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IMMERSED INTO CONSTANT CHANGE:
USAGE OF GENERATIVE SYSTEMS IN IMMERSIVE & INTERACTIVE INSTALLATION ART

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IMMERSED INTO CONSTANT CHANGE:
USAGE OF GENERATIVE SYSTEMS IN IMMERSIVE & INTERACTIVE INSTALLATION ART

A Master's Thesis

by

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INTERACTIVE INSTALLATION ART

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ANKARA
December 2019

I certify that I have read this thesis and have found that it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts in Media and Design.

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ABSTRACT

IMMERSED INTO CONSTANT CHANGE:
USAGE OF GENERATIVE SYSTEMS IN IMMERSIVE & INTERACTIVE INSTALLATION ART

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This thesis aims to investigate the immersive & interactive installations in terms of bodily experience and cybernetic identity. By touching upon the recent discussions on the generative system design and relational aesthetics, an experiential approach towards user interaction and bodily immersion is obtained. As a result, project *intersect();* is presented and described with its content, interaction design, software and hardware components. Finally, a discussion is presented towards the meaning and implications of the work.

Keywords: Creative Coding, Generative Art, Grammar of Interaction, Immersion, Interactive Installation, Relational Aesthetics

ÖZET

SÜREĞEN DEĞİŞKENLİKLE SARMALANMAK:
KAPSAYICI VE ETKİLEŞİMLİ YERLEŞTİRME SANATINDA OTO-ÜRETKEN SİSTEMLERİN KULLANIMI

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Bu tez, etkileşimli sanat pratiği içerisinde kapsayıcı sanat yerleştirmelerini bedensel deneyim ve sibernetik kimlik açısından araştırmayı hedeflemektedir. Oto-üretken tasarım ve ilişkisel estetik kavramları ile ilgili yakın tarihli tartışmalar çerçevesinde, kullanıcı etkileşimi ve bedensel sarmalanma üzerine deneyimsel bir bakış açısı benimsenmiştir. Sonuçta, *intersect();* adındaki tez projesi sunulmuş ve içeriği, deneyim tasarımı, yazılım ve donanım öğeleriyle birlikte açıklanmıştır. Son olarak, projenin anlamı ve çıkarımlarına dair bir tartışma sunularak çalışma tamamlanmıştır.

Anahtar Kelimeler: Etkileşim Grameri, Etkileşimli Yerleştirme, İlişkisel Estetik, Oto-Üretken Sanat, Sarmalanma, Yaratıcı Kodlama,

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CHAPTER 1

INTRODUCTION

“Art exists because reality is neither real nor significant.”

J.G. Ballard

“Just as we can use an array of pixels to create any image we please within the confines of a screen, or a three-dimensional array of voxels to create any form within the confines of an overall volume, so we can create a precise sense-shape with an array or volume of appropriate senses. Such a shape would be exact, but invisible, a region of activated, hypersensitive space.”

Marcos Novak, *Eversion: Brushing against Avatars, Aliens and Angels*, 1997 (74)

In Novak’s above statement, the hypersensitive space is described as an activated volume of appropriate senses. This quote is particularly selected because it refers to the dream of activating such a space with the means of system design and leveraging visual technology, while keeping it affective to human and real in its own sense. In other words, this thesis narrates and discusses a desire to discover a new way of expression within two fields of research: *generative system design* and *perceptual transformation of a space.* Therefore, the main discussion is formed around the investigation of *bodily immersion* of the spectator within a systems-based approach to the artwork.

Consequently, the main endeavor of this thesis can be formulized in three interrelated questions, stated as following:

1. What can be expected from a relatively new field of design, that is generative, in terms of transforming environments and people's embodied existence?

2. Is art getting further away from its representational grounds into a more dynamic, blurry and experience-based fashion?

3. Looking from a systems-based perspective, what can be said about the expanding relationship and dependency between art, design and technology?

While trying to answer these questions, a hybrid and relatively new medium is taken into account, which is usually called as an *immersive* or a *mixed reality* environment, that integrates the digital modalities of image and lighting with the architectural space, while also incorporates sound and other sensual stimuli. Since the 1970s, this particular modality of a space has attracted researchers' attention in diverse disciplines and developed into a "massive worldwide research project" that developed its own methodologies like CAVE environments and head-mounted display systems. (Elwes, 2015) However, one particular point of motivation during the preparation of this thesis and project was to imagine this hybrid space as a playground for collective imagination, which therefore directed the author to explorations of bodily interaction, instead of a performance study. In harmony with these motivations, different modalities and implications of virtual reality environments with their historical precedents are investigated and an argumentative justification of mixed reality environments in terms of their integration of bodily facilitations with immersive qualities are arrived at, while retaining the existence of a collective space. Therefore, the practice-based development of this thesis also questions the applicability and the anticipated results of this justification of mixed realities.

As a practical methodology for this work, the principles of generative system design are leveraged to interpret the concept of *ever-changing environments*. This adoption of a procedural, systems-based approach also constructed a bridge between the notions of artwork and the spectator, as well as characterized the artwork as a living entity with its own mode of vitality. To do so, the fundamental theories of artwork as a system of social and technological factors are discussed with respect to cybernetic theories of 20^{th} century, initiated with Norbert Wiener's identification of such systems from his influential work *Cybernetics* (1948). Along the discussion, the artwork gets related to several other phenomena, including the systems approach to art and society by Niklas Luhmann via visiting his concept of *autopoiesis*, which points at the self-regulatory mechanisms of an entity to maintain its continuity. The concept of *autopoiesis* is correlated with the usage of generative systems in the artistic practice, which in turn amplifies the reception of the artwork as an ever-changing system. Furthermore, art's affinity with other social and technological systems in Luhmann's view is also acknowledged in several other parts of this thesis, such as the continuous unfolding of meaning and convergence of art and technology. Informing each other in a cross-referential manner, the modulations about art's autonomy within a social system setting are discussed to prepare an experience-based understanding for the interactive installation art.

This thesis is formed of seven chapters. Following this introduction, general concepts of computer-generated imagery are introduced such as its definition and usage in visual media disciplines. As a primary remark, the differences between real-time rendering and physically-based, realistic rendering are introduced. The main aim of this chapter is to introduce the fusion between the disciplines of art and design with the technological means of the 20th and 21st centuries.

The third chapter defines the generative art practice in its historical context and considers *complexity* as an applicable methodology to introduce generative systems into the image-making practice. The principles of aesthetics & computational research are also considered to provide a ground for the incorporation of the numeric, automated processes into the artistic practice. The idea of an autonomous system to provide a ground for an automated design process is introduced and several techniques are discussed to help reader understand the project's implementation process, which is explained in more detail at the Chapter 6.

Within the fourth chapter, immersive and interactive installations are introduced with their main characteristics that separate them from the previous artistic practices and with their unique implications about the relationship between the artist, the artwork and the spectator. Various fundamental works from the late 20th and early

21^{st} centuries are examined in terms of the issues of virtuality, immersion and interactivity. The human perception is juxtaposed with the existence of a virtual environment, and the resulting implications are visited continually to provide a ground for the discussion. Besides that, prominent emphasis is put upon the meaning of these works, which visits the concept of relational aesthetics, that takes its grounding from the variety of social relations. At its core, this chapter is a collection of several ideas concerning the *meaning of work* and the *implications of body* in immersive and interactive installations.

Fifth chapter is a preparation for the presentation of the project *intersect();* and about how it bridges fundamental aspects of immersion & interactivity with the principles of generative coding. Here, three aspects of interactive installation art, which are "randomization", "relational aesthetics" and "architectural body" are correlated with the usage of generative coding as a tool. Also, the systems approach is evocated again in detail by references to "*art as a system"* by Luhmann's words.

The sixth chapter is the core chapter for the practice-based nature of this thesis, with its inclusive narration of the project *intersect();*. The project is handled in three parts; with its conceptual design choices, content and implementation, and process and output. Detailed information about the project preparation phase and the software development process is addressed. Regarding the output and the audience engagement, a discussion section is provided to place this work within the current practice of immersive & interactive installation art, about how it re-considers certain values and trends, and describes a possible further space which this work can be expanded upon in the future. Finally, the overall motivation & practice of this thesis are summarized within a conclusion chapter.

CHAPTER 2

COMPUTER-GENERATED IMAGERY: A SHORT HISTORY AND REAL-TIME VISUAL COMPUTING

Computer-generated imagery, or commonly abbreviated as CGI, is the imagery created with the help of or as a result of computational processing, with the principles of "computer graphics". Although CGI is mostly considered to be displayed with the aid of an electronic environment, it has been affecting the practice in many diverse disciplines of art, design, fabrication, engineering and science. For the purposes of this work, I will be mainly discussing the applications of CGI in the fields of art, films and videos, printed media, video games and simulators.

Throughout the centuries of image-making activity in human history, we have used many different tools and mediums to depict our imagination. Also, this activity has always propagated as a collaboration between the human and the tools to ensure that light reflects and refracts at desired directions and amounts. Sean Cubitt, in his genealogical work *The Practice of Light* (2014), describes the history of image-making activity as "the visual technology, that reveals a centuries-long project aimed at controlling light,” from paint, to prints and finally to the pixels. Computer-generated imagery, from this point of view, is an advanced realization of this dream of controlling light, with the unleashed capability of programming the behavior of light within a computationally generated environment and seen through simulated cameras, as well as transferring the data to many other media to fabricate the created imagery.

Computer-generated imagery heavily depends on the principles of geometry to create and store the data structures, which eventually yield to the *rendered* imagery. To quote Cubitt again, “the rise of geometry as a governing principle in visual technology with Dürer, Hogarth, and Disney, among others” (Cubitt, 2014) has eventually led the computational processes to have an advantage over image-making. Here, one critical assumption of computer-generated imagery becomes visible: It imagines the space as a finite set of *points*; and it places objects, lights and cameras to model their behavior inclusively, however in a highly abstracted level. The data structures which generate imagery within the computer are basically arrays and matrices of binary fashion, organized and developed in line with the fundamental laws and principles of optics, physics and geometry.

One of the early examples of the usage of computationally available mathematical operations in the image making is *Sine Curve Man* by Charles Csuri, from 1967. (Fig. 1) In this work, “a digitized line drawing of a man was used as the input figure to a computer program which applied a mathematical function” (Retrieved April, 2019 from https://www.siggraph.org/artdesign/profile/csuri/)

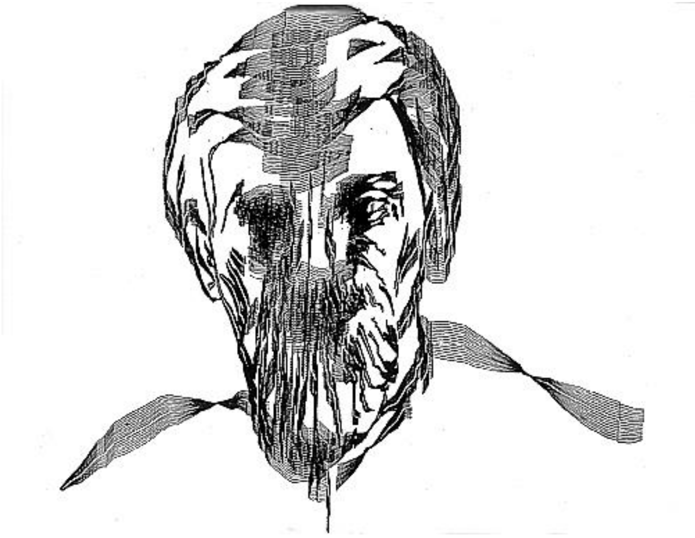


Fig. 1. *Sine Curve Man* (1967) by Charles Csuri

Computer graphics, as the umbrella term, has emerged as a sub-discipline of computer science in the early 1950s to study methods for digital synthesis and manipulation of visual content. (Carlson, 2017) Thanks to the usage of cathode-ray tube (CRT) as a viable display and the inclination towards the discovery of input devices as well as human-computer interaction, the field attracted many researchers throughout the 1960s and 1970s. During this time, researchers at MIT and Stanford University prominently led the first instances of computer-graphics-oriented devices and interfaces, such as TX-2 by Wesley A. Clark (1958), Sketchpad by Ivan Sutherland (1963) until the first attempts at 3D modelling by Edwin Catmull during 1970s. Along the advances such as bump and texture mapping, hidden surface determination and shaders; the representation of computationally generated, illuminated and shot scenes quickly promoted and became a fundamental element of 1980s' home computer proliferation (Carlson, 2017). From this point on, computer graphics exponentially widened its horizon proportionally with the advancements especially in the hardware. 1980s were mainly the years of fast adolescence of computer graphics, with the aims directed at high-speed realistic rendering with the help of high-performance microprocessors, which was going to yield into the prominence of GPUs.

The unified force of research and development in both fields, namely computer graphics and human-computer interaction, has transformed the technological scene of 1980s and 1990s into a rapid diffusion of these practices into many fields. Especially with the ability of integrated processors to perform calculations that are too complex and large, CGI also became a main tool to visualize various data structures, high-degree mathematical algorithms and simulations. As an early example of the usage of computer-generated imagery, John Whitney's work Arabesque (1975) provides a ground for the computational drawing. (Fig. 2) In this work, Whitney, who is regarded as one of the fathers of computer graphics, used an IBM 360 mainframe system with Fortran to animate transforming sine waves and parabolic curves (Retrieved April 2019, from http://www.dataisnature.com/?p=435). What Whitney calls as "Computational Periodics", this practice is one of the first instances of making a computer system to depict an inner working, by relying upon its rapid capability to perform repetitive tasks in the desired direction of the programmer.

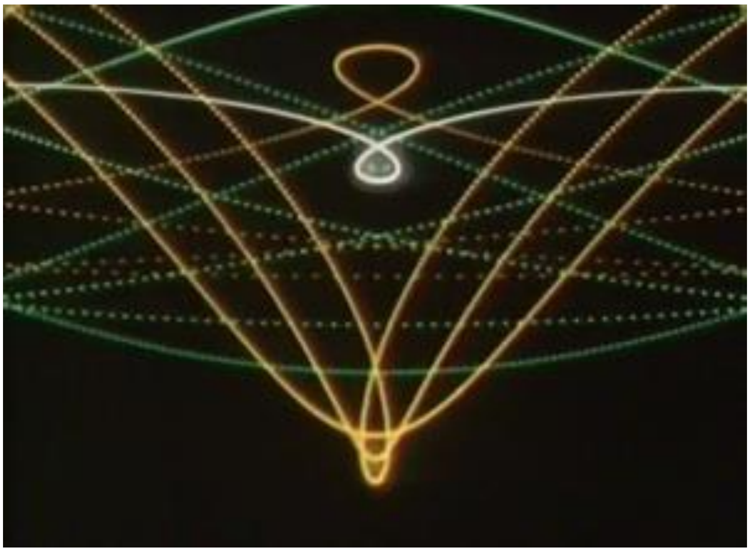


Fig. 2. A still image from *Arabesque* (1975) by John Whitney.

The fact that Arabesque is also an audiovisual work, that is, it provides a synchronous relationship between the temporal oscillations of music and visuals, it also suggests a common ground between computer-aided image-making practice and other forms of creative expression. This common ground also helped CGI to form quick relationships with many other media practices, including films, videos, animations and video games.

Early examples of computer-generated imagery in films and videos appeared as the visualization of scientific data. As Noll (2016) states, early computer animated films were “a series of images (...) programmed and drawn on the plotter to create a movie”. Through the fast adoption of computer animation techniques by first the researchers and the artists, the hype spread into movies of various kinds in 1970s.

Among the first uses of CGI in high-budget blockbuster films was Star Wars (1977), directed by George Lucas. To depict the content within the screens of Empire HQ and IT Departments, computer animation artist Larry Cuba was hired to provide line-based CGI works. (Carlson, 2017) These animated images were reminiscent of the previous works which depicted 3D geometry as a wireframe, without any shading. The interaction during the programming of the graphics was including a drawing interface, a pointing device and an IBM computer, which was used to copy and order the primitive geometries. Also, the real-time interaction with the designed scenes was repetitively recalled by Cuba, in an interview with him. (Fig. 3 and 4) Towards the end of 1970s, computer-generated imagery was in its primitive form aesthetically, however the interaction and rendering times already became a concern to ensure seamless interaction with the imagery.

