the microcontroller ADC pin, and we get a range of numbers from 0 to the maximum that the ADC can return, 1024.

When we want to connect an encoder we connect the outer sides to two different ADC pins and the center one to the ground.
The sketch that was used to read the encoder's values was found in the Arduino site, and then translated to C# in order to send the values to Unity 3d. There are many ways to read the waveforms of the two channels. But we had to find the one that shouted us. Because we weren't using the encoder as feedback for a servo or robot wheel we didn't mind to lose a pulse, we could trick it out within the code. So we used *Paul Badger's* example.

The encoder was working and was working well in Unity as well. Now the second challenge had to be solved. The clock that we've founded had a classic quartz clock mechanism (Figure 36), which uses an electronic oscillator that is regulated by a quartz crystal to keep time. Its design was interesting and bizarre. The Time Cube carves off one corner of its 6-sided box to form a series of layered triangles which rotate to tell the current time. The largest triangle displays hours, while the medium-sized one tells minutes, and the small spinning triangle on top acts as a second hand.
It was difficult though to have an analog input from the three hands, since the mechanism uses gears that are moving the hands. So we detached the mechanism and attached the encoder, but only to the one hand actually. It was difficult though to have an analog input from the three hands, since the mechanism uses gears that are moving the hands. So we detached the mechanism and attached the encoder, but only to the one hand actually.

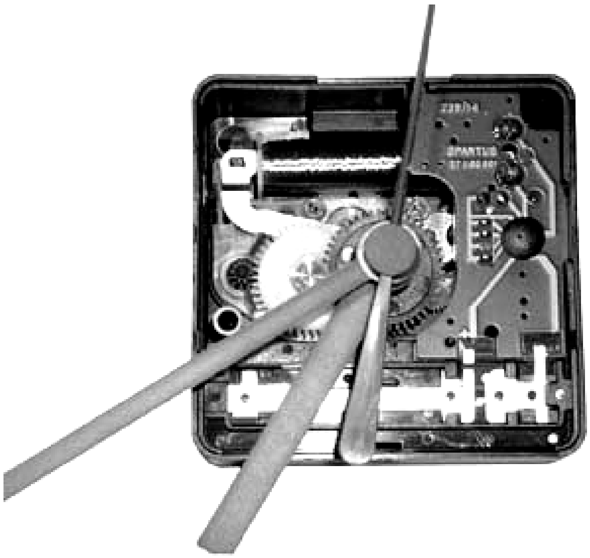
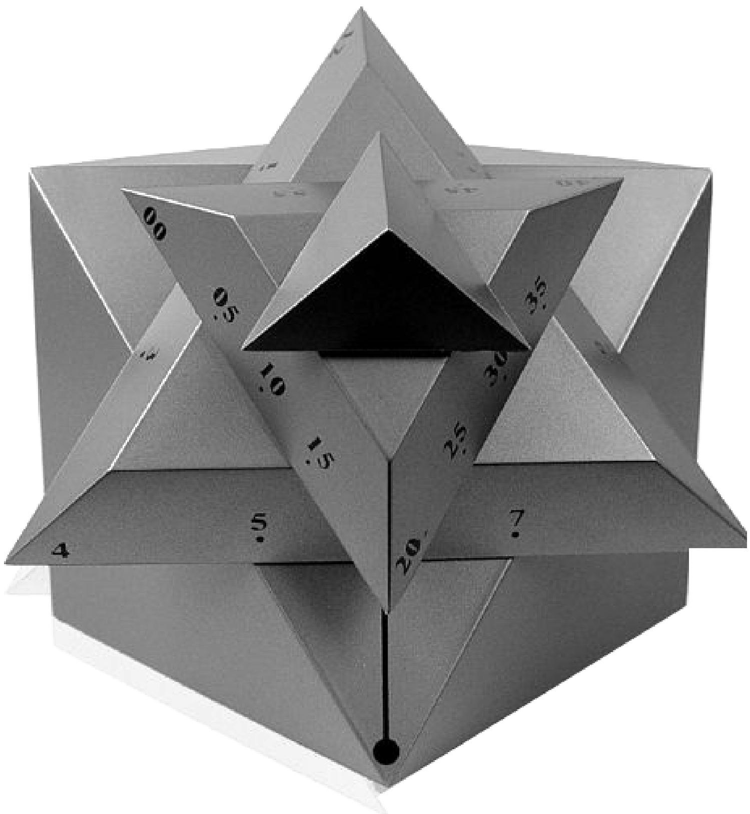


Figure 36 Photo of a quartz mechanism
http://www.prc68.com/I/QuartzClk.shtml



So the player could manipulate time, but we also wanted him to be able to manipulate the «forces» of each universe. We needed another sensor in order to accomplish that, and the specificity of the object, the fact that it was a cube gave us an answer.

We could put an accelerometer inside so the player could rotate the Time Cube in x,z axes. It could work a bit like a die. Dice (singular die or dice; from French dé; from Latin datum "something which is given or played") are small throwable objects with multiple resting positions, used for generating random numbers.

And that is what we wanted the player to do; to generate numbers that would change the structure of the universe. So we needed an analog device once again. Although the concept with the die didn't work we kept the accelerometer inside the cube.

Accelerometers measure the change in speed of movement, or acceleration. The accelerometer sees the acceleration associated with weight experienced by any test mass at rest in the frame of reference of the accelerometer device. Some smartphones, digital audio players and personal digital assistants contain accelerometers for user interface control; often the accelerometer is used to present landscape or portrait views of the device's screen, based on the way the device is being held.

Nintendo Wii Remote also has an accelerometer and also DualShock 3 remote.

The connection with the Arduino board is quite simple; each output pin goes to one of the analog pins on the Arduino, the + pin goes to the 3.3V pin on the Arduino and the GND pin to the GND pin on the Arduino.

The communication between Unity 3d and Arduino was quite simple by using the Uniduino plug-in By EDWON. Through this communication it is easy to create custom controllers, make physical feedback or immerse players in interactive environments. On EDWON's' facebook page he writes:

> «*Uniduino 1.2 is up on the Unity Asset Store! If you don't know what the heck this is, just so know that it's a really cool tool that me and Lazer (aka Daniel MacDonald) made together and it lets you become an Imagineer*».[45]

He is actually telling us that we can easily do what the Walt Disney Imagineering team does.

So what EDWON achieved is to use simple, Arduino-like code to incorporate Arduino into Unity projects. Any electronic input or output that can be connected to an Arduino can now be connected to Unity.

[45] As sited in https://www.facebook.com/edwonia/posts/10151564616002555

Figure 37 TimeCube with the Arduino board

e)Creating a unique art object

We saw how a real object can create a general scenario for a virtual world and how its (real object) connection with it (virtual world) through physical computing determines the output result; determines a path, a mode.

