IN RELATION:
RE-ASSESSING RESPONSIVENESS THROUGH HUMAN-MACHINE INTERACTION

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ABSTRACT

IN RELATION:
RE-ASSESSING RESPONSIVENESS THROUGH HUMAN-MACHINE INTERACTION

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Advances in cybernetics, material research and network technologies affected the volume and the interpretation of human involvement in responsive architecture. The study scrutinizes the notion of responsiveness and its reflection(s) on/in the field of architecture. In this respect, it aims to investigate the role of the human in responsive bodies and seeks to redefine the boundaries of the participants through human-machine interaction in a responsive manner.

The thesis offers a reassessment of the in-relation state between the human and the machine and investigates its re-problematization by responsive bodies. Dissolved boundaries between the components of the body are examined in light of ontological and philosophical machine debates. The effects of adopting machinic approaches in the definition of responsive bodies are examined with selected case studies from various contexts, and the dissolution of limitations between the human and the machine/non-human are questioned in line with these transformations.

Keywords: Responsiveness, Liveliness, Behavior, Body, Responsive Architecture, Human-Machine Interaction

ÖZ

İLİŞKİLENİM:
YANIT VERİRLİLİĞİN İNSAN-MAKİNE ETKİLEŞİMİ YOLUYLA YENİDEN DEĞERLENDİRİLMESİ

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Sibernetik, malzeme araştırmaları ve ağ teknolojilerindeki gelişmeler, yanıt verir mimariye insan katılımının hacmini ve yorumlanmasını etkiledi. Araştırma, yanıt verirlik kavramını ve kavramın mimarlık alanındaki yansıma(lar)ını incelemektedir. Bu doğrultuda tez, yanıt verir gövdedeki insan rolünü araştırmayı amaçlar ve insan-makine etkileşimi aracılığıyla katılımcıların sınırlarını yanıt verirlilik bakış açısı ile yeniden tanımlamayı hedefler.

Tez, insan ve makine arasındaki ilişkilenimin yeniden değerlendirir ve yanıt verir gövde kavramı ile yeniden sorunsallaştırılmasını araştırır. Gövde bileşenleri arasındaki çözülmüş sınırlar, makine üzerine ontolojik ve felsefi tartışmalar ışığında incelenir. Yanıt verir gövdelerin tanımlanmasında makinesel yaklaşımların benimsenmesinin etkileri, çeşitli bağlamlardan seçilmiş vaka çalışmaları ile incelenmekte ve bu dönüşümler doğrultusunda insan ile makine/insan olmayan arasındaki sınırlamaların ortadan kalkma hali sorgulanmaktadır.

Anahtar sözcükler: Yanıt Verirlilik, Canlılık, Davranış, Gövde, Yanıt Verir Mimari, İnsan-Makine Etkileşimi

To my dearest family

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LIST OF ABBREVIATIONS

ABBREVIATIONS

AI	Artificial Intelligence
A2H	Architecture to Human
HMI	Human-Machine Interaction
H2A	Human to Architecture
ICT	Information and Communication Technology
IoT	Internet of Things

CHAPTER 1

INTRODUCTION

The perception of the world, whether related with social, financial or cultural issues, is co-dependent to the technology at hand. Since the 20th century, computer-aided systems dominated the technological fields and network technologies redefined the purposes of digital information and the accessibility of the data. The Fourth Industrial Revolution -in other words Industry 4.0- that is being introduced through robotics, artificial intelligence (AI) and cybernetics has broadened the horizon of the production processes and material properties. Intelligent machines, which are described as cyber-physical systems that permit interactions between humans and machines, helped fabrication processes to become smarter.[1] These newly developed technologies which enabled swift and smart processing have promoted a rebirth in the lexicon of numerous disciplines. Architecture, as one of the fields that is conjoint to technological advancements was introduced to an atmosphere where the behavioral interaction between human and technology is made more available, similar to the early conceptions of this relation in the 1960s.

The transformation of architectural discourse over these improvements reflected itself as the need to establish a relation between the participant and the environment by means of flexibility and relatability. The conception of the human-machine interaction (HMI) which has been made available by Industry 3.0 was perceived as a pathway to convey such relation. Responsive environments, as a field of

[1] Brettel, M., et al. "How Virtualization, Decentralization and Network Building Change The Manufacturing Landscape: An Industry 4.0 Perspective". International Journal of Mechanical, Industrial Science and Engineering, 8, 2014

architecture integrated with computer science and network technologies emerged as an embodiment of these shifts and breakthroughs in recent decades.[2]

Responsive Architecture was first introduced as a term by Nicholas Negroponte in the late 1960s, inspired from the developing automation and computation technologies introduced along with Industry 3.0. Negroponte reflected upon the event of cybernetic implementation on architectural discourse and defined responsive architecture as "the natural product of the integration of computing power into built spaces and structures"[3]. He focused on the computer-aided structures governed with intelligent behavior that are designed to study the utilization patterns and aimed to reveal the stance of the architect less as an administrator and the human as data rather than the user. In his book, *Soft Architecture Machines*, he proposed a new kind of architecture without architects by breaking down the subject to intelligence, the making of architecture, the analysis of architectural design and activities related to the designed space.[4] The main idea was to achieve a better, non-traditional combination of the human and the machine based on user experience and intelligent behavior, where the designated roles of both participants are left behind: *"Each chapter (in the book) removes the architect and his design function more and more from the design process; the limit of this progression is giving the physical environment the ability to design itself, to be knowledgeable, and to have an autogenic existence."*[5].

Early attempts to conceptualize responsive architecture failed due to numerous reasons: lack of cognitive capacity of computation, experiments on the notion

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[2] Uçar, B. "An Inquiry into the Ontology of Responsiveness: Assessing Embodiment and Human-Machine Interaction in Responsive Environments", PhD. diss., Middle East Technical University, September 2011

[3] d'Estrée Sterk , T. "Building Upon Negroponte: A Hybridized Model Of Control Suitable For Responsive Architecture". Automation in Construction, Volume 14, Issue 2, 2005, Pages 225-232, p. 226

[4] Negroponte, Nicholas. Soft Architecture Machines (Cambridge, MA: MIT Press, 1975)

[5] Ibid.

through improperly designed mechanical systems and so on. Therefore, a utilitarian method on responsiveness dominated the implementation in the architectural field. Generally regarded as a one-way interaction, the responsive environment accomplished the task through the gathered input, which was provided from either participant or natural conditions. Responsiveness was mostly studied through computer-aided programs with the intent to satisfy the needs of the user. In other words, the attitude towards responsive environment was that of a mechanism or a machine with a certain function which provides expected actions according to the projected inputs. Along with the technological advancements Industry 4.0 initiated, the 21st century suggested another perspective on responsiveness considering the cognitive capacity of the machine and the potential the human-machine interaction carries.