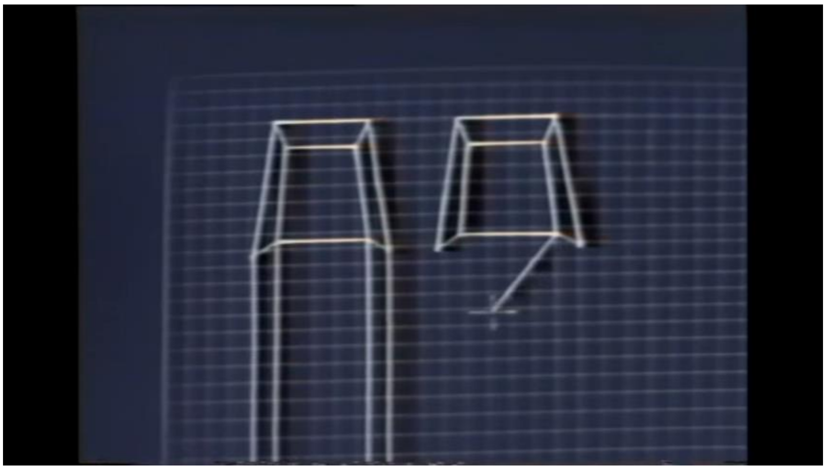


Fig. 3. The visual interface of CGI design for *Star Wars* by Larry Cuba (1977) from *Making of the Computer Graphics for Star Wars (Episode IV)* [Video file]. Retrieved April 18, 2019

Fig. 4. Knobs for real-time interaction with the designed imagery in *Star Wars* by Larry Cuba (1977) from *Making of the Computer Graphics for Star Wars (Episode IV)* [Video file]. Retrieved April 18, 2019

The beginning of 1980s and the adoption of CGI by the movie industry have opened a new direction in the research and application of CGI: the photorealism. Development of various lighting, shading and rendering methods has accelerated within this period and proved to be producing more photorealistic outputs with the advancement of each iteration. However, keeping the computer generated image consistent with the shot scenes created a trade-off within the CGI world, of which the effects lasted until today: Creating CGI sequences and effects to be composited seamlessly into the camera-shot films with its 3D structure, lighting, occlusion and rendering became a main concern for a certain group of professional researchers, designers and VFX artists. Due to the fact that creating such an advanced imagery is an expensive operation computationally, the Silicon Valley entrepreneurs of 1980s and 1990s invested highly in the CG researchers, from which they obtained expertise and ever-increasing photorealism within the animations and rendering of more movies each year. (Carlson, 2017) This constant feedback placed the CGI in the movie industry to the top of a hill, hard to be reachable by individual or small group of programmers or artists. Especially, the computational power that these studios encapsulate was able to render highly realistic sequences of movies and full-feature animations, which are rendered frame by frame, using many different modelling, simulating and lighting algorithms on them.

During the same time, the interactive industry was experiencing a slightly different flow of development in the CGI field. Keeping the interactivity in the imagery entirely depended on being able to render the content in real-time. Therefore, while the aesthetics of photorealism dragged the offline rendering into its own peak, the game industry remained in the real-time rendering of the created content because of the notion of interaction that requires a real-time or low-latency feedback between the user input and the computer. This became the main reason that the gaming graphics remained initially at low-resolution and in 8-bit & 16-bit pixel displays at the early consoles. This limitation, however, also caused the gaming and interactive graphics to explore its own aesthetics while providing real-time interaction & imagery, yet remaining at low-poly primitive structures. As Carlson (2017) states, the general CGI research has benefited a lot from “the constraint of creating real-time graphics with as much precision as possible with the computing capacity at hand.” Various generation algorithms and shading models were developed in the 1990s and 2000s as a continuing effort of computer graphics researchers. Apart from the unanticipated results and aesthetics that real-time CGI created, the allocation of computing power into alternative processes rather than precise modelling and lighting while generating imagery also matured into various disciplines in art and design. One example of those alternative CGI-based image generation paradigms is “procedural design”, which describes an algorithmically directed design process rather than being manually created. Opposed to the content that is entirely created via human input, procedural generation offers an algorithmic calculation of a differing complexities to populate the imagery. The advantages of procedural generation, such as smaller file sizes and larger amounts of content made it a commonly used tool especially in the game industry.

The study of generative systems within a creative coding perspective can be considered as a form of procedural generation and the third chapter of this thesis is established upon it, which originates from the idea of programming an autonomous agent to perform a creative job, by using algorithms and systems of self-generation.

CHAPTER 3

GENERATIVE ART AND CREATIVE CODING

Human qualities constitute a basis for the practice of art and design. What is accumulated over centuries of creative activity yields at several guiding principles where being human is the essential condition for production and appreciation of aesthetics. In the previous chapter, it is proposed that this essential basis have been expanded into a more symbiotic relationship with the aid of computers during the design activity. In this chapter, another influential method of this symbiotic creative activity will be discussed, which is leveraging generative systems. At first sight, this chapter will reference not only the computer-generated content but also will take a broader look at the system-based approach in art and design.

3.1 Contextual Definition of Generative Art and Usage in Creative Practices

The broad definition of a “generative” system can be understood in a few different ways. Philip Galanter (2003) describes the generative art activity in two different contexts and it is worth referencing both to understand and detect the key generative characteristics of such work.

3.1.1 Contextual Definition and Systems Aesthetics

One approach of Galanter is by looking at the literal meaning of the term "generative" and defining the key aspects of generative art. Galanter describes generative art as following:

> "Generative art refers to any art practice where the artist uses a system, such as a set of natural language rules, a computer program, a machine, or other procedural invention, which is set into motion with some degree of autonomy contributing to or resulting in a completed work of art." (Galanter, 2003)

Considering this definition, it is first imperative to think of generative art decoupled from any particular technology. The key element is more of a *system*, where the artist is in total or partial control. Secondly, the autonomy of the system should be available with or without outside control.

The usage of algorithmic decision-making systems in art making is definitely not a new paradigm for humanity. Since the ancient ages, the mathematical and geometrical approaches in image-making have had a transcending nature while creating aesthetic excellence. Many number of geometrical concepts also found their way into the artistic terminology such as line, form, shape, pattern, symmetry, scale and proportion. The interchange between these elements and how they can be used for problem-solving in spatial design and placement in two and three-dimensional spaces have long been the main question of artists and mathematicians.

Taking it from the ancient Greek design principles, Greenberg (2007) asserts that the mathematical and physical principles were at the core of a certain period between 900 and 700 BC. The period is called as the Geometric Period, which included the art forms that contained repetitions of shapes rather than the more realistic and representational works of the earlier periods. Furthermore, principles of systematic isomorphic reflected patterns as well as various ornamentations have occupied a vast space of architectural memories of early modern cultures of America (Fig. 5) and Europe. Greenberg elaborates on the motivations of this computationally-based image-making activity with an emphasis on integrating the functions of the right and the left brain hemispheres.

> "Serious interest in aesthetics + computation as an integrated activity is evident in all cultures and is manifest in many of the objects, structures, and technologies of the times in which they were created. Regardless of whether the technology is an engraving stick, a loom, a plow, or a supercomputer, the impulse to work and play in an integrated left/right-brain way is universally evident, and the technical innovations of the day most often coincide with parallel developments in aesthetics. Early astrological and calendar systems, across many cultures, combined observed empirical data with richly expressive, mythological narratives as a way of interpreting and ultimately preserving and disseminating the data. Weavings, textiles, engravings, mandalas, and graphs from cultures around the world employ complex algorithmic patterns based upon mathematical principles, yet most often are not developed by mathematicians. Rather, these developments seem to reflect a universal human impulse to integrate right-brain and left-brain activities, combining qualitative notions of aesthetic beauty with analytical systems for structuring visual data." (Greenberg, 2007)

Fig. 5. *Aztec Sun Stone*, dating back to the 16th century, now at National Anthropology Museum in Mexico City.

When it comes to the Renaissance period, a much more unitary approach from the prominent figures of the time has appeared. Based upon Greek geometry, major Renaissance painters including Piero della Francesca, Albrecht Dürer, and Leonardo da Vinci not only experimented and applied principles of perspective and geometry in their work, but also published treatises on mathematics. (Greenberg, 2007) The Renaissance period has blurred the distinction between art and science into an equal contribution field by its practitioners.

Algorithmic decision making constitutes a central position at this convergence between art and science. The algorithmic approach defines a systematic decision tree including mathematical and logical operators and processes. What is important about algorithms within the domain of art and science relies on their ability to mimic the cause-effect relation of objective reality. The machine's ability to perform these operations in a logical order with high reliability only appeared two centuries after the Enlightenment period, with Charles Babbage's reductional engine and Ada Lovelace's treatise on it as an expandable machine with abilities of systematic creative tasks. *The Analytical Engine*, which has a replica of the original model by Babbage & Lovelace in London today, is the first precursor to the computers of the 20th century with its ability to transcend a repetitive task and feeding back to a machine. After 100 years of non-recognition and further development, the information age has transformed the computer to an accessible technology in the 1950s. As early as 1956, just five years after the UNIVAC was developed, artists began experimenting with computing as an expressive medium. (Greenberg, 2007)

The systems approach to art and design has been one of the most prominent philosophies to understand the changes in the contemporary art practices in the 20th century. Halsall (2008) suggests that "the historical interest in the aesthetics of systems between the late 1960s and the early 1970s emerged from a matrix of influences. At the time a number of key exhibitions and publications based around the theme of systems, structure, seriality, information and technology took place." Such exhibitions were designed upon popular understandings of systems theory and most notably cybernetics, information theory and general systems theory. The primary attempt was to find artistic and curatorial expressions for the new ideas.

Halsall (2008) elaborates on the 1960s' inclination towards *systems as a medium* as "having parallels in the radical art practice of the late 1960s, which both questioned and then replaced the singular art object of modernism with the "de-materialised" art object of conceptualism, minimalism and other postmodern art practices.” The outcome was the replacement of traditional media of artistic expression with the medium of systems. The primary figure in these transitions was Jack Burnham, who was central in theorizing the systems aesthetics and the idea of a system as medium.

According to Halsall (2008), the origins of this new medium were not decoupled from the overall socio-political picture. He argues that, towards the end of the 1960s, “the interest in the application of systems-thinking by the military-industrial complex began to filter into cultural life.” The beginning of 1970s marked a number of important exhibitions and publications that took the idea of *systematicity* as their central organizing principle, with titles such as *Systems; Information; Software and Radical Software* and *Cybernetic Serendipity: The Computer and the Arts (I.C.A., London, 1968)*.

Although the access to the viable computing resources were relatively low, the period of *seriality* in 1960’s modern art characterized a process towards an inclination towards depicting the systems approach. Sol LeWitt’s Incomplete Open Cubes is a remarkable example of the so-called movement of serial art and elaborates upon a mathematical problem. (Fig. 6)

LeWitt systematically explored the 122 ways of "not making a cube, all the ways of the cube not being complete," per the artist. (Retrieved 21.05.2019 https://www.metmuseum.org/art/collection/search/691091)

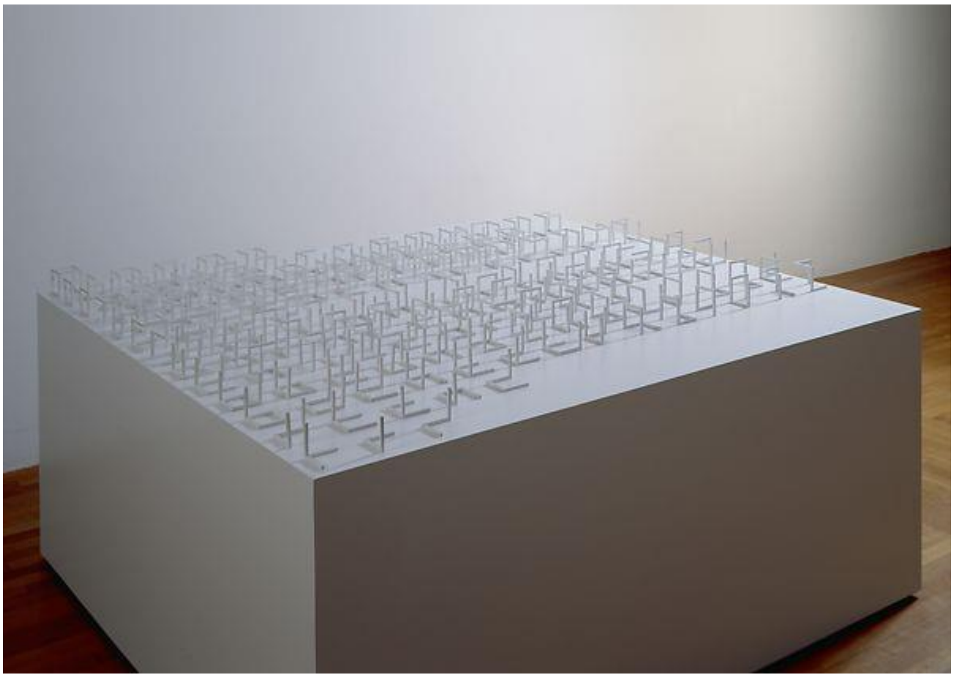


Fig. 6. Sol LeWitt's *Incomplete Open Cubes* (1974/1982)

On the purely computational side, the true entanglement of computer with the artist's continued interest did not occur until 1960s. According to Jasia Reichardt in her 1971 book *The Computer in Art*, "one can assume that there are probably no more than 1000 people in the world working with computer graphics for purposes other than the practical ones." The emphasis on the *practical side of computer graphics* is worth noticing here. It signifies the main stream of applied computer graphics in the fields explained in the previous chapter. As stated above, a generative system defines an agency of autonomy that determines the way of operation. The mainstream practice on computer graphics has completely been a manual and illustrative human construct at the early days. However, considering the fact that computers also evolved into machines of high computational complexity, the generative mindset also found itself as being a decision-support system. Treating the available computational advances to examine the possibilities of algorithmic image-making and re-contextualizing this image with the occurrences of natural and mental images of human history has created its own Renaissance in the field computational art. The famous Aesthetics + Computational Research Group at MIT Media Lab led by John Maeda found the fundamental academic perspective on the realization of this renaissance. Believing in a computationally-based design perspective, Maeda "took a leading part in the group's efforts to involve the design and art community in the introduction of the underlying concepts of computing technology in the design area." (Popper, 2007)

In 1999, John Maeda published *Design by Numbers*, a series of tutorials on both the philosophy and techniques of programming for artists. Not limited to *Design by Numbers*, Maeda continually emphasized the significance of "understanding the motivation behind computer programming as well as the many wonders that emerge from well-written programs." (Popper, 2007) These wonders and "surprising outcomes" of programmed design processes gathered many artists to practice what has been once seen mathematically challenging.

The primary catalyst of *design programming* in the 21st century came with the development of Processing, an open-source Java-based environment for visual coding for digital artists and designers, developed by Casey Reas and Ben Fry, from MIT's Aesthetics and Computation Research Group, supervised by John Maeda. The primary motivation of Processing, besides its technical simplification of a development environment, is to introduce the fundamental concepts of programming through visual practice, instead of pure data-based practice scenarios of traditional programming education. Revolutionary in its own sense, Processing made its way into the curricula of many institutions through a decade, by the efforts of Processing

Foundation and revealed the applicability and rapid expansion of open-source programming culture among the digital artists.

3.1.2 Definition by Practices

In Galanter's (2003) definition, the second approach to identify generative art is to have a bottom-up approach, where certain clusters of current generative art activities are examined. It is also useful for the purposes of this thesis to identify these fields and how they incorporate systematic autonomous agents to the process of creative activity.

3.1.2.1 Electronic Music and Algorithmic Composition

The community of electronic music practitioners and most of the pioneering figures of 21th century avant-garde composers adopted the use of generative methods in their works. The applications appeared in all manners, including creation of musical scores and the subtle modulation of performance and timbre. (Galanter, 2003) Not limited to the academic and avant-garde musical communities, generative techniques also found reception in popular and working musical communities. *Aleatoric music* is a term to describe a total or partial composition, which is left to chance procedures. A considerable amount of John Cage's compositions has depended on assemblages of procedurally generated sequences and chance events. Brian Eno popularized the term and produced systems of chance-based control to perpetually create improvisations and variations. (Fig. 7)

Fig. 7. Brian Eno, *Generative Music 1*, performing at Parochialkirche Berlin, 1996

Photo: Anno Dittmer

3.1.2.2 Computer Graphics and Animation

As the most fruitful ground of research for generative systems and their applications, the computer graphics researchers and practitioners have developed and documented many techniques and approaches over the decades. The vast body of literature published by ACM SIGGRAPH organization over the years have examined methods for the most useful practices of generative techniques to be employed in games, animation, CGI and interactive industries. Some of the generative advances of SIGGRAPH publishings included Perlin Noise for the synthesis of smoke, fire and hair imagery, the use of L-systems to grow virtual plants to populate forests, valleys and natural landscapes, and the use of physical modeling to create animations that depict real-world behavior without requiring the artist to choreograph every detail. (Galanter, 2005) As an example, procedural methods of terrain generation can be given. These methods are being revisited each year by researchers and are increasingly being used in games and other media. Especially in game mechanics, the term *worldbuilding* depends on the use of procedural generation, in which the content is entirely generated algorithmically. This technique allows the game designers to create levels and worlds of differing complexities, while also keeping it believable as powerful simulations.