Modality is a path of communication between the human and the computer.

> *«Modality may refer to the ways in which we interface and interact with objects. Art practices encourage things like pluralism in representation, interaction, dynamism, and materiality One might ascribe these concepts to fields such as human–computer interaction, when in actuality; these are part and parcel of the arts. Exploring one or more modalities in the interface is what artists do, therefore, any aspect of computing that stresses this approach owes a significant debt to the arts. However, fields such as HCI, ubiquitous computing, augmented reality, virtual reality, and tangible computing are made possible only by rapid advances in computer-related technology. We have had to wait for the technology to become available to leverage the arts. This same requirement for advanced technology to apply art to computing is present for the next group*.»[46]

[46] Paul A. Fishwick (2006) Aesthetic Computing, The MIT Press,Cambridge MA p.13

And that is the group of physical computing artists who are starting to modify and create their own microcontrollers in order to create art. Three artists have modified the Arduino board for various projects: Usman Haque[83], Bjöern Hartmann[84], and HC Gilje[85].

What was interesting through this procession was the discovery of how everyday object actually are working. Objects like clocks; one of the oldest human inventions, meeting the need to consistently measure intervals of time shorter than the natural units: the day; the lunar month; and the year. Devices operating on several physical processes have been used over the millennia.
And yet most of us have no clue how a quartz clock works as well as what is quark. It is in front of us almost every day but there is no need to know how it works as long it works. We can find out if we want, it is very easy to open it up without breaking it but we don't do it. And the truth is that it is not important but when you do it it's beautiful.
That's exactly what physical computing offers. While working with Arduino for making art projects you are learning how the world works. Like painters, they were studying about how the world works in order to represent it.
Because we couldn't alter the Arduino board, I mentioned some examples but they are the exemption, we had to remake the clock. (Figure 38)

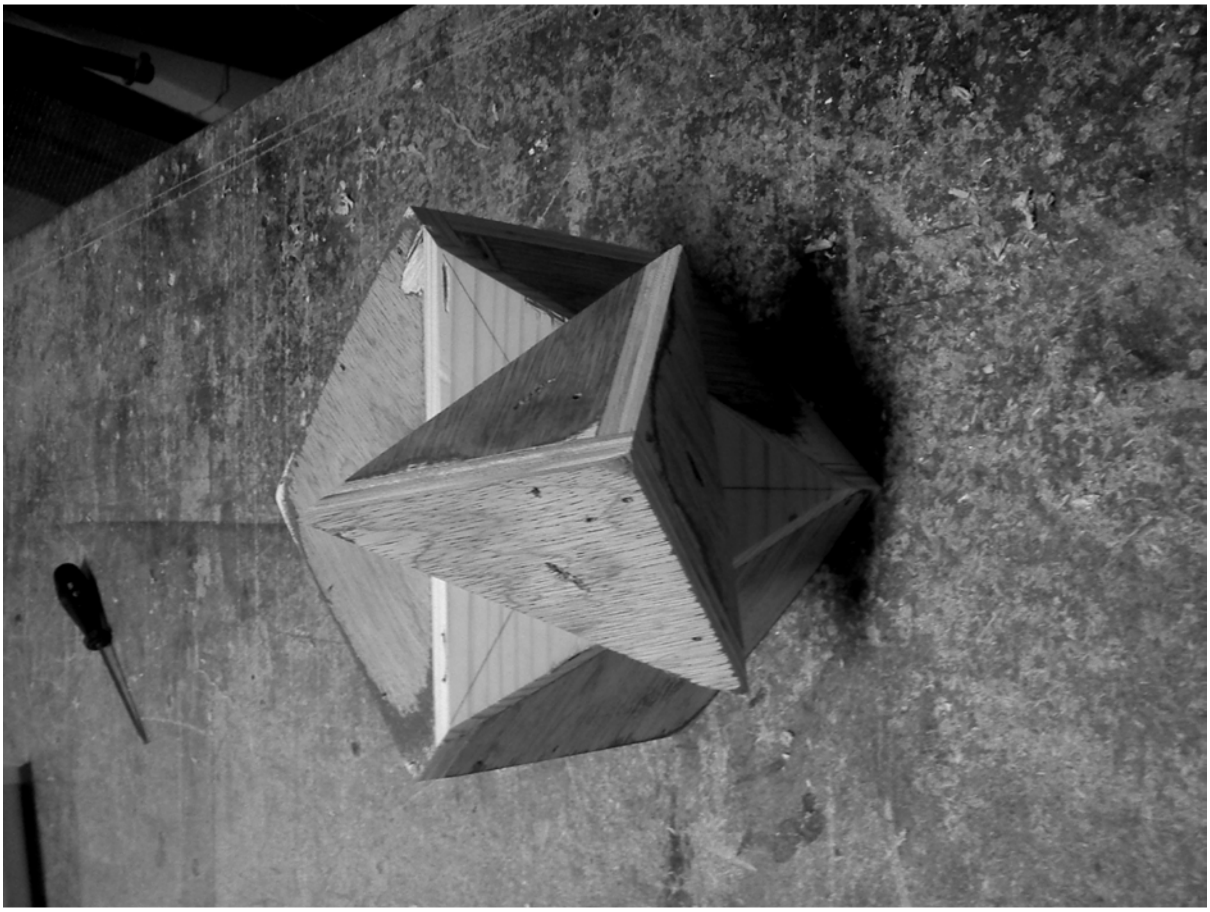


Figure 38 Time Cube, remake

So inspired by a clock and the needs of our installation, we made the cube a bit bigger in order for the Arduino board to fit inside; we made one pyramid with which the player could manipulate time and in which the rotary encoder fitted perfectly. We also found a rotary encoder that we could screw inside the wooden cube.

f) Creating an interactive world for projection mapping

Having in mind the object of interaction, we had to make the universes. We decided that each one of us should make his own universe. The main idea behind my scene in Unity was to create a universe with a repetitive unit; based in fractal algorithm I created a sphere based universe. Since each universe had its own clock, an evolution in time, the questioning for me was how to create a «scene» in Unity in which the player couldn't actually navigate, as a First or Third Person Controller since the controller was the clock/time, and yet he could still fill like we was moving through a space. Another task was how the values from the accelerometer could be translated to a visual output, an output that every time was going to be different. And the last problem was how this universe was going to transform the physical environment, the 3d structure at which the projection was going to take place.

1) For the first task I experimented with «effects» that could give the sense of time-travel/moving. An effect that is used in sci-fi movies in order to create the illusion of moving/travelling in time is the radial blur effect. Radial blur is used to make an illusion of speed. It is often used in racing games for an added effect when the player accelerates. It blurs the image toward a centre point (or any other specified point).