1.1 Problem Area and Definition

Since the emergence of the responsive bodies which is engendered with the technological advancements introduced with Industry 3.0, the experiments scrutinizing this new field remained within the boundaries of logical approaches.[6] The main focus of these implementations on structure or environment was to establish an administrable equation created with units similar to: "input (human/nature) – process (algorithm) – output (algorithm)"[7]. The limitations on the perception of responsiveness were produced by the expected rational relationship conveyed between the human and the surrounding environment. Rather than discovering the potential that this new area introduced to the architectural discipline,

[6] Uçar, B. "An Inquiry into the Ontology of Responsiveness: Assessing Embodiment and Human-Machine Interaction in Responsive Environments", PhD. diss., Middle East Technical University, September 2011

[7] d'Estrée Sterk , T. "Using Actuated Tensegrity Structures to Produce a Responsive Architecture". In Annual Conference of the Association for Computer Aided Design in Architecture, Proceedings, 85 - 93. India, 2003.

earlier examples of computer-aided systems adopted a utilitarian approach, as a tool to optimize natural environmental conditions.

The common characteristics of these applications are that the responsive body is practiced with mechanic features, which can be defined as a closed machine with a purpose.[8] Since the mechanic approach solely provides self-contained movement that is unable to transform[9], together with the implementation of "purpose" along the utilitarian approach, the accomplishment of the early conceptions of responsive architecture were restricted in terms of the in-relation state realized between the human, the machine and the space. In this context, the potential of the in-relation state was yet to be discovered.

Since the beginning of the 21st century, contemporary applications inspired with the desire to unlock the potential of responsive bodies engendered a different attitude towards space alteration. These applications aimed to rediscover the limits of the notion of responsiveness, and the boundaries between the human and space. Rather than investigating the effect of the human on the environment, these recent implementations of responsiveness focused on the impact of the altered space on the human, or tried to establish the simultaneous interaction of both parties. In such practices which alter the environment far from a concern for utilitarianism, computer-aided systems, cybernetics and AI are extensively utilized to stimulate the relation between the human and a responsive body. With these attempts, the boundaries between entities and the distinction between the human and the environment start to blur. "Response", which was regarded as an "output" is now acknowledged as "behavior" in contemporary approaches to responsiveness.

The study aims to investigate this transformation of the notion of responsiveness by means of the changing relationship between the human and the machine. Through a scrutiny of carefully selected case studies, of the philosophical perspective provided

[8] Colebrook, C. "Gilles Deleuze", London; Routledge, 2002. p. 56

[9] Deleuze, G., Guattari, F., 1977. Anti-Oedipus: Capitalism and Schizophrenia, Viking Press. p. 67

by Gilles Deleuze on the issue of human-machine interaction and a study of a redefinition of the notion of responsiveness, the thesis will investigate the reflections of this alteration on responsive bodies, the boundaries of the human, the expansion of the space and the quality of liveliness. The significance of this study is to reveal the potential that space alteration and the disruption of boundaries between human and non-human entities brings forth. The thesis adopts a Deleuzian definition of the "body". To reveal the intertwined state established between the human and the environment (or space), the use of the term "body" or "responsive body" refers to the following statement by Gilles Deleuze:

> "A body can be anything; it can be an animal, a body of sounds, a mind or an idea; it can be a linguistic corpus, a social body, a collectivity. We call longitude of a body the set of relations of speed and slowness, of motion and rest, between particles that compose it from this point of view, that is, between unformed elements."[10]

The scope of the research is structured as follows: The thesis will present an evaluation of selected case studies by means of their responsive characteristics and emphasize the significance of human-machine interaction through the Deleuzian idea of the machine, adopting the non-anthropocentric approach entailed in the Deleuzian concepts of the machine and the *rhizome* while establishing a responsive body. The thesis will scrutinize the shift in the notion of responsiveness from a utilitarian perspective towards a more experimental one, as displayed by the hybrid physical/digital environments of the 21st century.

Although the contemporary applications are increasing in number for the last twenty years along with an increased cognitive capacity offered by advances in technology and mainly cybernetics, there are still not enough data regarding experiments that illustrate the gradual dismantling of boundaries between the human, the machine and

[10] Deleuze, G. "Spinoza: Practical Philosophy", City Lights Books, San Francisco, 1988, p. 127

the space. Therefore, this study may not be inclusive of diverse contemporary applications of responsiveness.

1.2 Methodological Approach and Structure of the Thesis

To understand the notion of responsiveness and to comprehend how the human-machine interaction (HMI) influenced responsive bodies to establish a reciprocal communication, the meaning of "response" and the emergence of the term "responsive architecture" is studied in a first place. Conditions that led to the development of responsive architecture are examined and the anthropocentric approach that instigated the early cases of responsive architecture are thoroughly analyzed by means of their effects on current applications. The implementation of intelligent behavior to architecture which was forethought by Negroponte as referred in *Soft Architecture Machine*[11] and his conception of the "architecture machine" with Cedric Price's *Fun Palace* project, the role and the influence of those conceptions, the integration of cybernetics to architecture and the pervasiveness of information and communication technologies (ICT) on responsive bodies is scrutinized.

Secondly, diverse machine conceptions are analyzed to emphasize the difference between machine and mechanism and their numerous applications in recent responsive bodies. The study focuses on revealing the potential that an in-relation state carries: Theorizing these applications with the idea of the Deleuzian machine and *rhizome*, this study aims to reconceptualize the relation between human and machine, human and non-human.