3.1.2.3 The Demo Scene and VJ Culture

In conjunction with the above, techniques of generative design are being increasingly adapt into different settings of emerging cultural movements such as the demo scenes and VJ events. These movements take the generative technology out of the well-funded labs, recording studios and animation companies (Galanter, 2003) and transforming them into low-cost alternatives for different social settings. In the demo parties, source codes of advanced games and other interactive media are being transformed into adaptive storytelling tools, while VJs are using generative methods to create a new material every day. Randomization, tessellations and noise-generators in such practices are the most commonly applied and discussed techniques, however the increasing computational power makes it possible to include other techniques of simulation, fractalization and artificial systems into the scenes as well.

3.1.2.4 Industrial Design and Architecture

The iterative nature of the design process, that is creating a multitude of samples and refining and improving the outcomes to achieve the desired result, is strongly reminiscent of the algorithmic process of variations. Constrained by a set of rules and limitations, the design process is strongly intertwined with the generative processes since the adoption of computer-aided design.

It is for no doubt that all of the above disciplines can be exemplified by many artists and designers of the 20th century about how they employed methods of autonomous creations with computational agents. While it still may be controversial to call all of these systems-based works as “generative”, it is a fact that the advancements in the technologies of computational agents have attracted many artists and designers to pronounce their own techniques and practices in a hybrid labor with machines.

3.2 Creative Coding to Illustrate Emergent Scenarios

The practitioners of generative art refer to their practice sometimes as “creative coding” since it requires programming an autonomous system that performs a creative task to produce ever-changing structures of visual narratives. During this practice, keeping a system to procedurally generate structures with enough variability and uniqueness became one of the main concerns. All of the practice-based applications listed above more or less use *emergent* systems to leverage computing’s ability to produce random walks and variations, as well as systematic approaches to variance with mathematical and probabilistic principles.

3.2.1 Randomization and Noise Generation

The realization of convincing simulations in design computing uses randomization as a core mechanism. Very early on the development of computation, “people started searching for ways to obtain random numbers, however it has been an ongoing challenge as computers are precise calculating machines.” (Retrieved 9.06.2019 from https://www.courses.tegabrain.com/CC17/unpredictability-tutorial/) The precision within a computer’s organizational system basically inhibited it from replicating the behavior of throwing a dice. Addressing this problem, the RAND Corporation published a book *A Million Random Digits with 100,000 Normal Deviates* in 1955. (Fig. 8) Various types of experimental probability procedures needed a large supply of random digits in order to solve stochastic problems with Monte Carlo methods. The book provided a vast amount of random digits to assist the requirements of such problems.

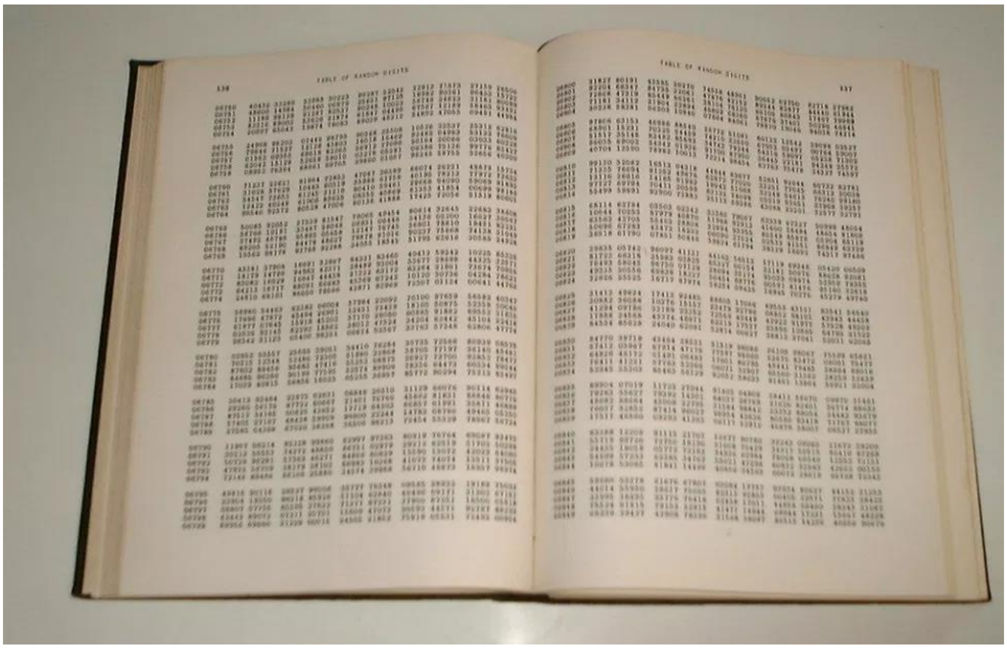


Fig. 8. Pages from *A Million Random Digits with 100,000 Normal Deviates*, published by the RAND Corporation in 1955.

John von Neumann, one of the most pioneering mathematicians of the 20th century suggested several ways of programmatically calculating random numbers in 1946 by taking the square of the previous random number and by removing the middle digits.

One expected objection to this was that this generation is completely deterministic by relying on the predecessor for each number. However, it is imperative to produce random numbers in computational environments with a deterministic approach and this brought forth the concept of *pseudorandomness*, which is obtaining a random series with statistical randomness, so that the occurrence of recognizable patterns or sequences is minimized.

Daniel Shiffman, one of the board members of Processing Foundation, writes in *The Nature of Code* (2012) that “random walks can be used to model phenomena that occur in the real world, from the movements of molecules in a gas to the behavior of a gambler spending a day at the casino.” Mapping the stacked values of a random walk series to a set of other values in interconnected systems helps to create lifelike and organic behaviors in computational design processes.

Randomization-based generation in computational design is usually carried out with *noise generation*. Noise, with its vast body of epistemological implications, delicately narrated by Cecile Malaspina in *An Epistemology of Noise* (2018), is a certain guiding principle in simulating the behavior of many physical realities of nature as well as movements of human-centered fluctuations and even cultural and psycho-social aspects. As described above, randomization can be used to model the lifelike behavior of many elements, however, “randomness as the single guiding principle is not necessarily natural” says Shiffman (2012). Fundamentally, noise algorithms exhibit a more natural and smooth progression compared to random generations. (Fig. 9)

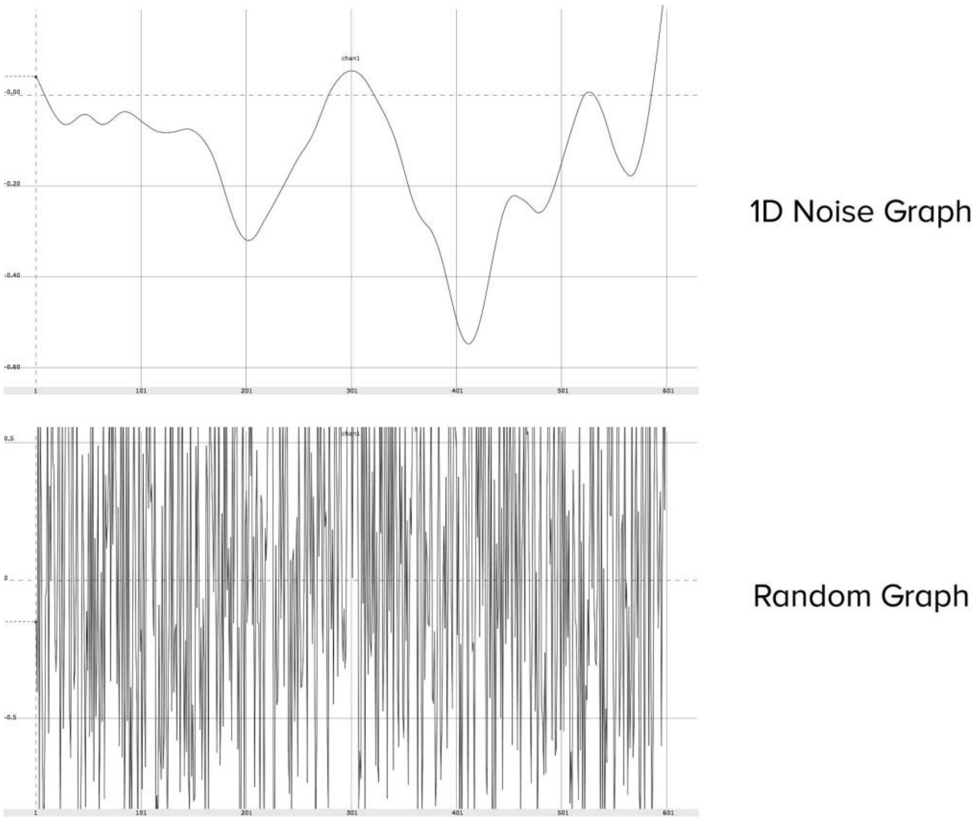


Fig. 9. Comparison of a single-dimensional noise function with a random generator shows that the noise function exhibits a smoother and more natural progression

A noise generation algorithm known as Perlin noise, invented by Ken Perlin, considers this issue of naturality. Perlin developed the noise function while working on the original *Tron* movie in the early 1980s; it was designed to create procedural textures for computer-generated effects. (Shiffman 2012) Perlin was awarded an Academy Award in Technical Achievement for this work in 1997. Perlin noise can be used to generate various effects with natural qualities, such as clouds, landscapes, and patterned textures. (Fig. 10) Its wide applications in the field led to an adaptation of noise fields, which many artworks of today's digital artists are based on.

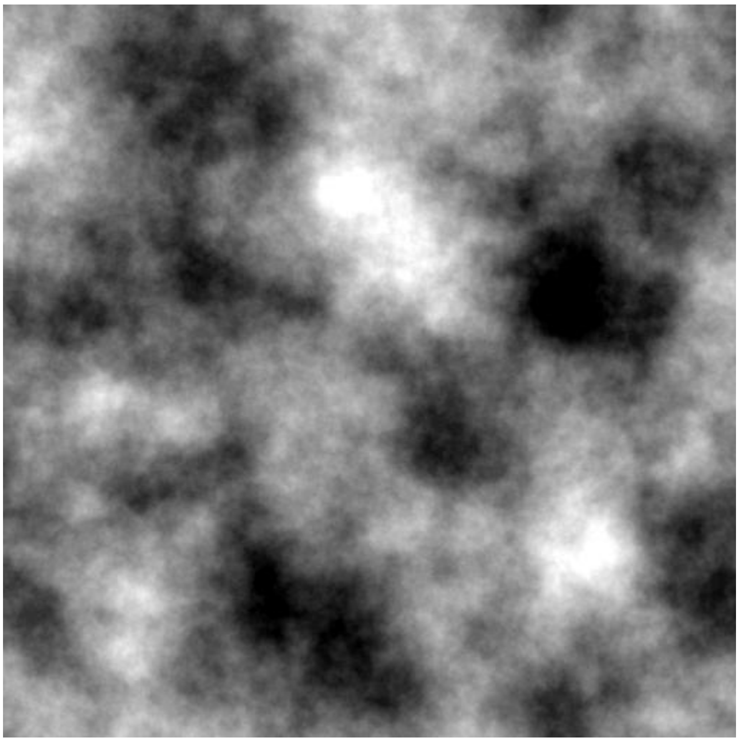


Fig. 10. A cloudy monochromatic pattern, entirely generated by the Perlin Noise algorithm with a high harmonic parameter setup

The fact that Perlin Noise eventually generates close-to-natural gradient structures in multidimensional arrays also made it useful for the emergence of other forms of noise generation algorithms, such as Curl Noise to generate curly strands and their growth behavior, Fractal Noise to generate cloudy or smoky effects or Voronoi (Worley) Noise to simulate stone, water or cell noise. The applications of these algorithms uniquely contribute to generate different desired effects and they interchangeably work within a set of different plane division algorithms such as with Voronoi Noise, in which the main algorithm relies on Delaunay Triangulation.

3.2.2 Particle Systems

The first discussion of a particle system was coined when William T. Reeves, a researcher at Lucasfilm Ltd. was working on the film *Star Trek II: The Wrath of Khan*. Shiffman (2012) tells the story of its emergence as following:

> "Much of the movie revolves around the Genesis Device, a torpedo that when shot at a barren, lifeless planet has the ability to reorganize matter and create a habitable world for colonization. During the sequence, a wall of fire ripples over the planet while it is being "terraformed." The term *particle system*, an incredibly common and useful technique in computer graphics, was coined in the creation of this particular effect."

According to its first creator Reeves (1983), "a particle system is a collection of many minute particles that together represent a fuzzy object." As the time passes, particles are generated, they move, change and die within the system. Particle systems have been one of the most used tools to simulate the emergence of many natural phenomena, especially the irregular behaviors. Movements and transformations of ever-changing occurrences and *pluralities* such as fire, smoke, rain and snow; as well as fog and grass are modelled with the adjustment of particle system parameters.

Among the typical parameters and components of particle systems, the most noteworthy ones are the particle emitters, particle attractors, particle lifespan, force fields, wind and turbulence. Each of these parameters and components are used to give a particle system its desired behavior in a span of time. The computational complexity of holding many particles at one instance brings forth the "particle lifespan" parameter, which eliminates a set of particles, from the system at desired time intervals or when a certain situation happens, such as when they hit the ground because of gravity.

The collection of generative methods in today's algorithmic creativity trends is not limited to noise generators and particle systems, however these two provide a common-sense ground about how they bridge the language between the processes of natural occurrence and the computational systems. On the other hand, their power to open up a new frontier within the design methodology makes them valuable to incorporate into the different fields of artistic practice. This thesis aims to apply the generative system design to the immersive and interactive environments, which are elaborated in the next chapter.

CHAPTER 4

IMMERSIVE & INTERACTIVE INSTALLATIONS

This chapter will be formed as a comprehensive look at the immersive & interactive installation art practice with its history and meaning as a distinct art form. The concept of immersion will be first identified with its relations to the virtual reality and thereafter will be discussed within a mixed reality perspective. The immersive installation practices of the 20th and 21st century artists will be discussed in conjunction with the interactive arts. Upon this conjunction, the immersive & interactive installation art will also be juxtaposed with the generative art practice and the common grounds they share will be elicited.

Immersion, as an umbrella term, is an ambiguous concept that has been used to describe a specific encounter of an environment with a sensing organism. It can be defined as to become *completely* involved in something, so that *you do not notice anything else.* The significant part of this definition is the blockage of one's senses to the exclusion of that *something*, that leaves no disbelief about the reality of the surrounding environment. This fact directly transfers the definition of immersion into another related concept, which is virtual reality, abbreviated as VR. As a popular term of the visual media of late 20th and early 21st centuries, virtual reality is an engrossing term that has close connections with the concept of immersion and represents one of the fundamental discussion grounds of this thesis.

4.1 Immersive Art History and Practices

Considering the history of visual media within a broad perspective, the immersion as a motivation of artists has its roots in antiquity. Oliver Grau, in his 2003 book *Virtual Reality: from Illusion to Immersion* handles the art historical antecedents to virtual reality and the impact of virtual reality on contemporary conceptions of art. According to Grau, “the idea of installing an observer in a hermetically closed-off image space of illusion did not make its first appearance with the technical invention of computer-aided virtual realities.” (Grau, 2003) On the contrary, he argues that the idea has its roots at least in the classical world, and today’s immersion strategies of virtual art uses the same idea. Many examples of Renaissance illusion spaces, such as Sala delle Prospettive (Fig. 11) and ceiling panoramas of Baroque churches marks the beginning of such illusory environments that immerses the spectator in a closed image space.