The other one that I tested was the infinity mirror effect. Which metaphorically was used to the "La Jetee" film; the man sees himself seeing himself die. The infinite Citizen Kane, Orson Welles' famous hall of mirrors scene, that creates an endless tunnel; a magical illusion that gives a perception of great depth.

Changing the field view of the camera in combination with the above effects worked.

So with the rotation of the cube towards the y direction I was going to change the camera's field of view in order to give the sense of moving through time and not just filling like time passes by.

2) For the second issue I thought, since I wanted a real–time changing environment, to use an algorithm (Phyllotaxis) that could give me various outputs; while the user was going to change its values.

For that purpose I used the Mathematical model of floret arrangement or else the sunflower arrangement. I founded a C# script made by Sergey Taraban for Unity, in which he had created a spiral representation in order to make Christmas tree with a particle system. With the help of that script I managed to manipulate my own particle system, creating a floret arrangement visual output, with its values and forms were transformed by the Arduino inputs.

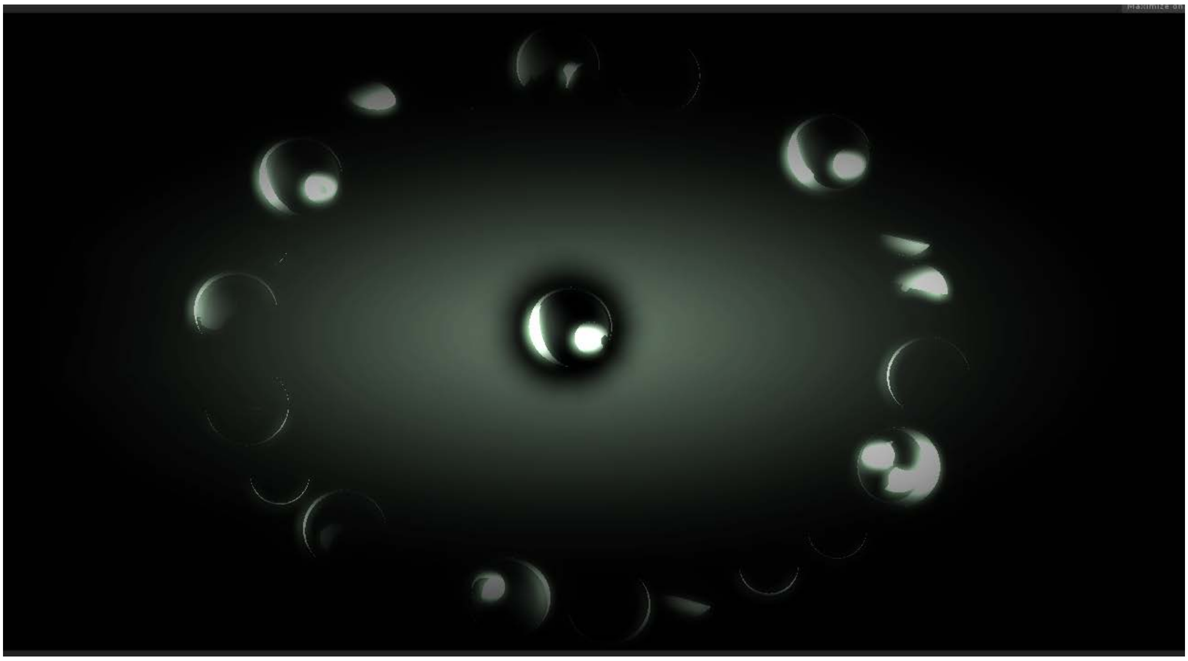


Figure 39. Snqpshot of my universe

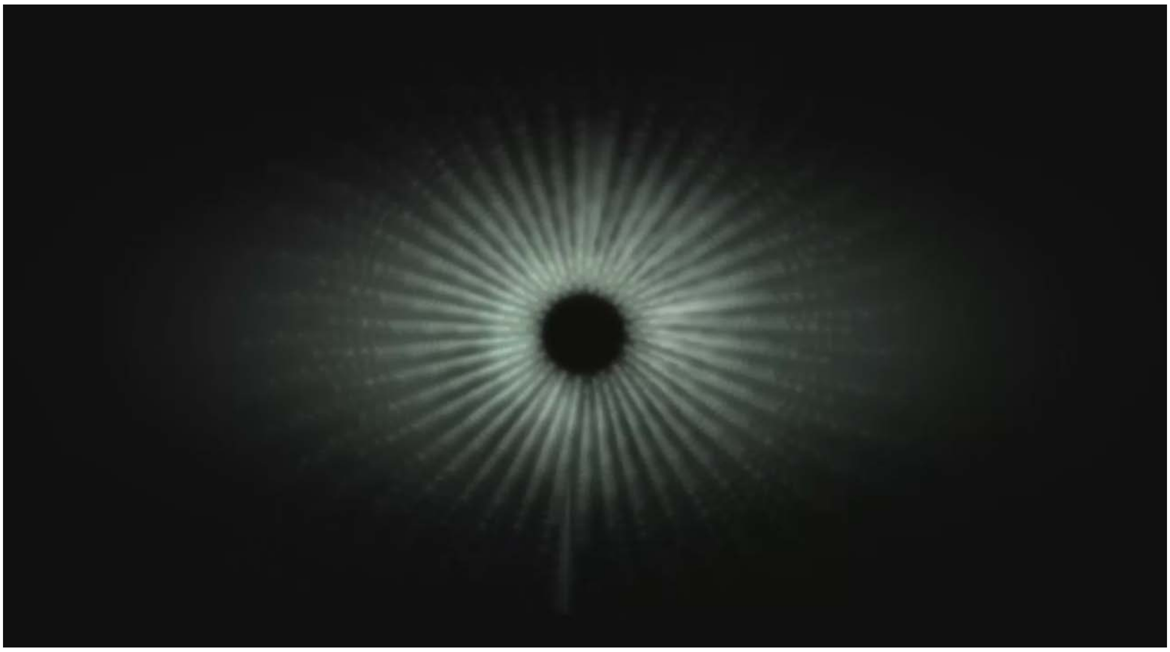


Figure 40. Snqpshot of my universe

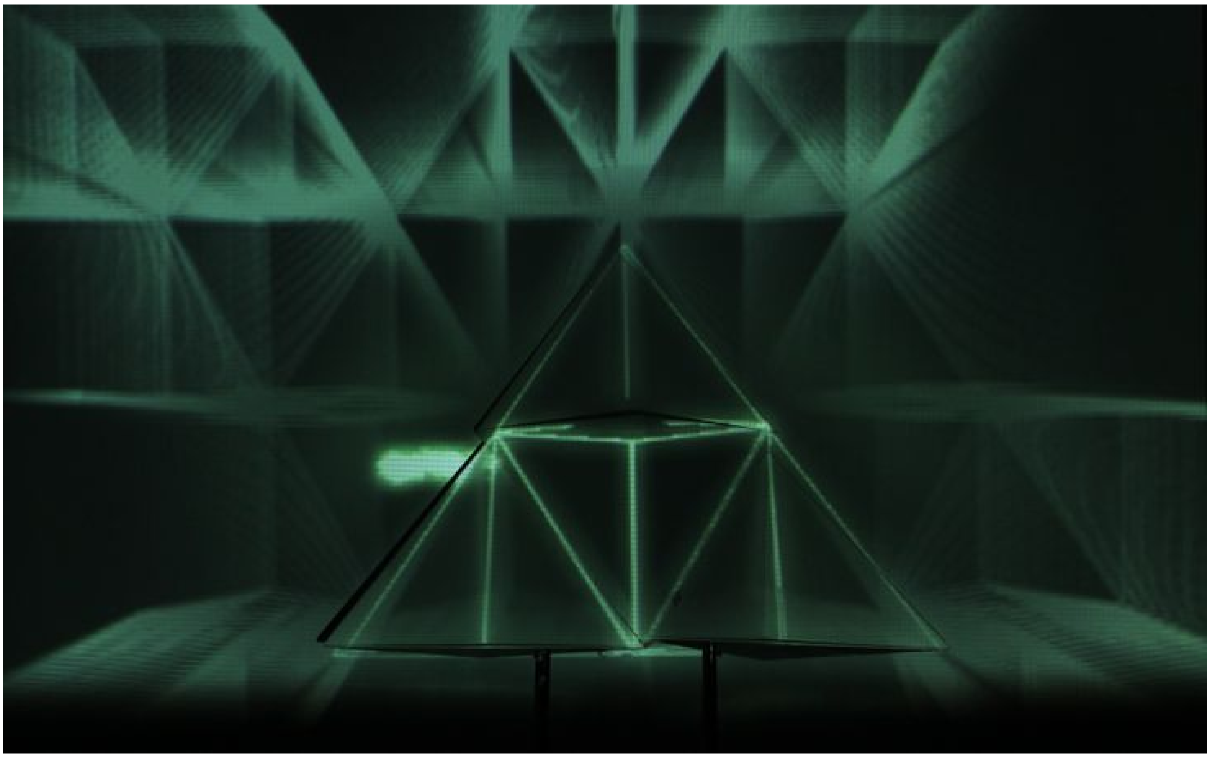
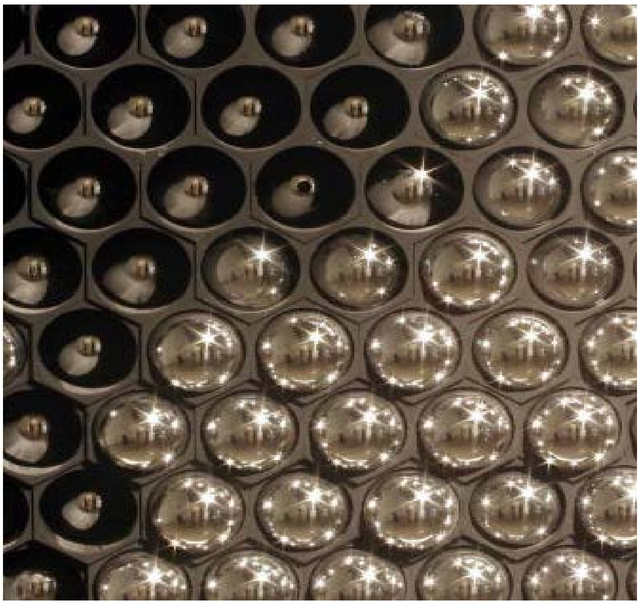


Figure 41. The first structure for Time Cube

g) The structure/physical world

3) The last issue was about the projection on the 3d structure.
The structure that we first made consisted from 4 triangles (Figure 41), one for each universe to be projected on. The concept for this structure was based in Fractal Geometry Triangle. We took as a unit the rotating triangle of the Time Cube and repeated it 4 times in order to form bigger one.

When we projected for the first time on that structure we realized that it was small, and it was going to be difficult for the player to immerse. That led us in an experiment where the projection was going to be extended also on the wall. In that case the universes were going to be «trapped» in the triangle and we someone managed to get out, a virtual structure was suppose to unfold on the wall.