Thirdly, focusing on the utilization of material properties and computer-aided systems in responsive bodies, the loosening of the boundaries between the human and the space through machine interaction is presented. By reevaluating the transformation of the interest between those bodies towards a non-anthropocentric perspective where all the participants/constituents of a 'body' are perceived as

[11] Negroponte, N. "Soft Architecture Machines" (Cambridge, MA: MIT Press, 1975)

equals, the study aims to redefine responsiveness through investigating the individuality of the parties that establish responsive bodies and the exhibition of liveliness among them.

Following this conceptual structure, Chapter 2 presents the definition of the notion responsiveness and gives examples from early rule-based attempts in the 1930s to achieve a "house as a machine for living"[12]. By adding the utilization of vernacular architecture, the thesis introduces the developments and the inspirations that led to the emergence of the term "responsive architecture". An investigation into the background events that set off the search for a responsive body follows this discussion. Chapter 2 also focuses on a chronological study on the concept of responsiveness with carefully selected applications. These case studies create the framework through which the technological advancements pave the way to the transformation of the HMI and represent the earlier trials of how a responsive body alters the notion of space. First considered as two independent entities, the study focuses on the intertwined and indistinguishable state of the human and the machine while configuring the responsive body for the human or the other way around. After tracing the evolution and history of cybernetics, computing and material properties, these are taken into consideration as the three primary modern methodologies used to define responsive bodies. Presented case studies that were established through these methodologies reveal a different approach in responsive applications. Within this chapter, *Institut du Monde Arabe*, *Muscle Re-Configured*, *Dune 4.2*, and *Pop-Up Interactive Apartment* projects are four significant case studies that seek to unveil the potential that different approaches engender on responsive bodies. The chapter concludes by presenting a discussion on the relation that the human and the responsive body establish on each case.

Chapter 3 discusses the differentiation of machine and mechanism by exemplifying applications for both. These applications in responsive architecture are examined

[12] Le Corbusier. "Vers Une Architecture" Toward an Architecture, 1923. Translated by John Goodman, Getty Research Institute, 2007

with regards to the differing utilization of responsiveness through both machine and mechanism. Definitions of the terms are presented in various disciplines and the identities of both terminologies are revealed through the mutual points which have been made while conceptualizing these terms based upon the principles of different fields. The dehumanization of architecture and the idea of conceiving the environment as a mutative machine is explained through Negroponte's *Soft Architecture Machine* and Cedric Price's *Fun Palace*. Chapter 3 then introduces the Deleuzian concepts of machine and *rhizome*. With conceptions of notions such as "body", "machine" and the potential that *rhizome* introduces by decentering the human, the study proposes a concept of responsiveness distinct from the early utilitarian approach.

Chapter 4 considers the role of technological developments that affected the transformation of the relationship between the human and the machine. By presenting the impact of computation on architecture and material properties, the transition from hard architecture to soft architecture is discussed. Emphasizing the reciprocal communication among HMI with the integration of cybernetics, the thesis reflects upon the alterations in architectural discourse. The reconceptualized notion of responsiveness is defined in this chapter through new practices of HMI and the in-relation state this practice offers. The established in-relation state proposes a discussion on the notion of the machine and the notion of liveliness embraced by these machinic approaches. Contemporary applications which adopt a non-anthropocentric approach reflect upon the Deleuzian notion of the machine and *rhizome* in responsive bodies. Selected case studies such as Philip Beesley's *Hylozoic Ground*, Philippe Rahm's *Hormonorium*, François Roche's *Altered State and* EcoLogicStudio'*s Urban Algae Canopy* expand the stance of the thesis on the in-relation state of participants in a responsive body and reveal the significant potential these new applications offer to architectural discourse with the decentering of the human.

CHAPTER 2

AN INQUIRY INTO RESPONSIVE ARCHITECTURE

2.1 Responsiveness as a Notion

Before a discussion of the notion of responsiveness, first, the use of the word "response" in daily life language can be defined. The meaning of "responsive" is established as "an interested and enthusiastic reaction to somebody/something" in the Oxford Dictionary[13]. This means that being responsive to a condition or an environment is fundamentally in relation with the concept of "interest". Starting from the early 2000s, responsiveness as a notion is more interpreted as a behavioral outcome of the input which is fed by the environment, participant, or a body with respect to the conditions that surround the unit or algorithm that provides the output. The term "behavior" needs therefore to be inclusive while rediscovering the boundaries that responsiveness covers. Whether the approach to the topic is theoretical or purely utilitarian, the primitive conception regarding the notion as "an output provided towards an input" is outdated with the advancements achieved with Industry 3.0, which are mainly on automation, computation and electronics[14]. The case studies which will be further exemplified in this chapter point out the vast areas of experiences that responsiveness reaches out while being reconceptualized. Through these examples, the critical meaning of the term "behavior" introduces itself

[13] Oxford Learner's Dictionaries. "Definition of responsive adjective from the Oxford Advanced American Dictionary" Retrieved from https://bit.ly/37sDg2S on December, 2019

[14] Colombo, A. W., et al. "A 70-year industrial electronics society evolution through industrial revolutions: The rise and flourishing of information and communication technologies." IEEE Industrial Electronics Magazine 15.1 (2021): 115-126.

as a prominent aspect while comprehending and evaluating the concept of responsiveness.

The terminology and the area that it covers started to test its boundaries with the technological developments achieved with Industry 4.0. Along with the potential that smart materials, integration of physical and cyber systems, and advanced robotics brought, the computational facilities that are being utilized in the field of architecture started to redefine their approach towards its use and the philosophy behind it. Rather than serving as a tool which simplifies daily life for people, computation and algorithm-controlled systems started to form a relationship with participants, whether the human or the environment itself. The understanding of responsiveness, which once was perceived as a one-way interaction, shifted towards a reciprocal dialogue where all the parties are attentive to one another. What should be emphasized is the embedded meaning of "relationship" through participants of the responsive body and the possibilities that the state of being "in-relation" offers. The medium makes it possible for a "being" to ever-mutate itself according to the introduced parameters on the controlling algorithm and create a variety of the changing conditions. This mutational power makes the environment available for new experiences, recognitions on human-scale perspective, and new definitions of what we call "environment", "body" and "alive". Moreover, this reinterpreted relationship introduced behavioral and psychological transformations on human beings which will be further analyzed in Chapter 4.