Besides ceiling paintings and all-painted rooms of Renaissance villas, the panorama image demands a special consideration, according to Grau. He suggests that the panorama image represented the highest developed form of illusionism as an intended effect. This, in fact, still keeps its validity in today’s strategies of immersion, which completely surrounds the spectator and does not leave a vanishing

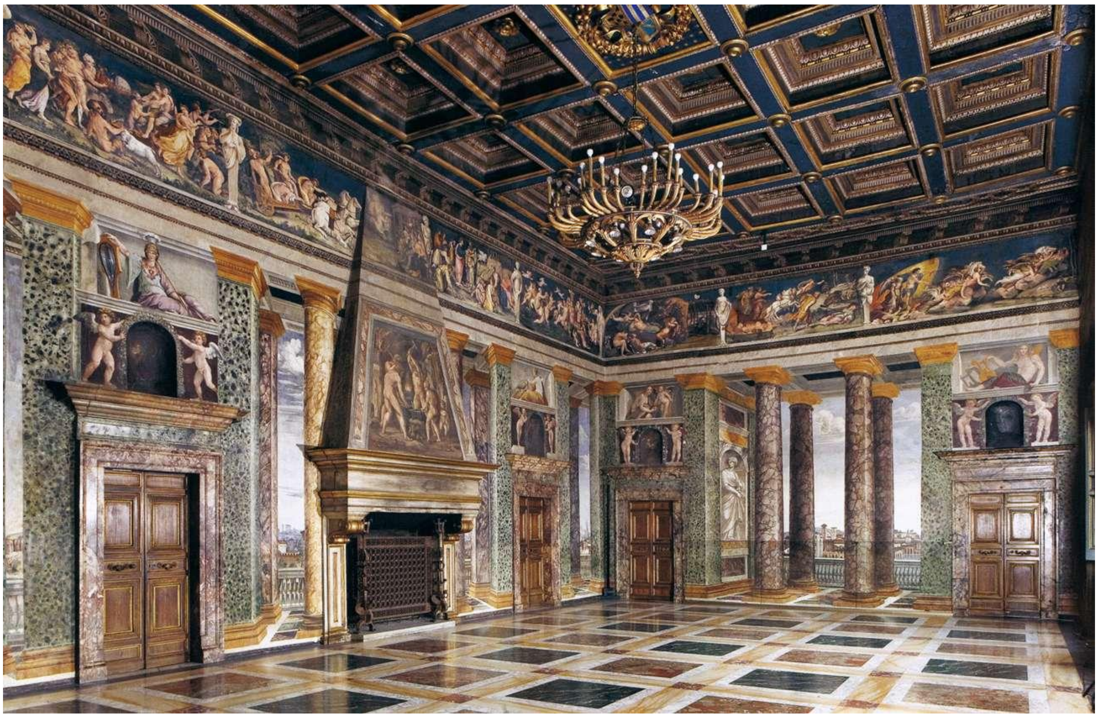


Fig. 11. Sala delle Prospettive of Villa Farnesina, Rome, Italy

point for the imagery. Therefore, it can be argued that panorama image is the precursor to the immersive installation practice of today’s digital media art.

Taking it off from the Renaissance methodologies, integration of virtual and computational techniques into the immersion in art somewhat appears as a “nothing new under the sun” approach, however the digital image and the conditions of CGI & virtual environments clearly promises a crystallized new specificity in this practice. The modern artwork methodologically uses the same instruments while surrounding the environment with virtual imagery, however setting this imagery into *motion* with its own autonomy provides a new ground to discuss the implications.

In this respect, the metamorphosis of the immersive image from Renaissance until the 21st century’s proliferation of head-mounted display, is driven by the conditions of computerization; such as interface design, interaction and the evolution of images. (Grau, 2003) The computerization of image-making and covering large displays adapted the mode of immersion into a whole new level. The encounters with CAVE systems, as well as quick adaptations of sensor systems into the head-mounted display with higher frame-rates escalated the realm of immersion in such environments.

It is for no doubt that the realm of simulacrum has been the main driving force behind the existence of interactive immersion. Either regarded as a shift or a run away from the regularities of the perceivable world, immersing ourselves into an artificial environment reinforces the power of simulacrum, which in turn raises the questions of body and identity. Based on the definitive characteristics of immersion, one's own encounter with a full-bodily sense in virtual reality has been one of the most questioned aspects of this medium. However, the applicable modalities of virtual reality within the environmental structures have been in several different modes within the various developments. The perceivable different modes of virtual reality environments are discussed in the next section.

4.2 Virtual Reality and Modalities

In a descriptive definition of virtual reality, the "sensorimotor exploration" of an image space is supplied into the panoramic view of the same image space that gives the impression of a "living environment". (Grau, 2003) One of the most extraordinary characteristics of this living modality is how it changes the parameters of time and space. Within a carefully designed sense of time and space, as well as well-executed modelling of physical presence, the simulacrum becomes inseparable from the reality. Grau further elaborates upon this type of environment as following:

> "The media strategy aims at producing a high-grade feeling of immersion, of presence (an impression suggestive of ''being there''), which can be enhanced further through interaction with apparently ''living'' environments in ''real time.'' The scenarios develop at random, based on genetic algorithms, that is, evolutionary image processes. These represent the link connecting research on presence (technology, perception, psychology) and research on artificial life or A-Life (bioinformatics), an art that has not only reflected on in recent years but also specifically contributed to the further development of image technology." (Grau, 2003)

Concerning these characteristics of immersive virtual spaces, it becomes important and necessary to explore the new aesthetic potentials that are made by this technology. Ranging from new possibilities of expression to the constraints that these technologies impose on artistic concepts, the digital and immersive imagery puts both the artist and the spectator into its own peaks of questioning the medium. Immersion, as defined in the beginning of this chapter, is the key to the understanding and development of this medium. It would not be appropriate to depict the situation simply as "either-or" relationship between immersion and critical distance, however the key characteristic of virtual reality space is to continually improve the experience and ensure "a passage from one mental state to the another" by "diminishing critical distance and increasing emotional involvement". (Grau, 2003)

Considering the two poles of ‘meaning of the image’, which are the *representative function* and the *constitution of presence*, immersion is for sure more related to the latter. This constitution of presence is maximized through the adoption of illusionism within the space via addressing as many senses as possible. Steuer (1992), Gigante (1993) and Rolland and Gibson (1995) describes this polysensorial illusionary interface as “natural”, “intuitive” and “physically intimate”. Simulated techniques of stereophonic or quadraphonic sound, tactile and haptic impressions, thermoreceptive and kinaesthetic sensations and feedback systems all combine to “convey the observer the illusion of being in a complex structured space of a natural world, producing the most intensive feeling of immersion possible.” (Esposito, 1995)

However, when being thought from a practice-based perspective, the modalities of immersion have had different forms and materialities. One of these forms had transcended into a completely virtual display, which is known as head-mounted display (HMD). The HMD technology basically puts the spectator into a completely closed-off and isolated image and sound space by blocking the senses to outer stimuli. This, in fact, is the highest form the illusionism can attain, when thought from a *single* spectator’s perspective. However, when thought from a collective and spatial point of view, HMD has its own problems of destructing the space-time continuum of the individual and trapping the experience completely into a closed form.

Contrary to the HMD notion, another methodology of creating illusionary spaces have been present in the display technologies for the last two decades. Generally regarded as *mixed reality,* the amalgamation of large electronic display systems with architectural space and audience promises an unprecedented sense of *being in a different space-time* and is being extensively used by the media artists of 21st century.

One particular discussion about the status of VR directs at the fact that the term virtual reality itself has a paradoxical nature. Grau (2003) elaborates upon this status by pointing out that it is “a contradiction in terms, and it describes a space of possibility or impossibility formed by illusionary addresses to the senses.” This is where the artistic applicability of *mixed realities* appears, and sets the factor of immersion into a more body-oriented perspective. Mark Hansen, in his influential book *Bodies in Code: Interfaces with Digital Media* names a whole chapter as “All Reality is Mixed Reality” and provides a new understanding of immersion in digitally-enhanced physical spaces. Hansen borrows the term *mixed reality* from artists Monika Fleischmann and Wolfgang Strauss, and introduces it as a second-phase in virtual reality research:

> “Having tired of the clichés of disembodied transcendence as well as the glacial pace of progress in head-mounted display and other interface technology, today’s artists and engineers envision a fluid interpenetration of realms. Central in this reimagining of VR as a mixed reality stage is a certain specification of the virtual. No longer a wholly distinct, if largely amorphous realm with rules all its own, the virtual now denotes a “space full of information” that can be “activated, revealed, reorganized and recombined, added to and transformed as the user navigates … real space.” (Hansen, 2006)

The body within this interface is central to this reimagining of the virtual space. A true convergence between virtual and physical spaces, Hansen suggests, only possible with the embodied motor activity. This can be considered as a refute to the

HMD technologies that can be empowered further. As an early researcher of VR and interactivity in artistic practice, Myron Krueger (1997) states that “whereas the HMD folks thought that 3D scenery was the essence of reality, I felt that the degree of physical involvement was the measure of immersion.” This desire for a complete convergence with the natural perception is at the foundation of this work because of its ability to create a more inclusive ground between the space, the image and the spectator.

4.3 Interactive Art and the Status of Body

As mentioned above, the responsive characteristic of the immersive environments is one significant factor that assigns a further reading of this art form. Interactive art, by definition, is unfinished and realized only as a function of audience interaction. (Simanowski, 2011) Inaugurating a dialogue between the artist, artwork and the audience has already been one of the primary roles of the art long before the interactive art. However, in the case of a “systems” approach to interactive art, the work gains a new meaning by “being created in such a dialogue.” (Simanowski, 2011)

Rather than presenting a fixed message to be deciphered by the audience, the interactive artwork presents an unfinished nature, thus the theoreticians and practitioners of interactive art have long been occupied by the motivation of “creating spaces and moments.” As one of the earliest theoreticians of this kind of artwork, Roy Ascott should definitely be quoted with his manifestation of a behavioral tendency in art. In his visionary article *Behaviourist Art and the*

Cybernetic Vision from 1967, Ascott calls for a liberation for the relationship between the artwork and its audience:

> “The participational, inclusive form of art has as its basic principle "feedback," and it is this loop which makes of the triad artist / artwork / observer an integral whole. For art to switch its role from the private, exclusive arena of a rarefied elite to the public, open field of general consciousness, the artist has had to create more flexible structures and images offering a greater variety of readings than were needed in art formerly. This situation, in which the artwork exists in a perpetual state of transition where the effort to establish a final resolution must come from the observer, may be seen in the context of games. We can say that in the past the artist played to win, and so set the conditions that he always dominated the play. The spectator was positioned to lose, in the sense that his moves were predetermined and he could form no strategy of his own. Nowadays we are moving towards a situation in which the game is never won but remains perpetually in a state of play. While the general context of the art-experience is set by the artist, its evolution in any specific sense is unpredictable and dependent on the total involvement of the spectator.”

The continuing nature of the game, as Ascott describes as “a perpetual state of play”, raises questions towards the perception of body as it also happens in the immersion. The invitation to physical self-discovery of the audience declares multiple facets of the interactive artwork. First of all, it is the elevation of the audience from only a *spectator* into a central, key element within the artwork’s lifecycle. To quote John Cage from his 1966 declarations, “the artist is no more extraordinary than the audience” and he demanded that “the artist be cast down from the pedestal.” Apart from the audience’s involvement into the process of creation, the diminishing role of the artist is a key element in the interactive artwork. In this sense, it is appropriate to say that the artist’s occupation with conveying a meaningful message is also diminished, or abandoned. Instead of presenting a message to deciphered, the interactive artwork creates a moment of dialogue, both between the artist and the audience, and between the members of the audience.

Secondly, the structure and narrative of the artwork gain a variance-based nature. Because of the non-deterministic fashion of the audience interaction, or the uncontrolled intervention of the audience with the work, the interactive arts exhibit very similar characteristics to the generative art that was described in the third chapter. David Rokeby, an influential interactive art practitioner, asserts that the structure of interactive artworks can be similar to those used by Cage in his chance compositions: “The primary difference is that the chance element is replaced by a complex, indeterminate yet sentient element, the spectator.” (Rokeby, 2002) It is common for both chance art and interactive art that the role of the creator / artist is reduced in the process of creation, but interactive art assigns a more privileged role to the audience. “Instead of mirroring nature’s manner of operation, as chance art does, the interactive artist holds up a mirror to the spectator.” (Simanowski, 2011) The function of this mirror is twofold. For one side, it reflects the spectator’s existence inside the system, and furthermore, it allows the spectator to experience him/herself in a new way. Thus, it is safe to say that interactive art is an opportunity for self-discovery, “it is an invitation to explore one’s own body in the process of interaction.” (Candy & Ferguson, 2016)

Considered together with the mixed reality approach, which is producing a *collective* space-time of installation practice, interactive art is also capable of producing inter-human experiences. The main characteristic of those experiences is the conviviality of conveying people with an alternative environment and assessing the primary reactions of people towards each other. Nicolas Bourriaud describes such "spaces where we can elaborate alternative forms of sociability, critical models and moments of constructed conviviality." (Bourriaud, 2002) According to Simanowski (2011), "such spaces and moments are important as alternatives to the ideology of mass communications" as well as they form substitutes for the futurist utopian scenarios. Considering the depreciation of utopian dreams in the post-truth age with the loss of grand-narratives, Bourriaud (2002) states that "utopia is now experienced as a day-to-day subjectivity" and "the role of the artwork is no longer to form imaginary and utopian realities, but to actually be ways of living and models of action within the existing real." This articulation of the artwork as a convergent complementary of the real opens up a new perspective for thinking it at a spatial element of our everyday lives.

Revisiting Hansen's *Bodies in Code,* the expansion in the status of body is a significant aspect of interactive installations. The use of body as a tool or an instrument results in an enhancement of perceptual qualities. The ocular-centric tradition of Western art served the eye as the locus of perception, Hansen (2006) argues, however, in interactive installations, the interface expands its locus from the eye to the entire body, thus transforming the body into a "privileged site for experience." Hansen describes this expansion with the phrase "seeing with the body", pointing at a direction where the boundaries between body and world blur and dissolve to ensure an affective relationship with the digital, reactive imagery.

The *bodily sense of vision* attributed to interactive installations finds its phenomenological grounding in Maurice Merleau-Ponty's (2002) *Phenomenology of*

Perception, as “the body is our general medium for having a world.” Merleau-Ponty identifies this by elaborating upon the unity of the senses, which creates a holistic picture of the environmental qualities we sense. It can thus be argued that immersion and interactivity should be targeting the body and senses as a whole if they are meant to be all-inclusive, affective instruments of practice. Contrary to this notion, the digital technology initially advanced in the direction of a notion of disembodiment, which virtualized the existence of the body in cyberspace. The development towards the HMD can be thought as an evidence for that. However, the recent return to the body with physical immersion and interactivity makes electronic digitalism investing in “bodily affectivity and nonrepresentational experience.” (Ridgeway and Stern, 2008) This return to bodily affectivity therefore acknowledges this work as its standing for a mixed reality environment.

4.4 Meaning and Grammar of Interaction

In Ascott’s conceptualization of behaviorist art, the main concern of this art form goes through a shift: As a general remark of behaviorist art, or modern art in general, the *facts or objects* are no longer concerned, but the *events* are:

> “The dominant feature of art of the past was the wish to transmit a clearly defined message to the spectator as a more or less passive receptor, from the artist as a unique and highly individualized source. This deterministic aesthetic was centered upon the structuring, or ‘composition,’ of facts, of concepts of the essence of things, encapsulated in a factually correct field. Modern Art, by contrast, is concerned to initiative events and with the forming of concepts of existence” (Ascott, 2003).

This shift subsequently results in a “change from a specific message to a space for interaction.” (Simanowski, 2011) From Ascott’s visionary assertions until the recent times, the interactive art form is conceptualized as providing an open site for exploration and experience. The common point in all these views, Simanowski (2011) argues, is that “the *meaning* of the work can be produced within the moment of interaction, but it is not to be found as something already created by the artist.” Therefore, the overall conceptualization of interactive installations tends to be called as *experiences* by most of the practitioners.

As a direct result of the emergent behavior, one would expect it to be unfold continuously in meaning, a fact which also evocated by Lev Manovich in his famous book *The Language of New Media* (2001): He states that the new media object, or particularly for our discussion, the interactive art installation, “is not something fixed once and for all, but something, that can exist in different, potentially infinite versions due to the numerical coding and the modular structure of a media object. Instead of identical copies, a new media object typically gives rise to many different versions.”

Carried by the term *relational aesthetics*, which is defined as “a set of artistic practices which take as their theoretical and practical point of departure the whole of human relations and their social context” by Bourriaud (1998), the state of dialogue occurs within a set of possible ways. In this relational conceptualization, the artwork helps people to create a social environment, where they gather together to ignite a shared activity. Therefore, the art experience in relational view is not seen as a private encounter between the artwork and its spectator; instead, the audience is envisaged as a community and encounters between people are encouraged. This situation again assigns a new perspective to the meaning of the work: The individual does not experience and deduce the meaning privately, but it is created and elaborated collectively.