The result was quite good but we realized that a bigger structure was going to more impressive and that «conversation» between the real and the virtual was going to be more interesting. By repeating the geometry of the triangles (without varieties in its scale) we formed, at the end, an asymmetric shape. The universes were going to be projected in a bigger scale, and transform the real environment even more.
The projection mapping requires intense light, for that reason I put glow white particle material in my Scene. The other trick that makes projection mapping interesting is the transformation of the projected surface. So after several experiments I decided not to reveal the whole universe at one. I made a replica of the universe, the one universe had a bright white material and the other was totally black. I attached a sinus curve script to the white spheres in their x axe and I added a different speed for each one. With that «trick» I managed to make an effect of reflection; the black spheres were reviling only when the glowing ones were passing through them. The result looked something like Daniel Rozin's "Shiny Balls Mirror"(Figure 42), which was manipulated by the rotation of the clock.



Figur e 42. Daniel Rozin's "Shiny Balls Mirror" 2003

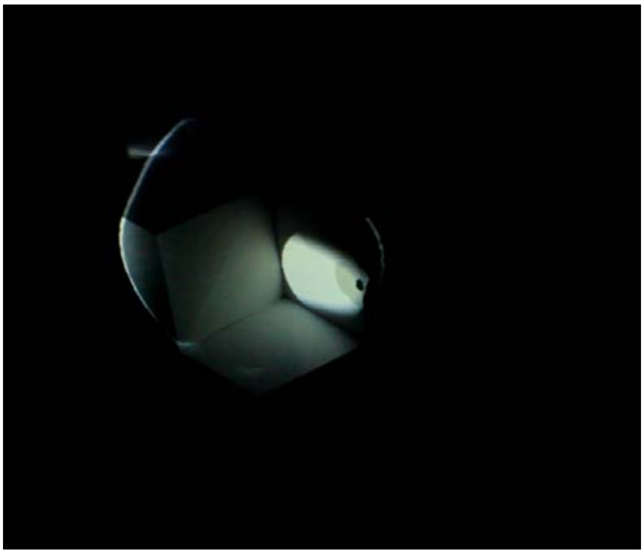


Figure 43 Time Cube Snapshot of the Virtual world on the structure

VIII) PROJECTION MAPPING ON MOVING SURFACE (FURTHER EXPERIMENTS)

There are many ways to use a game Engine platform (Unity 3D) for the creation of project as diverse as interactive installation and VJ performance for theatrical or architectural projection mapping. 3D Projection mapping is now established as one of the most popular and innovative approach to video projections and with the most current and innovative experimentation is going towards interactivity and its different applications. So in addition to the merging of digital visuals with the physical environment, the use of motors can make the activated object to seem total virtual, or entirely real.