With the integration of computation and architecture, and with the emerged interest in dynamic structures, examples of responsiveness became a somehow common application in the field of architecture for the last two decades (Table 1.1). Although generally considered as in relation with the computational approach and sensing technologies, responsiveness carries other meanings rather than merely being a system responding to environmental inputs under the authority of a computer. Being a responsive "organism" or an "algorithm" or an "environment" in general, means that the defined responsive body has the material properties or computational

Table 1.1 Responsive application examples from 1960 to 2020

1960 - 1970	1970 - 1980	1980 - 1990
1962 Los Angeles Hall of Records *USA*	**1980** Occidental Chemical Building *USA*	**1987** Institut du Monde Arabe *FR*
1990 - 2000	**2000 - 2010**	**2010 - 2020**
1993 Business Promotion Centre *DEU* SUVA Insurance Company *USA* **1994** Heliotrop *DEU* The Brundtland Centre Villa Vision DEN **1995** Headquarters of Götz *DEU* Burton Barr Central Library Phoenix Central Library *USA* **1997** Commerzbank Tower *DEU* Design Office for Gartner *USA* Stadttor - City Gate *DEU* Glaxo Wellcome House West *GBR* **1999** GSW Headquarters *DEU*	**2001** Quadracci Pavillion *USA* **2002** Blur Building *CHE* **2005** EWE Arena *DEU* **2006** Council House 2 - *AUS* TDCCBR - *CAN* Cafe - Restaurant Open - *NLD* **2007** Kiefer Technic Showroom- *AUT* Richard J. Kiarchek Information Commons - *USA* **2008** Beijing National Aquatics Center *CHN* California Academy of Science *USA* **2009** Surry Hills Library and Community Center Sydney Law School *AUS* Unilever Haus - *DEU* Adaptive Fritting - *USA*	**2010** Sebrae Headquarters - *BRA* Manitoba Hydro Place - *CAN* ThyssenKrupp Quarter Essen *DEU* Media - TIC Building - *ESP* Vivian and Seymour Milstein Family Heart Center Simon Center for Geometry and Physics *USA* **2011** 1 Bligh Street - *AUS* Gardens by the Bay - *SGP* Aldar Central Market - *UAE* **2012** RMIT Design Hub - *AUS* One Ocean - Pavillion 2012 *KOR* Dhabi Investment Council Building - *UAE* **2014** SDU Campus Kolding - *DNK* Head Office of AGC Glass *BEL* **2016** Dancing Pavillion - *BRA* **2017** La Seine Musicale - *FR* MOKYEONRI - *KOR* **2019** Operable Interactive Village Hut - *CHN*

facilities that react to the controlling algorithm for it to recognize the parameters that are previously defined and introduced to the body: such as proximity, volume and so on. The same scenario can also be accomplished by recognizing the quality of the material and utilizing the kinematic responses of the forementioned body -with wind power, light, heat and various natural variables similar to them.

Buildings, generally regarded as a fixed entity, carry changeable components within their lifespan. Rather than the fundamental load bearing units which are walls, slabs, columns and so on, all the furniture and the appliances inside of a housing unit are considered as dynamic and upgradable. To define it with a most primitive classification, they are considered as items. However, the approach towards the understanding of a house underwent a drastic chance during the early modernism era. The term "machine" was chosen to serve as a comprehensive definition for the concept of the modern house. Renowned brands such as General Electric endorsed fully electrified houses: The Talking Kitchen by General Electric was exhibited at the Chicago Century of Progress exhibition in 1933[15]. David Nye described this rather futuristic example as;

> "There are no attendants in this kitchen, but ... a voice from an unseen source announces that this is the last word in kitchen equipment. As if by magic the door of the electric refrigerator opens and the voice, coming apparently from the refrigerator, relates how the refrigerator saves money for the owner. Then a spotlight falls on the electric range, the oven door lowers,' and a voice explained its operation, and so on through the rest of the appliances. By eliminating the attendant, the company seemed to say that the kitchen worked by itself"[16]

The expected outcome from those all-electric houses was to program all the domestic activities for the people residing in a "machine-house". Self-decisive mechanisms

[15] Nye, D. "The Electrifying Future," in Electrifying America: Social Meanings of a New Technology, Cambridge: MIT Press, 1990, p.357-8.

[16] Ibid.

were to control the daily life of the dweller. This proposed relationship was not accepted since the dweller lost the feeling of control. The characteristic and the tradition of a house which is dependent on the dweller was surrendered to standardization by the technological advancements on this modern perspective of a house.[17] Prior to these cases, Le Corbusier initiated his attempts to conceptualize the house as a "Machine for a Living" (*Machine à Habiter*) since early modernism[18]. According to Le Corbusier, the house was a problem that required a precise solution. His extensive work includes a detailed account of the necessities of habitation as well as the significance of each room and component of the home, such as the terrace, the garage, the maid's room, and the bathroom. The list also includes the walls and furniture such tables, chairs, cabinets, and drawers, even the gramophone.[19] He approached all the elements as machines or parts of the machine. Famously indicated by him, the chair was defined as a machine for sitting.[20] Putting aside the "house as machine" perception for further investigation which will be carried out in Chapter 3, windows and doors are elements that are kinetic and operable as a simple and fundamental part of a shelter -considered as a primitive and basic version of a building. Le Corbusier defined the furniture of a house as "household equipment" ("*outillage*") as well as other components of a dwelling.[21] What is defined as a shelter must provide the possibility and the ability to adapt to the surrounding conditions since the environment is an ever-changing entity. When considering the foundation of the discipline of architecture itself, the emergence of the "shelter" was to adapt to the environmental conditions and to form a protective shell for their dwellers. The general principles of architecture in Laugier's iconic study, *Essay on Architecture*

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[17] Zavoleas, Y. "House-as-Machine: The Influences of Technology During Early Modernism." Rethinking the Human in Technology Driven Architecture. EAAE, 2012.

[18] Le Corbusier. "Vers Une Architecture" Toward an Architecture, 1923. Translated by John Goodman, Getty Research Institute, 2007.

[19] Ibid.