This set of ways that inaugurate the dialogue between the artist and the interactors is defined as “the grammar of interaction” by Masaki Fujihata. What makes the grammar of interaction significant is the fact that it defines the relation between the system and the interactor, and it reveals the artist’s viewpoint, “his vision, his thought and the communication he wishes to make.” (Fujihata, 2001)

As mentioned above, the interactive art holds up a mirror to the audience via its feedback cycles, and the relational aesthetics make the work behave in a somewhat ambiguous and collectively-defined way. The human input, in this sense, might disrupt the entire grammar of interaction at some points, where the interactors use it in a way the artist did not have in mind. This kind of discrepancies between the artist’s mindset and the interactors’ perception actually informs all the “relational” characteristics of interactive art that are described above. To put it in other words, conveying a meaning through a pre-defined grammar of interaction in artwork might result in an unprecedented audience reaction. Rather than meaning of the work, the responsive environment may inform different aspects of inter-human relations as well as surprising relationships between the audience and the system.

One example of the above mentioned disagreement between the grammar of interaction of the artist and of the audience is Rafael-Lozano Hemmer’s *Body*

Fig. 12. Rafael Lozano-Hemmer, *Body Movies* (2001). Photograph by Antimodular Research.

Movies from 2001. In *Body Movies*, the audience is expected to make visible the photo portraits taken on the streets of Rotterdam, which are projected onto the wall of the Pathé Cinema building at the Schouwburgplein Square in Rotterdam. (Fig. 12) The photos are programmed to appear only within the projected shadows of the interactors. The shadows exhibited various heights ranging from 2 meters to 25 meters, depending on how far people are from the light sources placed onto the floor of the square. Simanowski (2011) reads the work as following:

> "The essential element of the grammar of interaction is to give presence to those who are absent. In media ontological terms, one could say that the images exist only if they exist to somebody; that is, the image is physically created in the process of perception rather than production. The interactor's shadow also manifests a split between self and other. The interactor is symbolically deprived of her shadow, or rather of her self, because by functioning as a means of projection, her shadow represents another

> person. One can see an analogy with tattoos in that the body is being used as a canvas. Here, however, the image is revealed not on the skin but on the shadow, and is ephemeral. In addition, the person has no choice as to what is displayed on her body. *Body Movies* thus carries out an emblematic occupation: the body of those present is overwritten by absent others."

The intended embodiment of the photographs, however, was partly satisfied with Lozano-Hemmer's expectations. As Graham Coulter-Smith (2006) asserts, the actual grammar of interaction was "dull and boring" so that the audience primarily enjoyed playing with their own shadows rather than retaining with the intended frame of interaction. This surprise about the audience reaction demonstrates the two facets of the artist's role in the interaction design, as Simanowski (2011) elaborates: one is "expecting the audience to act in a specific way", and the other is "just providing the interactive environment for self-discovery."

Balancing these two facets of audience's grammar of interaction can be formulized as balancing the *objects* and *events* in the artwork. The signifiers in the interactive installation can be regarded as "objects" in this aspect, and as long as a deliberate set of actions are designed for the objects, these remain to be balanced with the event. "Possible actions building up to a specific meaning" ensure that the grammar of interaction is well-defined and provide a sufficient event-object agreement. However, on the other side, there are works in which one of these two sides diffuse into each other by providing either an obscure grammar of interaction or a set of signifiers. Such cases almost put no restriction to the interactor's actions at all, so that "it seems to be impossible to read the interactive setting as an object with a certain meaning." (Simanowski, 2011) Camille Utterback's interactive installation

Untitled 5 (2004) provides a fruitful example of such a case. Utterback describes the work as following:

> "The goal of these works is to create an aesthetic system which responds fluidly and intriguingly to physical movement in the exhibit space. The installations respond to their environment via input from an overhead video camera. Custom video tracking and drawing software outputs a changing wall projection in response to the activities in the space. The existence, positions, and behaviors of various parts of the projected image depend entirely on people's presence and movement in the exhibit area.
> *Untitled 5* creates imagery that is painterly, organic, and evocative while still being completely algorithmic. (...) The composition balances responses whose logic is immediately clear, with responses that feel connected to viewer's movements, but *whose logic remains complex and mysterious.*"
> (Retrieved 8.6.2019 from http://camilleutterback.com/projects/untitled-5/)

The complete freedom of the interactor in *Untitled 5* about how they engage with the work is the most significant aspect about the grammar of interaction. The obscurity of the grammar let the audience to use their body as an *instrument* or a *tool.*

Another application of an obscure grammar of interaction can be found in David Rokeby's influential interactive work *Very Nervous System* (1986 - 1990), in which he connected the intrinsic movement of any interactor's body to an ever-changing feedback of musical compositions by dynamically adjusting many parameters of the audio feedback with interactor's bodily gestures. Again regarded as an obscure grammar, Rokeby's work does not imply that it is void of meaning. As quoted in Simanowski (2011), Rokeby "deplores the general fetishization of control and considers it dangerous if we weed out of our lives those things that are uncertain, unpredictable and ambiguous." Therefore, he designs "systems of inexact control." As a motivation of this inexact controlling mechanisms, Rokeby states that the computer “sets up the illusion and fantasy of total control, which is not a useful paradigm for real-world encounters.”

Talking about the aspect of machine-human interrelations in interactive installations, *what is reminiscent of the relationship after the experience* is another noteworthy aspect. The strong corporeal co-existence within a reactive environment imprints lasting consequences on the body. An hour of the continuous, direct feedback in Rokeby’s Very Nervous System, Simanowski says, “strongly reinforces a sense of connection with the surrounding environment.” The instrumental capability of the body forces it to play again. Rokeby (1997) elaborates on this feeling as:

> “Walking down the street afterwards, I feel connected to all things. The sound of a passing car splashing through a puddle seems to be directly related to my movements. I feel implicated in every action around me. On the other hand, if I put on a CD, I quickly feel cheated that the music does not change with my actions.”

As a result, either strongly representational and pre-defined, or aural and spontaneous; the grammar of interaction is able to affect the reception of the work within the audience’s perspective. It is capable of transferring the audience beyond the gallery space and make them remain there, adjust perceptual qualities within a range of atmospheric and hypnotic states, as well as transforming the audience into “interactive guinea pigs” as Tilman Baumgartel’s (2000) powerful critics suggest. In each of these conditions, regardless of audience’s reaction, the artist wishes to communicate a state of unique experience, targeting an audience reaction within the boundaries of “been there/done that boredom” and naive enthusiasm.

4.5 Engagement and Critical Distance

The interactive artwork basically puts the audience into a dualism: either being an *interactor* or a *spectator*. This is a direct result of the dualism that is described above, which is about the artwork being an *event* and an *object*. Because of the fact that the boundaries of the medium dissolve into the space in immersive installations, the distinction between *immersion* and *staying distant in a critical position* blurs and requires further discussion.

“Aesthetic distance” as defined in Grau (2002), provides an overall viewpoint to evaluate the immersive environment with its organizational, structural and functional hypotheses and associations. He relates the distance to the basic act of understanding like Adorno: “Notwithstanding the longing for ‘transcending boundaries’ and ‘abandoning the self’, the human subject is constituted in the act of distancing, this is an integral part of the civilizational process.” (Grau 2002)

The distance of the audience can also be understood as taking different positions such as playing and watching, or being inside and outside. Grau elaborates on this by adopting the discussion from the aspect of Cartesian paradigm. The Cartesian paradigm assumes the head as the locus of perception and cognitive activity. As opposed to the central state of the visual sensorium in Cartesian focus, immersive interactive installations treat the body as the locus of perception and expands the viewpoint to *seeing with the body*. However, it can be argued that a direct immersion and interaction is not mandatory to understand a work with its grammar of interaction and other affiliations. As Simanowski (2011) puts it, “One can think about the concept of the work without experiencing it.” Given that these two poles of experiencing an immersive & interactive installation represent two different modalities, the oscillation between these two can lead to an enriched understanding of the work by representing two different aesthetic concepts. In other words, experiencing the work by bodily liberation and complete immersion is the key to feel the meaning of the grammar of interaction and the corporeal experience. On the other side, however, critically engaging with the work is requires stepping away from the immersion and observing what meta-qualities the work possesses. In this sense, the general approach to an immersive & interactive artwork provides the most insight by having this twofold fashion. Again, Simanowski (2011) summarizes the importance of this approach as following in the finishing of the relevant chapter of *Digital Art and Meaning*:

> “It is this combination of immersion and distance, bodily experience and cognitive reflection, that is important for critical interactive art. The privileged body in interactive installation art must not outplay the activity of the mind but rather become its favored subject.”

Based on this quotation, it can indeed be deduced that the interactive installation art is a unique ground for the interactor’s mind to play an alternating game with the body. When also combined with a relational component, this art form becomes an experimentation space for a thorough investigation of the cybernetic body and the human’s condition in this virtualized era.

CHAPTER 5

GETTING INTO THE INTERSECTIONS

As an understanding of emergent and variant system design by the principles of generative systems and creative coding is established in Chapter 3, this chapter will discuss how these systems have been used in the context of immersive & interactive installation art practice. Before diving into the discussion of these practices, the first section of this chapter will form one of the principal theoretical suggestions of this thesis: Art and design is going through an escalation and expansion with the application of systems theory and the convergence of these creates new possibilities and modes for both of these fields. Art's position and expansion with references to Luhmann's systems and evolution theories will be discussed and it will be suggested that *cybernetic identity* proposes a new, unexplored field for human's interaction with the art-technology-complex.

Naturally, the works mentioned in this chapter will cover more from the 21st century artists, with their ability to reach at advanced systems and perform efficient code structures even on the level of personal computers.

5.1 Intersection I: Systems Theory, Generative Design and Interactive Art

The systems theory encapsulates the objective world as “interrelated and interdependent parts”, which may either be operating on their own and exhibiting self-regulatory mechanisms, or be in an interdependent fashion to continue the complex and chaotic form of existence. Norbert Wiener’s subtitle of the influential Cybernetics book was “*Control and Communication in the Animal and the Machine”.* This subtitle states that both animals (biological systems) and machines (non-biological or “artificial” systems) can operate according to cybernetic principles. This was an explicit recognition that “both living and non-living systems can hav*e purpose.”* (Wiener, 1948)

What is suggested in the following paragraphs is about the convergence of two systems, that is art and technology, contributing to a greater sum of their parts added together and this convergence amplifies the possibility of *doubling the reality*.

The reflexive process, with its earnest definition, is what clearly defines the systems theory, according to Luhmann (2000): “a communication takes place, and it is either responded to or not. If it is not responded to, no recursion takes place and hence no system emerges.” In art and design’s account, it can be said that the convergence of these two systems happened to be in recursion and art’s autonomy as a system enabled it to disturb the technology with its promises. Brian Eno’s reflection on the electronic technology as a medium for artists states the following on this relationship of these two systems:

> “In the early seventies there was still a general consensus that technology was merely the machinery by which artists articulated their ‘vision’. Coupled with that was a deep suspicion of artists who ‘relied too heavily’ on technology. Technology was supposed to be the mute slave of ‘creativity’. To be over-reliant on it was cheating. But I found myself agreeing less and less, for what was happening to me was the discovery that the ‘vision’ doesn’t arise only out of the mind of the artist, but also out of the tools at his disposal. It’s a co-creation. ‘Technology’ and ‘creativity’ are interwoven and always have been. (...) ‘Visions’ arise not from individuals but from the whole communities, as indeed do tools and technologies: in fact, tools and technologies are communal visions embodied. This makes the whole issue of ‘originality’ much more contentious: although a work might carry my name, doesn’t it also internalise the talents and brains of a whole culture? A technology is a mesh of cultural ideas embodied in a tool.” (Eno, 2014)

What is suggested by Eno in this passage is also a classification of art and technology as social systems, that are in a “constant state of expansion in contraction” in Luhmann’s (2000) terms. This is also compared to the non-linearity of the evolutionary processes by Luhmann and explained by the term “autopoiesis”, which denotes a system ability to variate, select and re-stabilize its working parts in a state of “dynamic stability”. (Rampley, 2009)

This constant state of flux between the systems of art and technology has been the prominent field of intersection within the last decades, as shown with examples in the former chapters. To understand this fusion, it is again necessary to revisit Luhmann’s conceptualization of an art system, which states that it has gained the necessary autonomy to both self-organize itself and to diffuse with other systems. These abilities also echo in the Luhmann’s view to have irritations between art and technology. Luhmann, in this respect, argues that systems “intrude on one another, but for such intrusions—which he terms systemic “irritations”— to have any impact, they have to be re-coded in the terms of the system in question.” (Luhmann, 2000)

This *re-coding* exactly symbolizes both literally and metaphorically what is argued in this thesis. Art and technology can be regarded as primary domains to depict Luhmann’s intrusion of two domains to produce impact on both systems. And the evolutionary process –or say, emergent behavior, or autopoiesis- is the most accurate representation of this process of intrusion because these systems are neither linear, nor follow a preconception. Therefore, the debate gains a new dimension as a continuity of this evolutionary processes, which is the fact that *autopoiesis* results in the increased autonomy of the systems. In the end, this places the art system, which is the main concern here, into a more autonomous system in the contemporary culture, which is for sure in a feedback loop with the environment, however also free to determine its own boundaries in a constant state of flux.

To summarize this section, it must be briefly asked what is gained by approaching art through the medium of systems theory. Rampley (2009) asks the same question with an attempt to realize what original or subversive concepts system theory offers to the understanding of art, and evocates his suggestions as following:

> “In general terms it can be seen as a provocation to some basic assumptions underpinning many current social theories of art. (…) Luhmann opens up the possibility of rethinking the nature of historical change, of what it even means to talk about the *history* of art. This might consist in the analysis not only of how the art system defined itself in reference to its environment but also of how its environment—with its own exclusions and inclusions—was also defined.”

5.2 Intersection II: Relational Aesthetics and Architectural Body

Nicholas Bourriaud's umbrella term to describe the overall social situations that emerge from the interconnection of different actors in an environment gains importance in the recent installation artworks of many artists. One of the foremost tools of the practitioners of relationally aesthetic artworks is light, which is "the dominant component, ensuring the spectacular fascination with and very existence of this art form." (Popper, 2007)

The movement of the interactor, which is a liberating and displacing experience in the environment, is replied by the movement of light in the example that is going to be provided in this chapter. The sensory commons enabled by the digital technologies of light are brilliantly summarized by Mark Hansen in *Bodies of Code*. According to Hansen (2006), "digital technologies

1. Expand the scope of bodily (motor) activity; and thereby
2. Markedly broaden the domain of the prepersonal, the organism-environment coupling operated by our non-conscious, deep embodiment, and thus
3. Create a rich, anonymous "medium" for our enactive co-belonging or "being-with" one-another, which thereby
4. Transforms the agency off collective existence (of individual and collective *individuation*, to use French philosopher Gilbert Simondon's terminology) from a self-enclosed and primarily cognitive operation to an essentially open, only provisionally bounded, and fundamentally motor, participation."

Following these assertions, Hansen also elaborates on the concept of architectural body, as a subchapter of the chapter “Wearable Space”. Based on the defining qualities of architectural space, which is defined as “the art of frame” by Bernard Cache, Hansen considers the embodiment as “*the operator of framing*” for the space. The architectural body, in this sense, is the conjunction of the body and the architectural surround. “This concept is meant to capture the recursive correlation literally intertwining the body with space.” (Hansen 2006) In this respect, Japanese-American artist Arakawa (1994) emphasizes the role of “imaging” landing sites, which are responsible for rendering space potentially embodied or “embodiable”, for imbuing it with a sensory richness that catalyzes bodily response.

As a very recent example of this catalization, Japanese artists’ studio teamLab’s interactive digital installation *Moving Creates Vortices and Vortices Create Movement* can be examined, which was produced in 2017. (Fig. 13)

Fig. 13. *Moving Creates Vortices and Vortices Create Movement*, 2017, teamLab

In teamLab’s website, the installation is described as following:

> “When a person moves, a force is applied in that direction. As a result a flow occurs. When a fast flow occurs a rotation phenomenon is produced due to the difference in the flow velocity around it, creating a vortex. Flow in the artwork is expressed as a continuum of numerous particles and the interaction between the particles is calculated. Lines are drawn according to the trails of the particles. The cumulation of lines that represent the work are then “flattened” in line with what teamLab considers to be ultrasubjective space.
>
> The faster the person moves, the stronger the force is applied in that direction. If a person is not moving or there are no more people, no flow will occur and nothing will be present in the space. Works are born and continue to transform under the influence of people's movement.” (Retrieved 10.06.2019 from https://www.teamlab.art/w/vortices/)

As a fundamental exemplification of a generative particle system, the interactive nature of *Vortices* works in an embodied state. As described above, the imaging capability and the continuous nature of the space with a transformative but consistent pattern, the immersion is basically transformed into a unified architectural experience, amplified by the mirrors into infinity. One particular nuance about the interaction, as the work’s name implies, the movement and the vortices work in a *mutually necessary* nature. The sensory mechanism of the work affects the interactors’s movement by creating a space-time of its own nature, which reflects upon the behavioral conditions of the interactors. In agreement with Hansen’s (2006) condition, “imaging landing sites renders the space affective.”