As a further experimentation me and Ino Theodorou wanted to physical manipulate the environment/object of projection in the context of a game, in which the player could play with both worlds; the physical and the virtual. So we had to see with which way we could use Unity for this experiment. At this point we had three options, one to manipulate (rotate it in the case of using servo motors) the layers of VPT meaning that additional layers would be added upon the Unity layer, the second option was to rotate only the object in Unity which was projected through VPT via Syphon and the third was to project directly from Unity.

For the first condition we did an experiment without Unity, just to see how it works. It could also be done via Unity as well.

a) VPT and Arduino

The next level of this project was to make an experiment with a projection on a moving surface.
A servo motor, manipulated through a potentiometer, was going to rotate the surface on the Z axis.
First we tried to do the calibration with the VPT software.
VPT can communicate with serial devices like the Arduino microcontroller. This means that sensors and switches can control VPT behavior but also that VPT can control led lights, motors, Servo motors etc.

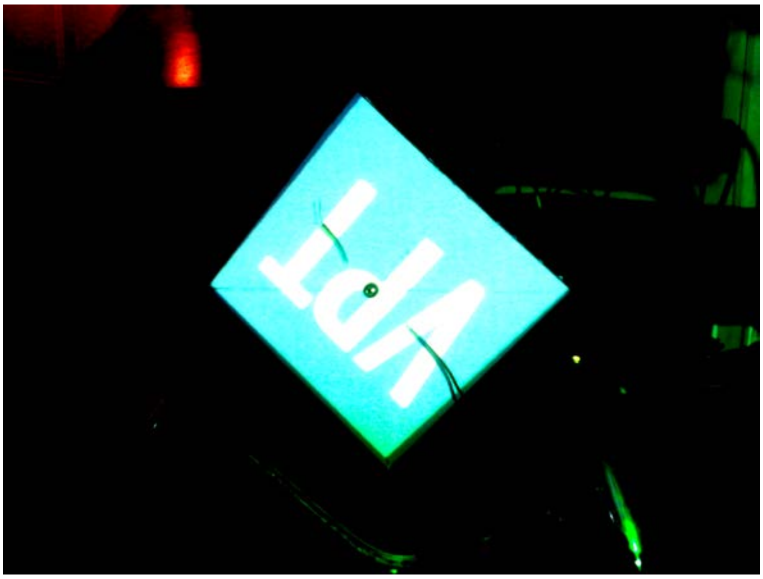


Figure 44 Experiment with projection mapping on moving surface

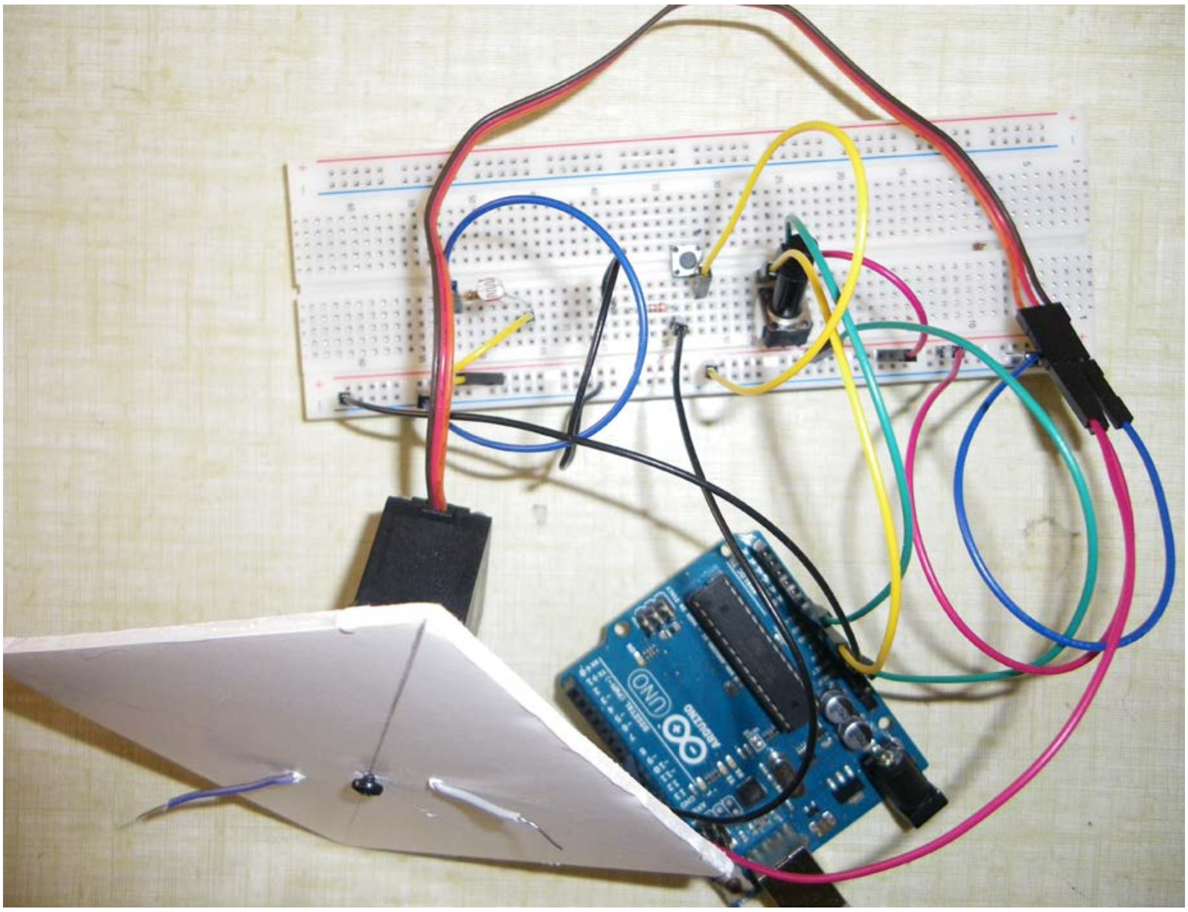


Figure 45 Experiment with projection mapping on moving surface

There is a serial tab at which is set the connection with the serial device, Arduino in our case.
The set up is done in a similar way with a midi device, by selecting the serial port from the menu.
For this experiment we worked on VPT 5 because in the 7 version there is no Osc command for rotating the layer and it was difficult to map the values of the servo motor according to the corner pin values of the VPT layer.
So we made an Arduino sketch based on HC Gilje's code for sending data in VPT, controlling in the same time the Vpt layer and the servo motor. For this is needed to set the sensormodules to the right id and datatype. The way to control motors from VPT is by using serial out. One way is to do it from the router, where you choose serial and then s1 to s8, and then the output range, and the other way is by sending serial data out from the cuelist using the O/o command.
The simplest way to do this after all is by sending/receiving messages through OSC communication.
The problem was that VPT is not a CAD program and it cannot find a complex's form center.
So when the projected layer is not orthogonal VPT rotates the layer from a non center point, meaning that this would work only with an orthogonal form positioned at the projection's center.

<u>b) Arduino Unity VPT</u>

At this experiment we used Unity 3D as a controller for VPT. The Arduino was communicating with VPT through Unity. In this case the Osc messages were sent to VPT through Unity, as we did in Time Cube. So at the same time a potentiometer was moving an object in the virtual and the physical world. The calibration was achieved through the manipulation of the VPT's layer and then the rotating cube in the Unity world was following the moving surface.

Generally what we figured out was in order to achieve projection onto a moving surface is better to use programs such VVVV or Touchdesigner. These programs are compatible with 3D animation software and it is easier to achieve better results.

Conclusion

Every kind of art expression (painting, sculpturing, filming, compositing etc.) presupposes the ability to give form in an idea. The material realization of the idea is very important. And that is what new technologies do in the field of HMI and communication, even when they emerge you in the most virtual world, at the end it is all about feeling it present and real. So what I realized from my practice this year and from my research on the subject is that material realisation and presence in space is important.