[20] Righini, P. 2000. "Thinking Architecturally: An Introduction to the Creation of Form and Place". University of Cape Town Press. p. 101

[21] Ibid.

indicate that a shelter must prevent and control environmental conditions[22]. When viewed in this perspective, vernacular architecture redefines itself by playing a critical role in discovering the roots of the notion responsiveness. Prior to the emergence of the term "Responsive Architecture" made by Negroponte and the "*Machine à Habiter*" idea by Le Corbusier; vernacular architecture, by using available resources in a certain environment and corresponding construction techniques, addresses specific necessities and evolves through time to adapt to the changing environmental, structural, cultural or economic requirements.[23]

Vernacular architecture is the root of the adaptive capacity of the shelter by using locally available sources to overcome the challenging environmental conditions.[24] By using the responsive characteristics of materials, vernacular architecture enables solutions that does not require technology and be a part of the natural equilibrium.

Figure 2.1: Spruce cone's reaction to moisture change

This approach has inspired solutions to deal with the emerging issues of climate change such as global warming and so on. Therefore, vernacular architecture can be regarded as the ancestor of the notion of responsiveness and the core figure of responsive architecture. To illustrate a more modern approach which utilizes the main principles of vernacular architecture combined with the advancements of Industry 4.0 such as intelligent manufacturing, Achim Menges in collaboration with

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[22] Laugier, M. A. 1755. An Essay on Architecture. London: T. Osbourne and Shipton.

[23] Uçar, B. "An Inquiry into the Ontology of Responsiveness: Assessing Embodiment and Human-Machine Interaction in Responsive Environments", PhD. diss., Middle East Technical University, September 2011

[24] Kazimee, B.A., "Representation of Vernacular Architecture and Lessons for Sustainable and Culturally Responsive Environment", WIT Press, 2009

Steffen Reichert took insight from spruce cone's moisture-driven movement (Figure 2.1) and they have focused on the anisotropic and hygroscopic characteristics of wood.[25]

"*At any rate, it is a question of surrendering to the wood, then following where it leads by connecting operations to a materiality, instead of imposing a form upon a matter"*[26]. Inspired by the ideas of Gilles Deleuze and Felix Guattari, Menges and his team investigated the use of wood and its responsive capacity to propose a climate-responsive structure based on spruce cone's biomimetic notions. Scales of spruce cones open when they are dry and close when wet through its bi-layered form and this movement is autonomous from the metabolism of the plant. Anisotropic materials' movement direction is related with the orientation of the material's body. Hygroscopic behavior can be summarized as maintaining equilibrium of moisture with environment's relative humidity by absorbing or adsorbing water molecules. This behavior enables movement according to moisture density. Wood's -in this case a simple quarter-cut maple veneer's- anisotropic characteristic and hygroscopic behavior makes it possible to maintain an embedded responsiveness to humidity by a simple physical programming[27]. The distance correlated to relative humidity between the micro fibrils in cell tissue of wood veneer is the core of alterations on shape and dimension of the material. This intrinsic response provides a system which is free from any sensory unit or motor function therefore can be regarded as an energy free solution.[28]

HygroSkin: Meteorosensitive Pavilion (Figure 2.2) by Achim Menges in collaboration with Oliver David Krieg and Steffen Reichert is created with the spruce cone's biomimetic principles. Aiming to provide an energy-free climate responsive

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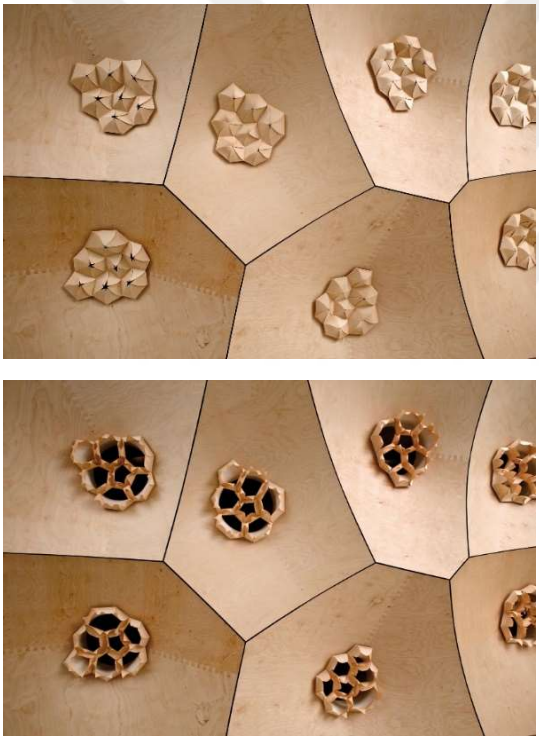
[25] Hovestadt, L. et al. "ALIVE: Advancements in Adaptive Architecture," in ALIVE: Advancements in Adaptive Architecture (Birkhäuser, 2014), p. 39-42.

[26] Deleuze, G., Guattari, F. "A Thousand Plateaus: Capitalism and Schizophrenia". Minneapolis: Continuum International, 2004. p. 451.

[27] Ibid.

[28] Ibid.

system, wood's instability towards moisture is exploited to assemble a meteorosensitive structure that independently opens and closes according to relative humidity. Menges took one of the most elementary shape – box and utilized plywood's ability to develop conical surfaces to create 28 units by 7-axis robotic manufacturing, each embedded with 1100 responsive apertures. Varying from relative humidity levels from 30% to 90% which can be translated as sunny weather to rainy weather, apertures adjust the pavilion's level of porosity and visual permeability of the skin. This adjustment merely takes few minutes in case of rapid rise in relative humidity.[29]



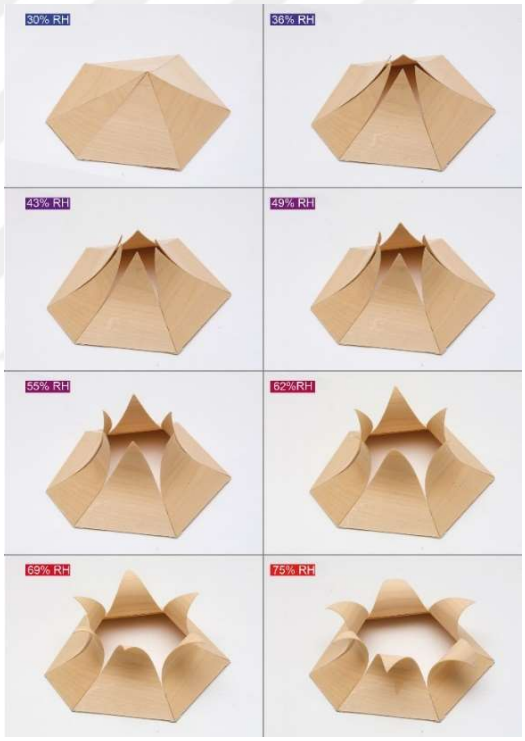


Figure 2.2: Closed & Opened State **Figure 2.3:** Shape Change according to Relative Humidity