The parametric agreement of the body with the surrounding space in *Vortices* is ensured by the generative characteristics of the work, a particle system and a feedback effect. The particle emitters are programmed to track the movements of the people within the environment and ensured the space to be animated by the projections of the body. This is also in agreement with the cybernetic theories of Wiener (1948), and bridges the system with the interactor.

CHAPTER 6

THE PROJECT: *INTERSECT();*

“We can’t control systems or figure them out.
But we can dance with them.”
Donella H. Meadows, *Dancing with Systems*, 2001

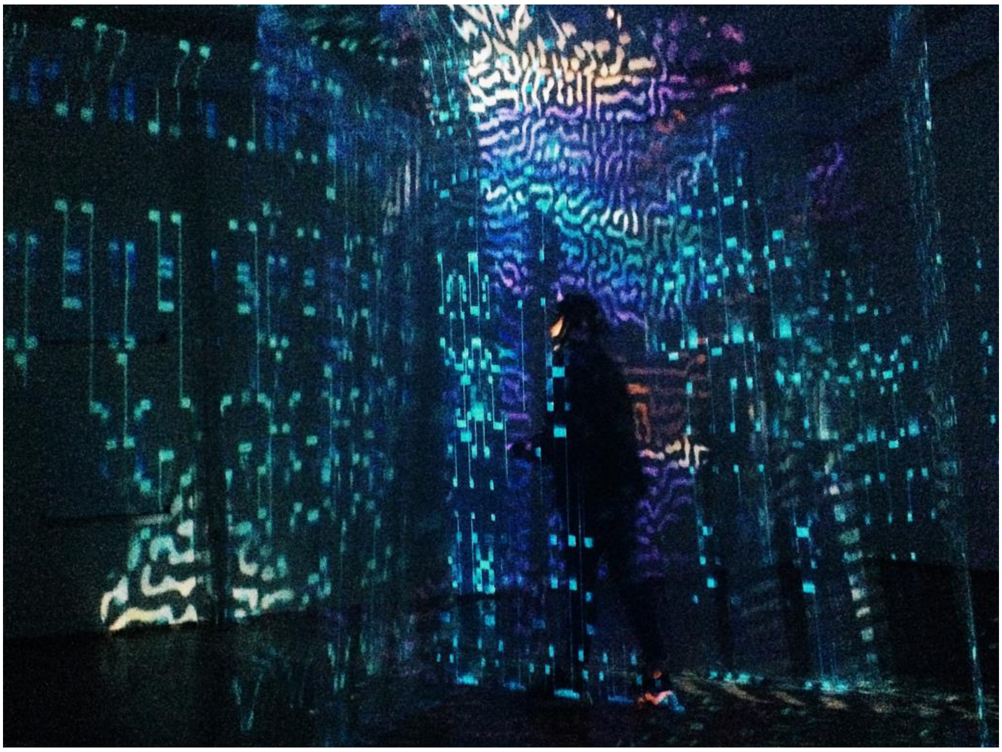


Fig. 14. Installation view from *intersect();*, Ali Bozkurt, 2019

intersect(); is an immersive & interactive experience, integrated with functions of space and body.

6.1 Motivations

The experience is originated from a quest for re-imagining virtual reality experience within a collective and spatial setting. With the help of tracking systems and light projection on the distributed gauze screens, the experience is designed in a free-form that invited interactors to a dreamy lightscape, and allowed them to openly interpret a multi-sensorial experience, while holding an aural and embodied connection with them.

6.2 Conceptual Design: Space, Dualism and Materializing Light

The work, in its conceptual level, tries to draw attention to human's status in today's intertwined world of digital & organic structures, called as *anthropocene* by social theorists. By juxtaposing these two realms metaphorically within two distinct generative patterns, the interactive area invites people to step inside, and as long as they are within, creates a swap between these two realms, which is shaped like & affected by the interactor's embodied existence. The mode of interaction particularly references the posthumanist theories of cyberspace, while it considers the blending of physical and virtual spaces as a distinct technological entity in a temporal encounter with the human input.

The dualistic structure of the project also references the other dualisms discussed throughout this thesis, such as computation vs. art, virtual reality vs. mixed reality, right brain vs. left brain, and immersion vs. interactivity. As a usage of generative practices in immersive & interactive environments, the work juxtaposes these two patterns as metaphors of dualisms. The coexistence of a colorful, organically structured fluid world with a strictly geometric, monochromatic pattern enabled to depict the facets of above-mentioned dualisms. The interference of those two patterns within the interactor's bodily silhouette also enabled an *identification of self* with the mirroring within the space. As stated before, the notion of architectural body is stressed out within the environment by relying on a human-centered quality.

Fig. 15. Installation view from *intersect();*, Ali Bozkurt, 2019

6.3 Implementation and Development

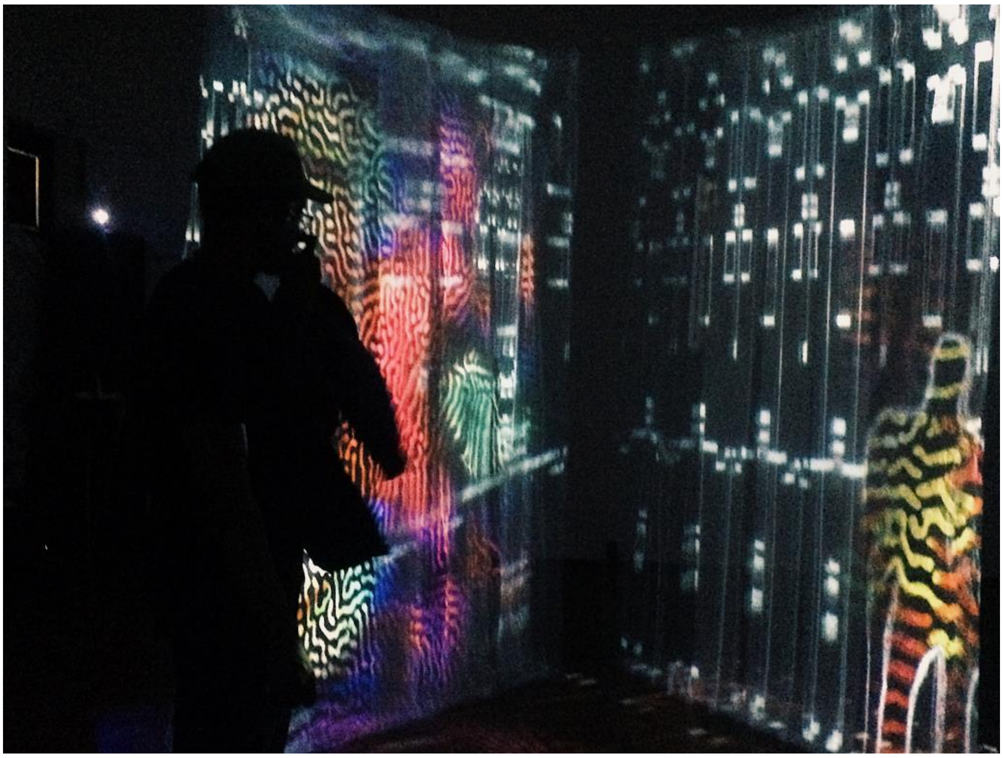
The two realms in the experience, which are labeled as contrasting to each other, are produced and projected in real-time with the help of procedural and generative algorithms. As one of the main parts of this research, visual programming environments like OpenGL, Python & Processing are examined; and compositing and connecting these to external input are carried out within an integrated environment, while running in real-time with Derivative TouchDesigner 099.

The organically labelled pattern is fundamentally based on a reaction-diffusion system, which is known as an essential basis for processes connected to morphogenesis in biology. (Harrison, 1993) What connects these patterns to our current understanding of pattern formation in nature is strongly reminiscent of the evolutionary and living characteristics of life on Earth. Therefore, the organic realm in this installation is produced as mimicking the growth behavior in nature. Especially, the self-organizing structure of this pattern and connecting it to the movements of the interactors enabled it to be received as a natural process of life.

The geometric realm, on the other hand; is again a procedurally generated pattern based on the Perlin Noise algorithm. As an overall look-and-feel, this part of the work exhibited a matrix-like structure, consisting of linear stripes with randomly filled squares and rectangles, which flows constantly upwards to describe the dynamics of technological development and the analytical mindset. One fundamental difference of the digital realm from the organic one is that it cannot be considered as a "self-organizing system" (Galanter, 2003). It is more of an artificial random system, which changes its parameters and structure based on a pseudo-random number generator, and any given state of the system does not have a sense of history. Inspired by Philip Galanter's influential paper *Complexity Theory as a Context for Art Theory,* this fundamental difference of self-organization between the two realms is worthy of notice. The randomness of the second image contributed it to be perceived as a non-controllable living entity with its own mode of vitality and enabled it to be easily opposed to the reaction-diffusion pattern.

The project implementation and exhibition are carried out in a work-in-progress status, therefore feedbacks from visitors and interactors are gathered to develop the project in a scope of three days.

The main trade-off of the implementation of the project was to balance the characteristics of immersion with the interactivity. The light density of the space was restricted to be supplied by two projectors, which are not identical in terms of intensity of illumination. The main material elements of the installation were gauze screens, which helped to hold the light on a designated surface, as well as holding a transparent characteristic, therefore letting light beams fall on the surfaces behind them. With this capability of materializing light on different surfaces within a dark room, the installation tried to warp the familiar visions of spatiality and create the immersion in an alternative way rather than 360-degree projection.



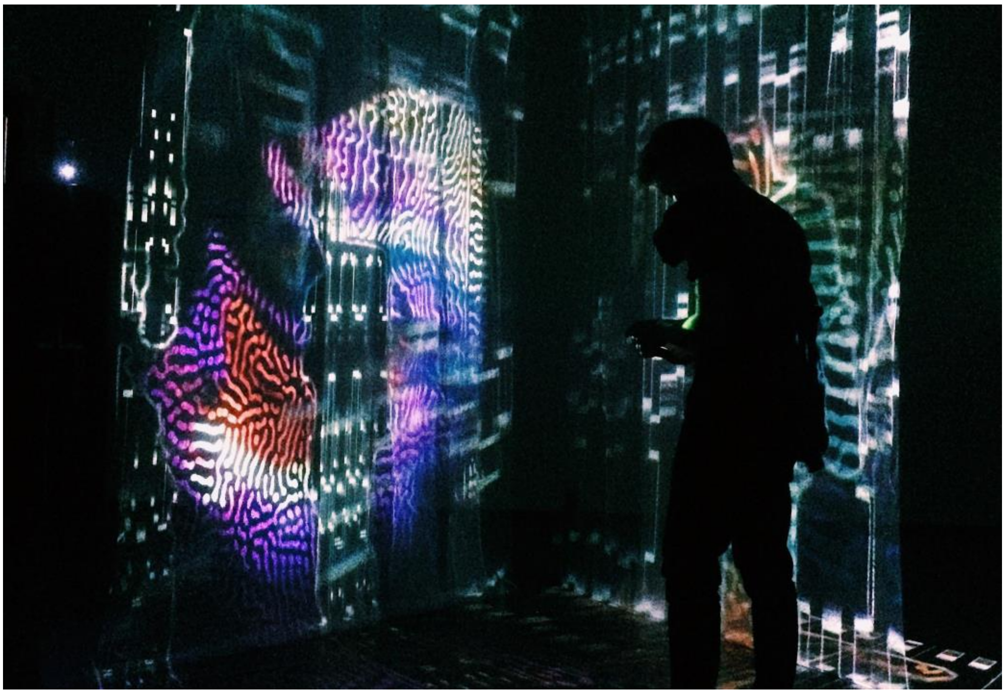


Fig. 16 & 17. Installation views from *intersect();*, Ali Bozkurt, 2019

Fig. 18. *intersect();* - Initial spatial design (Phase I)

The initial spatial design of the project implementation is shown in Fig. 18. Visitors are invited to experience this setting and provide feedback, and as their feedbacks accumulated, several problems with this implementation have appeared:

- The projected image has created the imagery both on the gauze screens 1 & 2 and the walls behind them, causing a confusion of focus for the interactors when they are oriented towards them within the interactive area. This orientation also caused an intervention of shadows on the images, which significantly affected the sense of immersion.

- The placement and the orientation of the sensors have intervened with the interior traffic within the experience. Especially the sensor placement has resulted in a blockage of the experience in the interactive area by the visitors who are waiting in the queue at the entrance between gauze screens 3 & 4. This blockage resulted in a drastic interruption of the experience and caused frustration.

With these problems and limitations in mind, the layout and orientation of the gauze screens, projectors and Kinect sensors are rearranged to develop the balance of immersion and interactivity elements of the project.

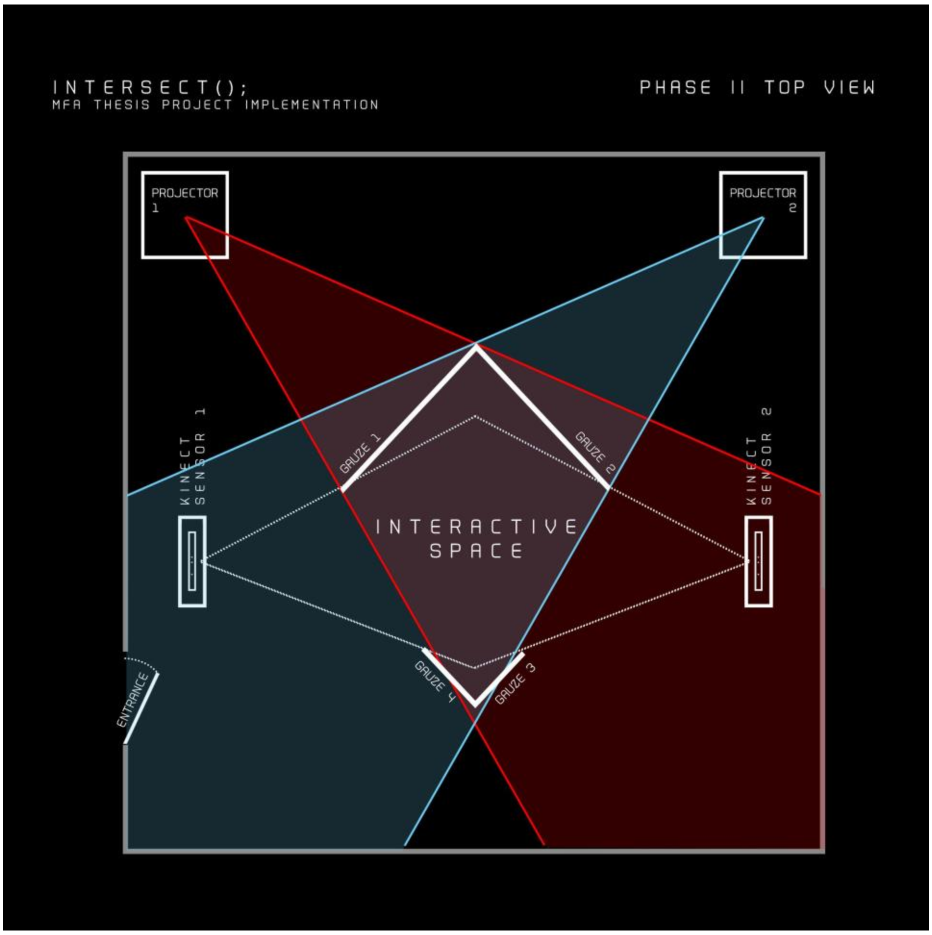


Fig. 19. *intersect();* - Improved spatial design (Phase II)

The improved design in Fig. 19 provided several enhancements about the visitor experience. First of all, the shadow problem of the interactors is eliminated while interacting with the system. Apart from that, the quality of the projection on gauze screens substantially increased and provided interactors a much clearer sight and rapid understanding of the concept of swapping and embodied existence in space. Surprisingly, the user's orientation and the Kinects' orientation were perpendicular to each other, and this served the ambiguity of the human embodiment within the experience. The realization of one's own body in this intersection space was not readily available, but it was dependent on one's own movement. Furthermore, the incidents of blocking one's experience by others decreased in the second phase of the implementation and users provided greater reaction to the quality and illumination of the gauze screens. (Fig. 20)

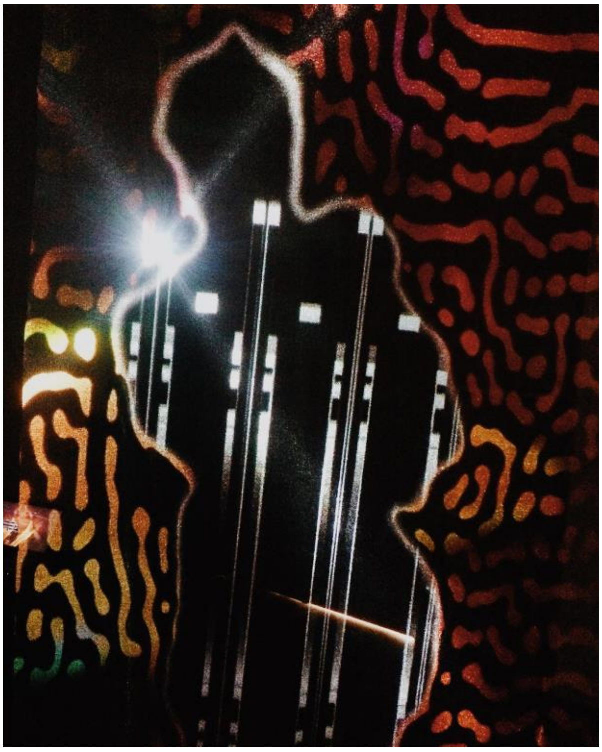


Fig. 20. Interactor's view from *intersect();* , Ali Bozkurt, 2019

6.4 Process and Output

intersect(); is designed as an infinitely running real-time generative system, which is not based on loops or any finite timescale. The project continually generated patterns of changing complexities based on the absolute time and interactor input, as well as noise generations of different complexities and types.