There are many techniques that you can use in order to create something and it is very interesting to explore them. Because at the end techniques are only a mean to realise what you would like to happen. It is never clearly shown before. On a screen you can do anything without limits. Trying to find where the limits in material realisation are is very interesting, trying to move them is better. And that in my opinion is the beauty in the conversation between virtual and physical, human and machine. The virtual representation of something physical is going to be at the end the inspiration of making physical the virtual.

For my future work I would like very much to continue my research on projection mapping on moving surfaces with the use of OpenBCI.

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X.Appendixes

Appendix 1 : Code in Unity 3d for the Rotary Encoder

```
using UnityEngine;
using System.Collections;
using Uniduino;


public class rotaryScript2 : MonoBehaviour {

    public Arduino arduino;
    public int pinA = 2;
    public int pinB = 4;


    public int prevState = Arduino.HIGH;

    public int encoder0Pos = 0;
    public int nextPos=0;
    public int previousPos=0;
    public int preValue=0;

    private GameObject cube;

    static int ardHIGH;
    static int ardLOW;


    void Start( )
    {
        arduino = Arduino.global;
        arduino.Setup(ConfigurePins);
        cube = GameObject.Find("Cube");
        ardHIGH = Arduino.HIGH;
        ardLOW = Arduino.LOW;

    }
    void ConfigurePins( )
    {

        arduino.pinMode(pinA, PinMode.INPUT);
        arduino.pinMode(pinB, PinMode.INPUT);

        arduino.digitalWrite(pinA, ardHIGH);
        arduino.digitalWrite(pinB, ardHIGH);
        arduino.reportDigital((byte)(pinA/8), 1);
    //  attach(ANALOG MESSAGE, analogWriteCallback);

    }
    void Update ()
    {
//

        int state = arduino.digitalRead(pinA);
        if(prevState !=state)
        if (state != prevState )
        {

            prevState = state;
            doEncoder Expanded();
        }
    }
    void doEncoder() {

        int currentLevel=Application.loadedLevel;

        if (arduino.digitalRead(pinA) == arduino.digitalRead(pinB)) {
            encoder0Pos++;
            nextPos=encoder0Pos ;

                cube.transform.Translate(Vector3.right,cube.transform);
            Debug.Log (nextPos);


        } else {

            previousPos--;

                cube.transform.Translate(Vector3.up,cube.transform);
            Debug.Log (previousPos);
```

```
        }

    }
    void doEncoder Expanded()
    {
        int currentLevel=Application.loadedLevel;
        if (arduino.digitalRead(pinA) == Arduino.HIGH) {   // found a low-to-high on channel A
            if (arduino.digitalRead(pinB) == Arduino.LOW) {  // check channel B to see which way
                // encoder is turning
                encoder0Pos = encoder0Pos - 1;
            }
            else {
                encoder0Pos = encoder0Pos + 1;

            }

        }
        else                                        // found a high-to-low on channel A
        {
            if (arduino.digitalRead(pinB) == Arduino.LOW) {   // check channel B to see which way
                // encoder is turning
                encoder0Pos = encoder0Pos + 1;

            }
            else {
                encoder0Pos = encoder0Pos - 1;

            }

        }

        if(encoder0Pos != preValue)
        {
            if(encoder0Pos == preValue+10 )
            {
                StartCoroutine(myLoadLevel(0.0f, ((currentLevel)+1)) );

                preValue = encoder0Pos;

            }
            else if (encoder0Pos == preValue-10)
            {
                StartCoroutine(myLoadLevel(0.0f, ((currentLevel)-1)) );
                preValue = encoder0Pos;
            }

        }
    }

    IEnumerator myLoadLevel(float delay, int level)
    {
        yield return new WaitForSeconds(delay);
        Application.LoadLevel(level);
    } // ends IEnumerator


}
```