Source: Menges, Achim. "HygroSkin: Meteorosensitive Pavilion, retrieved from www.achimmenges.net/?p=5612s

[29] HygroSkin: Meteorosensitive Pavilion, Retrieved from www.achimmenges.net/?p=5612s

Responsiveness of an architecture is generally regarded as a machine which has adaptive qualities that can be utilized to optimize environmental conditions, whether through material properties or computational approaches. However, the emergence of the notion must be analyzed thoroughly to understand what was foreseen and expected from such architecture. The synonyms that Negroponte determined for the word "responsive" were "reactive" and "adaptable"[30]. Rather than focusing on the material properties, he was attentive on how the intelligent behavior can be embedded to structures with a more holistic approach. Through "manipulative environment" which is the precursor of responsiveness "*it* (environment) *is taking an active role, initiating to a greater or lesser degree changes as a result and function of complex or simple computations.*"[31] The manipulations that Negroponte refers to may be integrated to a structure in various ways. He gives the example of the vertical circulation in a building, the elevator, while explaining about responsiveness in architecture[32]. He suggests that if the patterns are examined thoroughly, it is possible to construct an elevator that has no controller; in this case buttons, and which has the underlying algorithm that enables the elevator to stop at the relevant places and go to the right places so that the user is satisfied. Negroponte claims that this is a "*schedule*" which follows a pattern based on the user experience. Later on, he proposes another scenario where the elevator is full and incapable of containing one more participant: He criticizes that in that case the schedule should be converted into a "*model of appropriate behavior*" since the elevator will understand that the weight limit is reached through its sensory units and will not respond to the coming calls until there is sufficient room for the awaiting users[33]. As an ahead of its time concept, the "model of appropriate behavior" was introduced in 1976, which was only seven years after the stated start date of Industry 3.0 era. With a comparatively premature technology, MIT graduate architect Negroponte was one

[30] Negroponte, N. "Soft Architecture Machines". Cambridge, MA: MIT Press, 1975

[31] Ibid.

[32] Ibid.

[33] Ibid.

of the first people who studied the utilization of computers in architecture and architectural design. This new integration and the potentials that it offers were discovered through various applications on buildings and as alterations on defined spaces. Although the notion never lost its utilitarian characteristics, applications throughout time started indicating a separate area within the notion, which conceives responsiveness in more than its instrumental capacity.

2.2 Timeline of Responsiveness

When considering the emergence of the term responsive architecture and the first contemplations on this notion, the process can be seen to be mainly on the instrumental potential that it offers. Since the 1920s, the modernist approach has been to turn the house itself into a machine that serves people with a certain routine. The traditional and individual shelter was approached as a place where all programmes are planned, each facility standardized and where all units have designated roles, including the human. Even before the appearance of the notion itself, through vernacular architecture, the material properties of the resources were recognized with their potential to function. In order to adapt to the changes, available resources were used in a conventional way, not always revealing the true potential of the material. Frank Lloyd Wright said "*Folk building growing in response to actual needs, fitted into environment by people who knew no better than to fit them with native feeling*"[34].

Both these approaches involve a strict control on the parties and adopt a rule-based perspective. The 1936 publication of Ernst Neufert's book "Architect's Data" is a thorough manual on the incorporation of machine features into design, with a focus on the dwelling.[35] Starting from the early 2000s, technological developments made

[34] Oliver, P. "Dwellings". London: Phaidon Press. 2003. p. 9

[35] Zavoleas, Y. "House-as-Machine: The Influences of Technology During Early Modernism." Rethinking the Human in Technology Driven Architecture. EAAE, 2012.

it possible to rediscover the conventional approaches in architecture and building science, along with many other disciplines. In the *HygroSkin: Meteorosensitive Pavilion* example, wood is approached in order to reveal its potential and to analyze its behavior. By eliminating the traditional method and creating the concept itself on how it will behave on certain relative humidity, HygroSkin aims to discover its material behavior, rather than its material property.

From the earliest applications to more of the contemporary ones, the practice of responsiveness on architecture is transforming itself via the developing technology, through the uses of cybernetic systems, AI and by exploring the potentials that newly discovered material properties bring. This search for potential of mutational characteristics is leaning towards an encounter of a different kind of relationship, where the designated roles of each party lose their meaning and where clear boundaries between the and the responsive environment can no longer be distinguished.

The application of responsiveness on discipline of architecture is generally regarded as a one-way communication where the environment -buildings in this case- satisfies the needs of the human and the only result of the responsiveness which is embedded to the structure is making human life simpler. The barrier between participants changes and acquires the capacity to be dynamic in a connection where the participants respond to each other and redefine themselves in response to replies from the opposite party. Both the responding entity and the participant cannot be viewed as passive in the ongoing reinterpretation of this border. Instead, they each play a dynamic role in this newly defined relationship, continually refining and adjusting it so that each participant can develop as an extension of the other.

The notion of responsiveness will be presented on four different case studies with various specialties belonging to each example – from the one that is considered to be an ancestor of responsive application to three different applications that are inclusive to human behavior and the understanding and revaluing of space.

2.2.1 Institut du Monde Arabe

As previously mentioned, responsiveness does not need to be accomplished merely through computational authority. The notion can be applied to the field of architecture, by means of structure and environment through various ways. The south façade of the *Institut du Monde Arabe* in Paris built in 1987 and designed by Jean Nouvel is created with the idea of combining the need of sunlight control with a typical Islamic pattern called mashrabiyas.