6.4.1 Software

The interactive system design of project *intersect();* is carried out with Derivative TouchDesigner 099, which is a visual programming environment, integrated with functions and connections with various software-development-kits (SDK) and input devices, such as Kinect sensor. The primary reason for choice of Derivative TouchDesigner is its ability to host multiple systems working in synchronization, as well as connecting to input devices easily and high reliability. Moreover, considering the computational complexity of the patterns generated in real-time with high resolution, it became necessary to process the graphics on a GPU-based fashion, which TouchDesigner is able to deliver with 2D texture operators.

Within TouchDesigner, the data is carried between and processed within nodes, which are named as “operators” with dynamic parameters and functions. The visual signifiers of different types of nodes are their colors, which states the data type those nodes are processing. Each node in TouchDesigner is basically a Python class, which has inputs and parameters which determine the execution of the functions of that particular class. Most of the runtime operations and variables are stored globally within the background of a TouchDesigner instance, therefore the application of such processes are also simplified to create more room while coding the visual systems.

Simply put, the two systems of the installation worked in a single instance of a TouchDesigner project. Both of the patterns are separately generated in the project and they are composited into each other by masking each one with the silhouette input that is retrieved from the Kinect sensor. A flow diagram of the main system design is constructed as following:

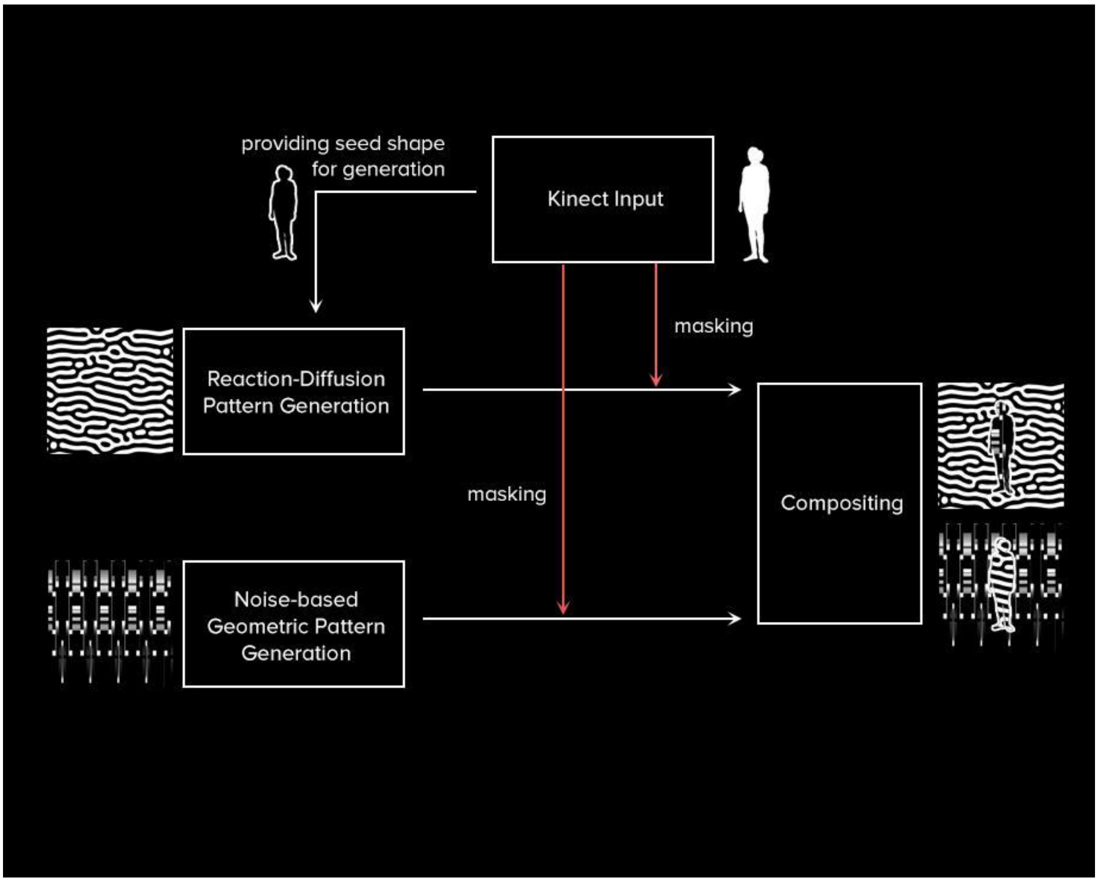


Fig. 21. Flowchart for the main software design of the system

Reaction-Diffusion System Generator

The reaction-diffusion system basically models two generic chemical species. They react with each other and they diffuse through the medium continually and as the absolute time changes, the system animates itself.

There are various algorithms to approximate the generation of a reaction-diffusion pattern. Creation of this pattern within the project relies on a replacement technique to model the behaviors of reaction and diffusion with respective image-processing techniques of subtracting and blurring. Blurring an image represents the diffusion behavior, and subtracting a more blurred version of the same image from the previously blurred one impersonates the reaction effect within these two images. Therefore, constructing a feedback loop which continuously repeats this blur-blur-subtract operation yields the generation of a reaction-diffusion pattern. The desired level of detail or transformations within the pattern are created with interfering the loop with a transformation operator, which slightly affects the pattern to deform in each iteration. In the following node-view from TouchDesigner, the reaction-diffusion loop is shown:

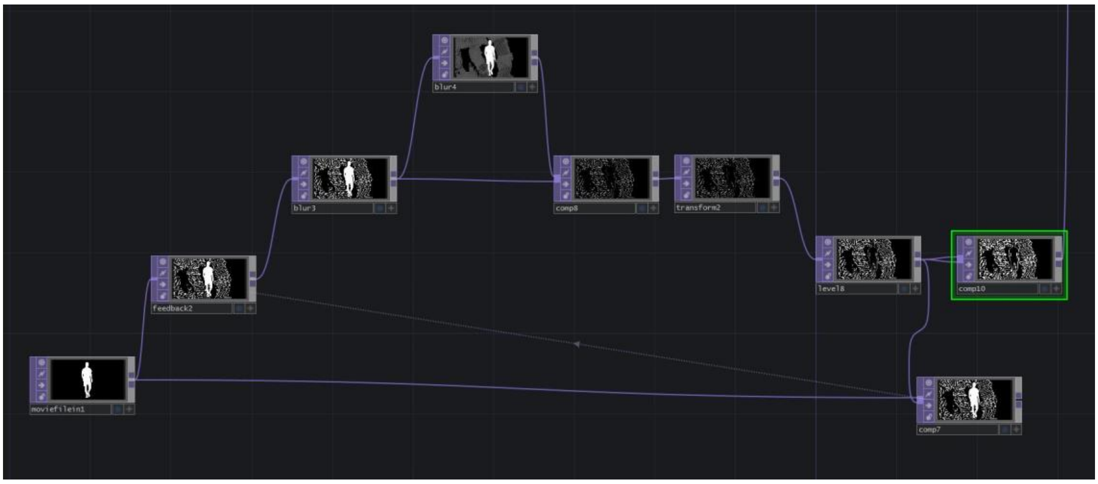


Fig. 22. The reaction-diffusion pattern generation in TouchDesigner, based on a silhouette image.

In the figure, the data flows from left-hand side to the right-hand side. The silhouette image is stored in the node at the most left-hand side node. A feedback loop is constructed between this image and the reaction-diffusion system, which is carried out within the upper level of the node graph. The data is transferred from the image to a feedback node, and it enters two consecutive blurring nodes. These blurring operations mimic the diffusion of the chemicals. A Composite TOP (texture operator) subtracts these two blurring nodes from each other, which performs the reaction operation. One critical point about blurring operations is that their filter sizes should be different than each other to make subtracting yield a difference. (Figure 23)

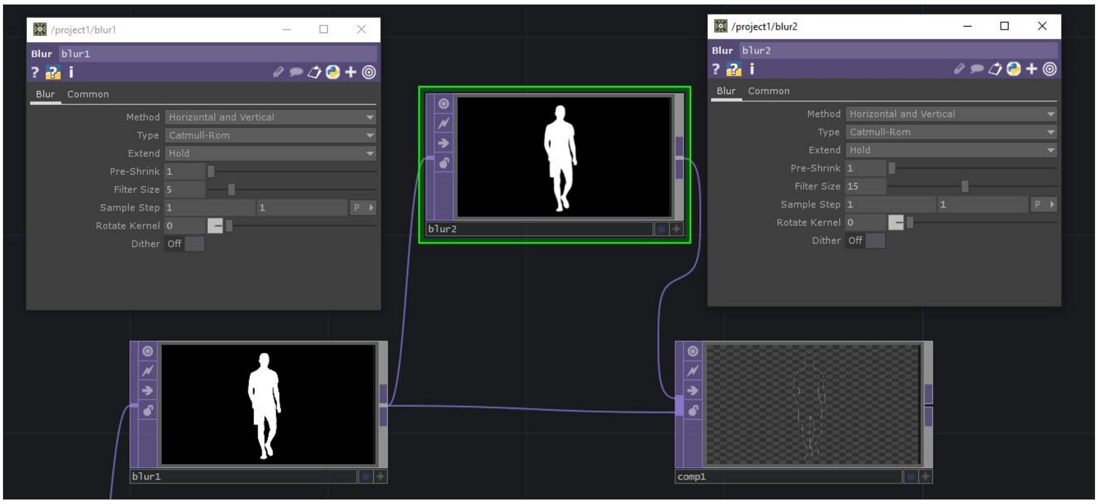


Fig. 23: Diffusion (blurring) and reaction (subtracting) of the seed image

After these two operations are completed, the feedback loop is completed with a Level TOP, which fine-tunes the RGB and Luma values of the feedback image. Lastly, a Composite TOP unifies all the fed-back images and adds them together. As the images accumulate through the feedback loop, the reaction-diffusion pattern grows.

After frame-based iterations of 300 frames, which is 5 seconds in the 60FPS setup, the algorithm populates the canvas with reaction-diffusion stripes, as seen in the following figure:

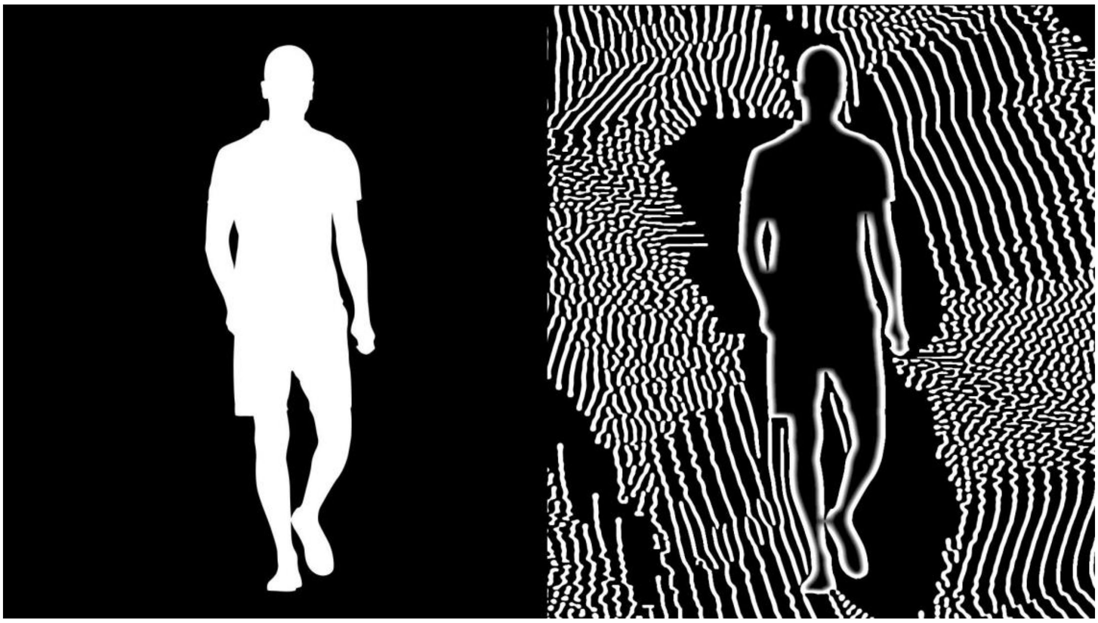


Fig. 24. The seed silhouette and the result of the reaction-diffusion algorithm applied into it after 300 frames of iteration

The noise-based geometric pattern, on the other hand, relies totally on the Perlin Noise algorithm to generate stripes of regeneration and stack them on the horizontal axis to achieve a randomized but harmonious result. The main algorithm is constructed of eight different 2-dimensional Perlin Noise generators of 1x900 pixels. Then, these generators are stretched to varying degrees of width, each determined by one sample value of a 1-dimensional noise generator. The node-view and the generated noise pattern are as following:

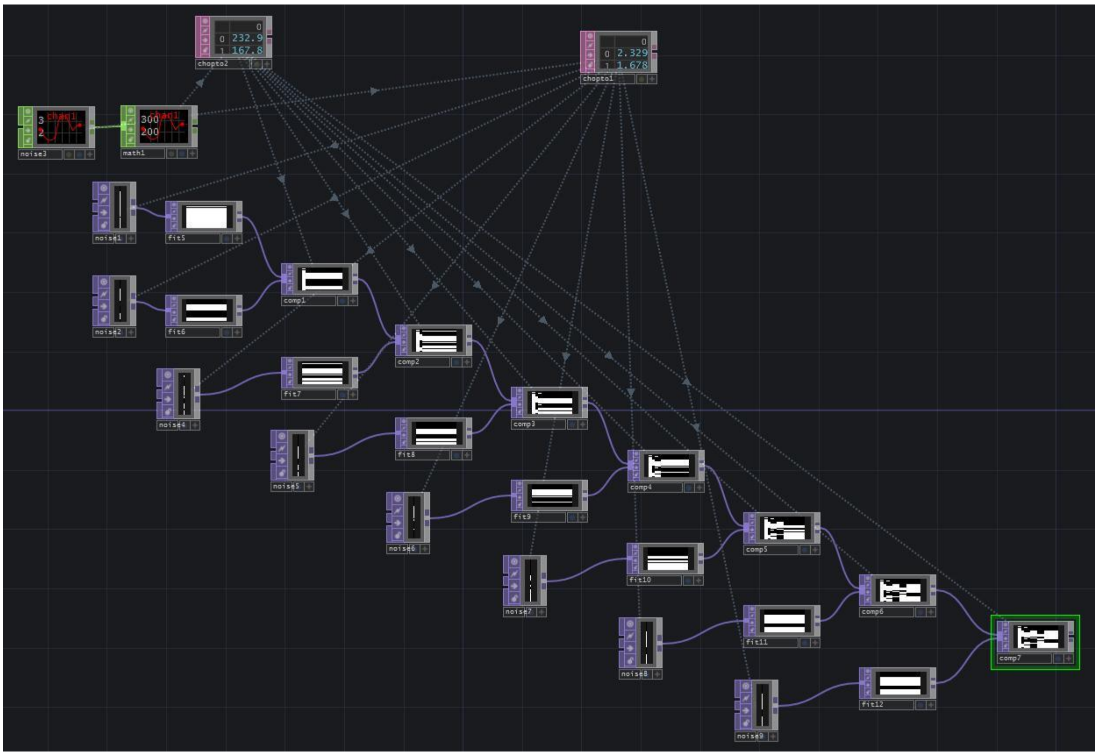


Fig. 25. Noise-based geometric pattern generation in TouchDesigner. Noise patterns are generated in the nodes on the left-hand side and gradually stretched and composited together according to the 1D-noise values, fed from above.