Appendix 2 : Code in Unity 3d for the accelerometer

```
using UnityEngine;
using System.Collections;
using Uniduino;

public class accelerometer : MonoBehaviour {

    public Arduino arduino;

    //public int pin = 0;
    //public int pinValue;
    public int pinValueX;
    public int pinValueY;
   // public float spinSpeed = 0.5f;

    private GameObject cube;

    const int xPin = 0;
    const int yPin = 1;
    const int zPin = 2;

    //The minimum and maximum values that came from
    //the accelerometer while standing still
    //You very well may need to change these


    int minVal = 265;
    int maxVal = 400;
    int middleVal =334;


    //to hold the caculated values
    double x;
    double y;
    double z;

    void Start( )
    {
        arduino = Arduino.global;
        arduino.Setup(ConfigurePins);
        cube = GameObject.Find("Cube");
    }

    void ConfigurePins( )
    {
        arduino.pinMode(xPin, PinMode.ANALOG);
        arduino.reportAnalog(yPin, 1);
        arduino.reportAnalog(xPin, 1);
    }

    void Update ()
    {

        int xRead = arduino.analogRead(xPin);
        int yRead = arduino.analogRead(yPin);

        pinValueY = arduino.analogRead(yPin);
        pinValueX = arduino.analogRead(xPin);
        if (yRead>300 && yRead<360 )
            pinValueY=0;
        if (yRead<300 )
            pinValueY=pinValueY/3;
        if (yRead>360 ){
            pinValueY=(pinValueY-135)/3*-1;
            cube.transform.Translate(Vector3.up,cube.transform);
        }

        if (xRead>300 && xRead<360 )
            pinValueX=0;
        if (xRead<300 )
            pinValueX=pinValueX/3;
        if (xRead>360 )
        {
            pinValueX=(pinValueX-135)/3*-1;

            cube.transform.Translate(Vector3.right,cube.transform);
        }

    }
}
```

Appendix 3 : Code in Unity 3d for the Servo Motor

```
using UnityEngine;
using System.Collections;
using Uniduino;

#if (UNITY 3 0 || UNITY 3 0 0 || UNITY 3 1 || UNITY 3 2 || UNITY 3 3 || UNITY 3 4 || UNITY 3 5)

public class ServoSlideControl : Uniduino.Examples.ServoSlideControl { } // for unity 3.x
#endif

namespace Uniduino.Examples
{

    public class ServoSlideControl : MonoBehaviour {

        public Arduino arduino;

        private GameObject cube;

        public int servo pin = 9;
        public int servo pos=0;

        public int potpin = 0;
        public float spinSpeed = 0.2f;
        public int pinValue;

        void StartHandler () {
            OSCHandler.Instance.Init();
        }


        void SentToClientOscScale(int rotation)
        {

            OSCHandler.Instance.SendMessageToClient( "vpt5","/layer1"+"/roty" ,rotation);

        }
        // Use this for initialization
        void Start () {

            arduino = Arduino.global;
            arduino.Log = (s) => Debug.Log("Arduino: " +s);

            arduino.Setup(ConfigurePins);
            ConfigurePins ();
        }

        void ConfigurePins ()
        {
            Debug.Log("set pin mode");
            arduino.pinMode(servo pin, PinMode.SERVO);
            arduino.pinMode(potpin, PinMode.ANALOG);
            arduino.reportAnalog(potpin, 1);
            //Debug.Log("set pin mode");
        }

        // Update is called once per frame
        void Update () {
            pinValue = arduino.analogRead(potpin);
            int new servo pos =(int)pinValue.Remap(0, 1023, 0, 180);
            Debug.Log (new servo pos);

            if (new servo pos != servo pos)
            {
                arduino.analogWrite(servo pin, (int)new servo pos);

                servo pos = new servo pos;
            }

            transform.localEulerAngles = new Vector3(0,-servo pos,0);
        /
            SentToClientOscScale (servo pos);

        }
    }
}
```