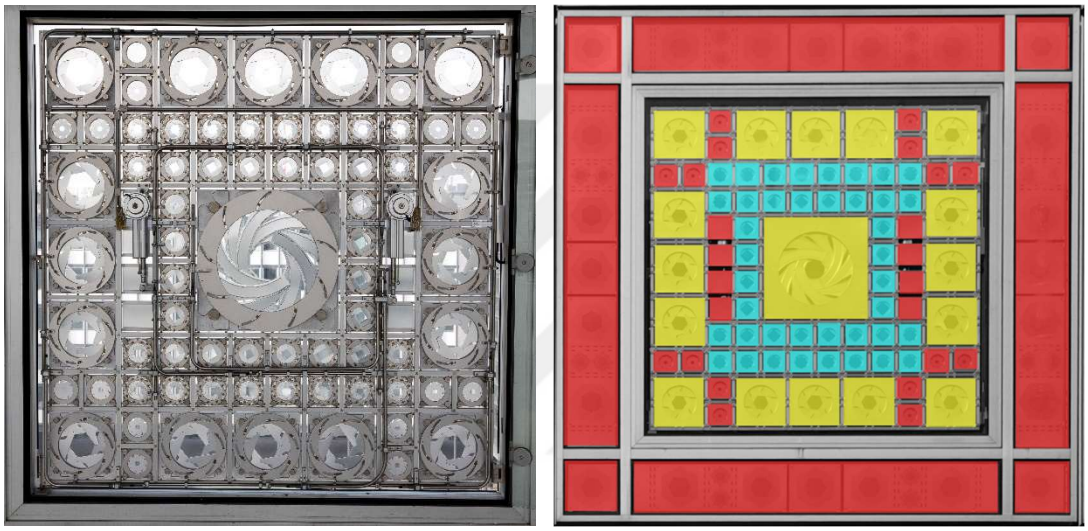


Figure 2.4: One of the Apertures and the diagram of different diaphragms

Source: Meagher, Mark. "Designing for Change: The Poetic Potential of Responsive Architecture". Frontiers of Architectural Research, 159 165, issue 4, 2015 and Institut du Monde Arabe website: https://www.imarabe.org/en/architecture

The aim of the façade is to show the combination of French and Arab culture to the region by integration of aesthetics into kinetics. The system consists of 240 mashrabiyas, which are "*a type of oriel window enclosed in carved wooden*

latticework"[36], half of which are composed of mobile apertures with operable light sensitive diaphragms, dilating according to outdoor light conditions (Figure 2.5). The 27,000 diaphragms that constitute the south façade mechanism can be examined in three groups (Figure 2.4). Each panel has 73 diaphragms but only 57 of them have the ability of motion and the moveable diaphragms have two different sizes. Each of the moveable diaphragms are controlled by actuators and also have their own light sensors.[37]

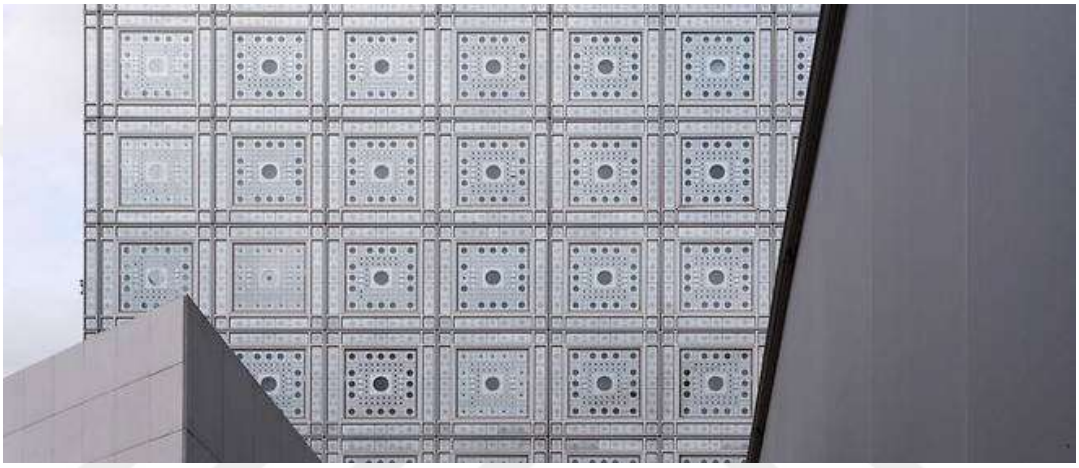


Figure 2.5: South Façade of Institut du Monde Arabe

Source: LePoint, retrieved from https://bit.ly/3cfEdmI

The complexity of the system led to serious mechanical issues and the 27,000 light-sensitive diaphragms required constant maintenance.[38] Responsive mechanism started to lose its functionality within three years and stopped operating in six years.[39]

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[36] Ashour, A. F. "Islamic Architectural Heritage: Mashrabiya," WIT Transactions on the Built Environment 177 (2018).

[37] Meagher, M. "Designing for Change: The Poetic Potential of Responsive Architecture". Frontiers of Architectural Research, 159 165, issue 4, 2015

[38] Hraska, J. "Adaptive Solar Shading of Buildings", International Review of Applied Sciences and Engineering 9, December 2018.

[39] Meagher, M. "Designing for Change: The Poetic Potential of Responsive Architecture". Frontiers of Architectural Research, 159 165, issue 4, 2015

2.2.2 Muscle Re-Configured

As another computer aided responsive design, Muscle Re-Configured exhibited at the Centre Pompidou curated by Zeynep Mennan and Frédéric Migayrou as part of the "Architectures Non Standard" exhibition in 2004, specifically aimed to materialize the "Muscle NSA" project by ONL (Oosterhuis_Lénárd) as an evolved, real time responsive version of it[40]. The prototype uses actuating components called *Pneumatic Fluidic Muscles* from Festo and the aim is to emphasize the internal spatial responsive capacity[41]. Muscle Re-Configured is considered as a "3D habitable strip"[42] – an interior space which acts as a responsive unit through sensing, processing and actuating – main phases of the network that facilitates the communication. "Hylite Panels", which are composite panels, each joined with two fluidic muscles to form the units, were used in order to construct the envelope (Figure 2.6) and the prototype is established as a unity of architectural design, computation, control and pneumatic systems. These panels enable the flexibility aspect for the envelope by linear compression and bending properties of the fluidic muscles. (Figure 2.7) Junction of these panels acts as nodes and these interdependent nodes utilize the data collected by sensors to reform and reshape the envelope. The interaction of the prototype has three phases. First, the prototype measures the proximity of the participants through its proximity and touch sensors. Secondly, the processing is being made with the help of computation in order to provide an output and as a final step, the actuator components, Pneumatic Fluidic Muscles provide response by shifting its shape according to the proximity and the behavior of the participants[43]. Although the pre-deformed shape of the strip captures the image of a

[40] Architectures Non Standard, 2004, Centre Pompidou, Paris, France

[41] Biloria, N. "Spatializing Real Time Interactive Environments in 1st International Conference on Tangible and Embedded Interaction", USA, February 2007

[42] Biloria, N. "Interactive morphologies: An investigation into integrated nodal networks and embedded computation processes for developing real-time responsive spatial systems"

[43] Ibid.