Fig. 26. A single instance of noise pattern (left) and eight of them stacked (right)

After the generations, the chain continued with the colorization of the reaction-diffusion pattern, which is based on the Curl Noise algorithm, producing a texture on RGB channels and composited into the monochromatic pattern. As discussed in the third chapter, Curl Noise is an adapted version of the Simplex Noise algorithm, which increases its dimensions into higher fields and provides a clearer set of coloring with more defined boundaries. Adaptation of a Curl Noise is preferred because of the defining boundaries and a more uniform balance of bright and dark areas, which yielded an organic distribution of colors. The Curl Noise generation algorithm is borrowed from an open-source GLSL implementation by David Braun, which is licensed under GNU General Public License v3.0. The source code is reachable at github.com/DBraun/TouchDesigner_Shared/blob/master/TOPs/curl_noise_4D.tox (Retrieved 11.06.2019) The following figure shows the comparison of a Curl Noise pattern with Perlin Noise within the same parameters.

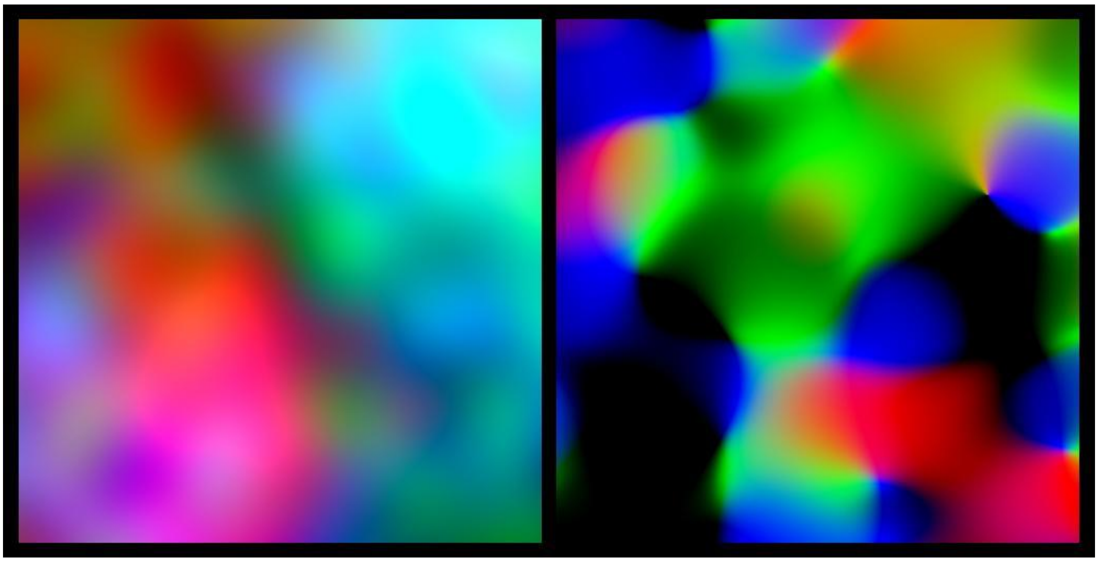


Fig. 27. Colored Perlin Noise texture (left) and the Curl Noise texture (right)

6.4.2 Hardware

The project employed two projectors, two Kinect XBOX360 motion sensors and two PCs, each synchronously running the same project with differing compositing modes. Kinect sensors are preferred because of their capability to pass a depth image with their infrared cameras. Since the project is designed in a dark room setting, regular camera setup could not provide an efficient body silhouette, which resulted in processing the depth images provided with Kinect cameras. (Fig. 27)

Fig. 28. Depth image from Kinect camera.

To create a transient light surface in the dark room, gauze screens are used, which are suspended down from a grid-like metal scaffold. To ensure sufficient tension with the gauze, lower edges of the screens are bonded to the surface. (Fig. 28)

Fig. 29. The pinning of the gauze screens to the surface.

6.5 Analysis and Discussion

Considering several drawbacks and technical limitations, *intersect();* demonstrated the primary issues with design programming and building an interactive & immersive environment. Accomplishing such an environment with limited resources has enabled me to integrate the spatial components with the light and materiality, and I will continue my artistic research in such medium with different materialities and spatial arrangements in the future.

The interactive component of the installation makes use of several simple computer vision algorithms and image processing methods such as edge detection and blob tracking. Besides the overall benefits of such approaches, there is still some room for possible developments in the mode of interaction of the project. Further research will focus on a better implementation of mapping human input to the parameters of generative components.

The fundamental discussion of the thesis project was based on the factors of body in an ever-changing, immersive environment. By utilizing implications of mirror image, immersion and grammar of interactions, the thesis project touched upon the factors that are discussed in the third and fourth chapters of this thesis. To be precise, certain components of *intersect();* can be evaluated within the following aspects of generative art and immersive & interactive installation art:

Generative Practices

The project successfully exemplified the usage of an algorithmic & generative approach within an artwork, as an alternative to the traditional methods of image-making. The systems approach presented has shown what can be expected from a continuous system of real-time generation, that can be modulated and transformed with various input from the surrounding environment. In this respect, one of the main objectives of this thesis is satisfied with leveraging parametric and procedural design approaches.

Mixed Reality

Another main motivation of this thesis was to describe the approach of mixed reality as a second-generation research of virtual reality technology. To promote the qualities of sensory environments and to combine the virtual art practice with real spaces in a collective setting, the implementation of the project *intersect();* raised an awareness within its visitors and interactors. The fascination and reception of the work by the visitors appreciated the transformation of architectural space into a wearable space with illusionary qualities and interactive settings.

Sensorimotor Exploration and Bodily Sense of Vision

As one of the foremost qualities of interactive artworks, it is argued in Chapter 4 that the sensorimotor exploration of the work opens the door to the bodily immersion. With the adjustment of the interactive space within *intersect();* the audience is given the role of fundamentally affecting the artwork by creating a space of intersection within the two halves of the installation. This allowed the audience to assist their ocular perceptual qualities with the inclusion of their body, or in other words, opened up a vision in a bodily sense. *intersect();*, in this sense, provided an "alternative way to the ocular-centric tradition."

Relational Aesthetics

The grammar of interaction in *intersect();* was considered to be open as much as possible, so that it allowed to be affected by multiple interactors. This setup, in its essence, provided a "space where we can elaborate alternative forms of sociability, critical models and moments of constructed conviviality." (Bourriaud, 2002) The reflections of collective moments gathered from the experience proved it to be igniting interactor's interpersonal relationships with its two-fold nature. Besides transferring the dual nature of the work described above, the work also created a situation similar to Lozano-Hemmer's work *Body Movies* in a sense that interactors reacted without showing a primary concern for the meaning of the work.

Body as an Instrument

As stated above, the reaction-diffusion pattern in the experience was dependent on the interactor's movement within the space, so that the interactor was freely able to use his most intrinsic ability, which is to move, to create patterns of diffusion. This allowed them to use their bodies as instruments, as described while narrating Rokeby's work *Very Nervous System*. The bodily consonance with the environment lasted after visitors' experience so that the reminiscence of interaction with the environment continued after they leave the experience.

CHAPTER 7

CONCLUSION

Everything is in constant change. To illustrate this change in a balance with the aspects which remain in their position for a long time, it is suggested that systems converge into each other and contribute to a greater sum than their parts added together. The irritation and resulting expansion of this process became the main suggestion of this research and reflected in a project.

Throughout this thesis, the main goal has been about establishing a bridge or a common space between different approaches to design, interactive art and immersion. While discussing each of them in their specific place, it became clear that they share some intersection points, especially when thought from the perspective of a combination among them. Of course, these combinations are also discussed with their reverse-echoic implications, which suggest a shift in the role of traditional approaches to the art and design professions.

Starting with a general approach to CGI and generative procedural design was especially important because of the fact that this systems approach introduces many new facets into the design practice. The autonomy of a system, which is capable of generating a wide variety given the sense of probabilistic approaches and randomized functions, creates a distinct mode of design for the practitioners of any expressive medium. For the purposes of this thesis as well, these continuously-generating systems are trusted to assist the immersion and interactivity in an environment. Indeed, the continuity of a system assigns a character and a personality to any system, not even necessary to mention a life-like behavior. Naturally, the investigation of these qualities about what they imply to the design activity of today and the future could not remain unvisited.

Although certain movements of today's design culture still promote the human-centered design activity, certain speculative approaches also look for different approaches to it. Generative design is capable of being a candidate to the main tools of design activity of the future with its promotion of *designing tools of generation* rather than final results. Especially recently, the wide research on Generative Adversarial Networks (GANs) that are able to estimate the characteristics of large image datasets and producing similar results based on them, made it possible to realize machine-based generations of photographic results. Although GANs are the subject of a whole another research, the implications are widely discussed in today's world with respect to AI-art. Not only limited to the photographic generation, other image media is leveraging tools of continuous generation and mimicking human's conception of artistic practice, which raises the questions towards the machine's ability to intervene with the qualities that are so far assigned to the human. Instead of speculating upon the answers to these questions with direct addressing it is preferred to focus on how these blurred boundaries are amplifying the unique position of art in the 21st century. Disruptive or disagreeing views aside, it is emphasized that art has arrived at a unique position among all the professions of today's world that is in the most converged position with the technology. Computational artists are the first adopters of many algorithms and they are even in a unique position of contributing to the development of them. This, in fact, puts the artistic practice into a wider field of research and applications in the current stage, either it is to adopt the methodologies to inform the artwork, or either to be able to properly comprehend and reflect on the works of other artists.

Moving onto the immersion and interactivity, it should be stated that primary aim was to discuss the emancipation of power to transform the space *from a single performer to the visitors of the environment*. Although the political and media-theoretical implications of immersion is still two-fold and a certain hype is being promoted “by the existing structures of power,” (Golumbia, 2009) this thesis remains optimistic about the upcoming phases of virtual-reality research to consider the spatial arrangements and mixed and augmented reality technologies to create alternative spaces of reality to tackle the digital isolation of human.

Besides that, as a secondary frame of reference, the dissolution of interfaces within digital media is adopted as an application ground for interactive installations. Through certain references to embodiment and intrinsic movement as a regulatory mechanism of installations, the *disappearance* of the interface also resonates with the primary aim stated above: distributing the control into a collective space. Dissolution of the concrete control interfaces between the interactor and the installation can be read as a representation of these two *systems’* intrusion into each other. These references, along with the de-framing of digital content in a space, have been a fruitful opportunity to examine the entanglement of digital media with the social aspects of everyday life. To state in other words, the entire discussion within this thesis can be received as a reading of the implications of treating the artistic practice in a systems approach. Borrowing terms from evolutionary biology and cybernetics theory, an illustration of the autonomy and the constant flux of the artistic practice is provided and it suggested an optimistic reading of the systems theories of the late 20th and early 21st centuries.

Within Manovich's paradigm of potential infinity that is referenced in Chapter 4, one argument of Luhmann again gains importance and provides a finishing remark for this thesis. Central to understanding the temporality in Luhmann's social systems is the interpretation of meaning. "The phenomenon of meaning appears as a surplus of references to other possibilities of experience and action. Thus the form of meaning, through its referential structure, forces the next step, to selection." Therefore, the perception of meaningfulness is connected to "an element of unrest. Meaning forces itself to change." Consequently, where there are no possible outcomes of *surplus*, or *surprise*, one cannot speak of meaning, for meaning is the "difference between what is actual at any moment and a horizon of possibilities." (Luhmann, 1995)

BIBLIOGRAPHY

Ascott, R., & Shanken, E. A. (2007). *Telematic embrace: Visionary theories of art, technology, and consciousness*. Berkeley, CA: University of California Press.

Arakawa & Madeleine G.. (1994). *Architecture: Sites of Reversible Destiny*. London: Academy Group

Bianchini, S., et al. (2016). *Practicable: from Participation to Interaction in Contemporary Art*. The MIT Press.

Bourriaud, N. (2002). *Relational Aesthetics*. Dijon: Les presses du réel.

Cage, J. (1966). *Silence: Lectures and Writings*. Cambridge, Mass.: MIT Press.

Candy, L. & Ferguson, S., ed. (2016). *Interactive Experience in the Digital Age: Evaluating New Art Practice*. Springer International Publishing.

Carlson, W. E. (2017). *Computer Graphics and Computer Animation: A Retrospective Overview*. The Ohio State University.

Coussement, P., et al. (2010). *Dynamic Mapping Strategies for Interactive Art Installations: an Embodied Combined HCI HRI HHI Approach*, "5th International Conference on Digital Arts Proceedings".

Cubitt, S. (2014). *The practice of light: A genealogy of visual technologies from prints to pixels*. Cambridge, MA: The MIT Press.

Elwes, C. (2015). *Installation and the Moving Image*. Columbia University Press & Wallflower Press.

Fujihata, M. (2001). "*On Interactivity*." In *Takeover: Who's Doing the Art of Tomorrow*, edited by ARS Electronica. New York: Springer.

Galanter, P. (2003). *What is generative art? Complexity theory as a context for art theory*. GA2003 – 6th Generative Art Conference.

Golumbia, D. (2009). *The Cultural Logic of Computation.* Cambridge, Mass.: Harvard University Press.

Grau, O. (2007). *Virtual Art: from Illusion to Immersion*. MIT Press.

Halsall, F. (2008). *Systems of art: Art, history and systems theory*. Bern: Peter Lang.

Hansen, M. B.N. (2006) *Bodies in Code: Interfaces with Digital Media.* Routledge.

Harrison, L. G. (1993). *Kinetic Theory of Living Pattern*. Cambridge University Press

Krueger, M. (1997). *Artificial Reality*, 2nd ed., cited in Söke Dinkla, *Pionere Interactiver Kunst* (Karlsruhe: ZKM/Ostfildern: Cantz, 1997)

Luhmann, N. (2000). *Art as a Social System*. Stanford, CA: Stanford University Press.

Luhmann, N. (1995). *Social Systems*. trans. John Bednarz, Jr., Stanford, CA: Stanford University Press

Making of the Computer Graphics for Star Wars (Episode IV) [Video file]. (2007, November 20). Retrieved April 18, 2019, from https://www.youtube.com/watch?v=yMeSw00n3Ac

Malaspina, C., & Brassier, R. (2018). *An Epistemology of Noise*. Bloomsbury Academic.

Manovich, L. (2001). *The language of new media*. Cambridge, MA: MIT Press.

Meadows, D. H. (2008). *Dancing With Systems.* Retrieved from http://donellameadows.org/archives/dancing-with-systems/

Merleau-Ponty, M. (2002). *Phenomenology of Perception: An Introduction*. London: Routledge.

Noll, A. a. (2016). *Early Digital Computer Art at Bell Telephone Laboratories, Incorporated*. Leonardo. 49(1), 55-65.

Penny, S. (2017). *Making Sense: Cognition, Computing, Art, and Embodiment*. The MIT Press.

Popper, F. (2007). *From Technological to Virtual Art.* The MIT Press.

Rampley, M. (2009). *Art as a Social System: The Sociological Aesthetics of Niklas Luhmann*. Telos, 2009(148), 111-140.

Reeves, W. (1983). *"Particle Systems—A Technique for Modeling a Class of Fuzzy Objects".* ACM Transactions on Graphics *2:2* (April 1983).

Shanken, E. A. (2015). *Systems*. The MIT Press.

Shiffman, D. (2012). *The Nature of Code.* 1st ed. The Nature of Code.

Simanowski, R. (2011). *Digital Art and Meaning: Reading Kinetic Poetry, Text Machines, Mapping Art and Interactive Installations.* University of Minnesota Press.

The working life of Brian Eno. [Interview by S. Frere-Jones]. (2014, June 30). The New Yorker.

Visual Music Classics #3-4 Permutations & Arabesque – John Whitney. (2012, March 14). Retrieved April 18, 2019, from https://www.dataisnature.com/?p=435

Wiener, N. (1948). *Cybernetics, or, Control and communication in the animal and in the machine*. New York: Wiley.