Appendix 4 : Code in Unity 3d for real-time visuals with accelerometer

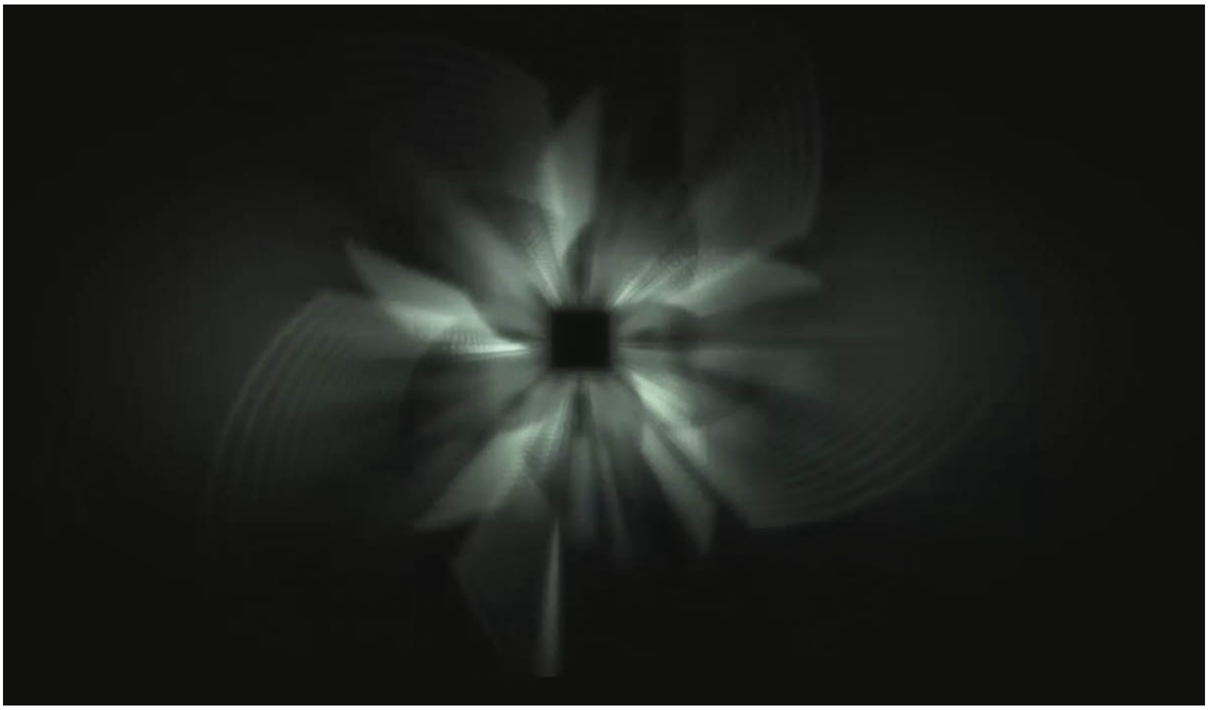
```
using UnityEngine;
using System.Collections;
using Uniduino;

public class nefAccelerometer1 : MonoBehaviour {

    public Arduino arduino;
    public int pinValueY;
    public int pinValueX;

    public GameObject animatedObject 1;
    public GameObject  Event;
    public AudioSource aSource;
    public float speed;

    float phi;
    float amplitude;
    float move speed= 12.0f;
    GameObject[] respawns;
    GameObject eventer;
    GameObject Cylinder;

    float mCurrPhaseOffset = 0.0f;

    public int MaxParticlesNum = 800;
    public bool showAllAprticles = false;
    public float Height = 0.1f;
    public float startRadius = 0.5f;
    public bool fixedLineStep = true;
    public float lineStep = 0.05f;
    public float angleStep = 0.5f;
    public float particleScaleMax = 4.0f;
    public float rotateSpeed = 1.0f;

    int switchCase = -1;
    float timer = 0;
    float mOldCangeColorTime = -10.0f;
    ParticlesController mParticlesController = null;


    /// <summary>
    /// T//////////Arduino /// </summary>/////////////////////////////////////////
    const int xPin = 0;
    const int yPin = 1;
    const int zPin = 2;

    int minVal = 265;
    int maxVal = 400;
    int middleVal =334;


    double x;
    double y;
    double z;

     // arduino////////////////////////////////////////////////////////////////////////////////

    void Start( )
    {
        arduino = Arduino.global;
        arduino.Setup(ConfigurePins);
        //////////////////////////
        speed=0;
        eventer = GameObject.Find("olaPivot");
        if (respawns == null)
        {
            respawns = GameObject.FindGameObjectsWithTag("glow");
        }
        foreach (GameObject respawn in respawns)
        {
            respawn.SetActive(true);
        }

        mParticlesController = GetComponent<ParticlesController>();
        Cylinder = GameObject.Find("Main Camera");
    }

    void ConfigurePins( )
    {
        arduino.pinMode(yPin, PinMode.ANALOG);
```

```
    arduino.pinMode(xPin, PinMode.ANALOG);
    //arduino.reportAnalog(xPin, 1);
    arduino.reportAnalog(yPin, 1);
    arduino.reportAnalog(xPin, 1);
}

void Update ()
{
    if (Input.GetKey (KeyCode.I))
    {
        Cylinder.animation["Take 001"].speed = 1.0f;
        Camera.main.GetComponent<XftRadialBlurTexAdd>().enabled=false;
        AudioChorusFilter chorus = aSource.GetComponent(typeof(AudioChorusFilter)) as AudioChorusFilter;
        chorus.enabled = false;
    }

    int xRead = arduino.analogRead(xPin);
    int yRead = arduino.analogRead(yPin);

    pinValueY = arduino.analogRead(yPin);
    if (yRead>300 && yRead<360 )
        pinValueY=0;

    pinValueX = arduino.analogRead(xPin);
    if (xRead>300 && xRead<360 )
        pinValueX=0;

   ////////////////////////////PHYLOTAXIS ///////////////////////////////////////////
    if(mParticlesController.IsReadyToUse())
    {
        timer += Time.deltaTime;
        int particlesNum = showAllAprticles ? MaxParticlesNum : (int)Mathf.Lerp(1, MaxParticlesNum, timer/8.0f);
        mParticlesController.SetVertexCount(particlesNum);
        mCurrPhaseOffset += rotateSpeed * Time.deltaTime;
        if(mCurrPhaseOffset >= 360.0f)
        {
            mCurrPhaseOffset = 360 - mCurrPhaseOffset;
        }
        float dAlpha = 0;
        float dL = lineStep;
        float heightOffset = 0.01f;
        float offset = heightOffset;
        bool isChangeColor = ((int)timer - mOldCangeColorTime >= 1.0f);
        if(isChangeColor)
        {
            mOldCangeColorTime = timer;
        }
        for(int i = 0; i < particlesNum; i++)
        {
            float R = offset * startRadius;
            float angle = dAlpha + mCurrPhaseOffset;
            if(angle >= 360.0f) {
                angle = 360.0f - angle;
            }

            float x = R * Mathf.Cos(angle);
            float z = R * Mathf.Sin(angle);
            mParticlesController.SetPosition(i, new Vector3(x, Height*i, z) + transform.position );
            mParticlesController.SetScale(i, Mathf.Lerp(1.0f, particleScaleMax, coeff));

            if(fixedLineStep)
            {
                dAlpha += dL * 180.0f / (Mathf.PI * R);
            }
            else
            {
                dAlpha += angleStep;
            }
            offset += heightOffset;
        }
        ///////////// y parameters ///////////////////////////////////////////
        if (yRead!=0 && yRead<300 )
        {
            Cylinder.animation["Take 001"].speed = 0.0f;
            angleStep += 0.1f;
            AudioChorusFilter chorus = aSource.GetComponent(typeof(AudioChorusFilter)) as AudioChorusFilter;
```

```
            chorus.enabled = true;
        }

        if (yRead>360 )
        {
            Cylinder.animation["Take 001"].speed = 0.0f;
            AudioChorusFilter chorus = aSource.GetComponent(typeof(AudioChorusFilter)) as
            AudioChorusFilter;
            chorus.enabled = true;
            eventer.SetActive(false);
            if(Mathf.Abs(Height) >= 1.5)
                switchCase = switchCase*(-1);
            //if(Height < 0)
            {
                Height -= switchCase*0.01f;
            }
        }
    }
    /////////////////////// X parameters
    ////////////////////////////////////////////////////////
    if (xRead!=0 && xRead<300 )
     {
        if (respawns == null)
        {
            respawns = GameObject.FindGameObjectsWithTag("glow");
        }

        foreach (GameObject respawn in respawns)
        {
            Debug.Log("xojhgfdd");
            respawn.SetActive(true);
        }
        eventer.SetActive(true);
        eventer.transform.rotation = Quaternion.identity;
        eventer.transform.localScale  =new  Vector3(1.0f,1.0f,1.0f);
        Cylinder.animation["Take 001"].speed = 1.0f;
        AudioChorusFilter chorus = aSource.GetComponent(typeof(AudioChorusFilter)) as
        AudioChorusFilter;
        chorus.enabled = false;
        Height=1.4f;

    }
    if (xRead>360 )
    {
        eventer.SetActive(true);

        if (respawns == null)
        {
            respawns = GameObject.FindGameObjectsWithTag("glow");
        }
        foreach (GameObject respawn in respawns) {
            respawn.SetActive(false);

        }

        eventer.transform.Rotate(Vector3.forward* Time.deltaTime * move speed);
        speed = Random.Range(0.01f, 0.05f);
        phi  = Time.time / speed * 1 * Mathf.PI;
        amplitude  = Mathf.Cos( phi ) * 1 + 0;
        eventer.transform.localScale  =new  Vector3(amplitude/2,amplitude/2,amplitude/2);
        Cylinder.animation["Take 001"].speed = 0.0f;
        AudioChorusFilter chorus = aSource.GetComponent(typeof(AudioChorusFilter)) as
        AudioChorusFilter;
        chorus.enabled = true;

    }

  }

}
```

Appendix 5 : Time Cube real – time interaction visuals

Annexe 6 : Real –time interaction with Arduino and ThouchDesigner



Annexe 7 : Real –time interaction with Arduino and ThouchDesigner