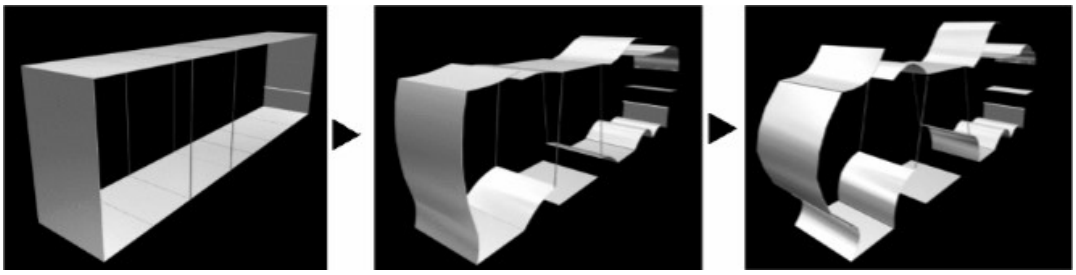

Figure 2.6: Muscle Re-Configured soft models (3D habitable strip)

Source: Biloria, N. "Spatializing Real Time Interactive Environments in 1st International Conference on Tangible and Embedded Interaction"

Figure 2.7: Muscle Re-Configured being tested for shape variations

Source: Biloria, N. "Interactive Morphologies: An Investigation into Integrated Nodal Networks and Embedded Computation Processes for Developing Real-Time Responsive Spatial Systems"

simple floor, wall and ceiling, the 3D strip acts as a closed loop which constantly configures the response given to the parameters provided by occupants. [44]

This installation has significant value while assessing the behavioral aspect that this study focuses on. By means of relation through spatial conformations, Muscle Re-Configured flashes on the pathway of understanding how mutating the occupied space is possible. Whether the occupant is a human, a crowd, or simply an object which applies pressure to the surface, the envelope itself re-configures the defined area and shows behavioral approach by reacting to the given parameter. Therefore, Muscle Re-Configured is a three-dimensional space which defines itself through behavior.

2.2.3 Dune 4.2

Dune 4.2 is a public interactive landscape designed by Daan Roosegaarde in 2009 besides the Maas River in Rotterdam, Netherlands. As the successor of Dune 4.0 which is also created by the same artist in 2006, Dune 4.2 embodies the same principles as its ancestor. It is designed as a responsive landscape, a fusion of nature and technology consisting of artificial marram grass, which pulsates through sound and movement created by the bodies existing in the same environment.[45] The main aim of this installation was to create a pathway which can be experienced as a "walk of light" (Figure 2.8 & 2.9) that responds accordingly to the volume of sound and movement[46]. To elaborate, Dune 4.2 resonates light as much as the volume caused by a person. Each led unit has its own sensor and the installation creates the illusion of "following" for the participant passing by. The 60 meters long interactive

[44] Biloria, N. "Interactive morphologies: An investigation into integrated nodal networks and embedded computation processes for developing real-time responsive spatial systems"

[45] BKOR - Visual Art & Public Space Rotterdam, https://www.bkor.nl/en/beelden/duin-4-2/

[46] Studio Roosegaarde. Dune 4.2, https://bit.ly/2ukmJQf

landscape is consisting of hundreds of fibers, steel, sensors, speakers, software and other media.

Figure 2.8 - 2.9: Dune 4.2

Source: Studio Roosegaarde. Dune 4.2, retrieved from https://bit.ly/2ukmJQf

This example illustrates how the responsive element introduced to the natural environment can alter the perception and the experience on a human scale. Rather than more conventional responsive cases which mainly focus on adapting according to natural parameters such as temperature, humidity and light control, this example illustrates the behavioral relation between the human and the environment. By taking a simple daily life routine such as walking, Roosegaarde emphasized the response of the environment via sensors, speakers and LED lights and converted this routine into a dialogue. The environment responds to people with mirror-like states. If hikers are fast and loud, Dune 4.2 "roars" as an answer to them with light and sound. The same mirroring behavior can also be encountered with rather calm attitude, if the sea next to the installation is tranquil, Dune 4.2 sparkles according to the movement and the sound caused by the tide.

This installation was dismantled in February 2013 after four years of testing period.[47]

[47] BKOR - Visual Art & Public Space Rotterdam, https://www.bkor.nl/en/beelden/duin-4-2/

2.2.4 Pop-Up Interactive Apartment

The aim of Robotic Building Lab of TU Delft students under the leadership of Henriette Bier was to scrutinize the effects of increasing number of human populations living in cities due to growing urbanization. This growth eventually leads to drastic decrease of area per person and the utilization of area is becoming more critical. The project which took place between 2021 and 2022 was determined as a 50 m^2 apartment which aims to respond the functional needs of the area by ever adapting and constantly changing with aiming to avoid the waste of valuable space.[48]

Materials that are used in this project are recycled wood, recyclable thermoplastic elastomers and biopolymers based on wood. To enable users to personalize the operation and use of the furniture, smart operation is done by integrating sensor-actuators such as light-dependent resistors, infrared distance sensors, pressure sensors, and so on to inform building components, lights, speakers and ventilators.[49] The panels that are used in the project can transform into walls, chairs, beds, and a desk by sliding over rails. A wide range of spatial arrangements are feasible; bedrooms that aren't used during the day can be converted into a working area or a sizable living room; the space is decided solely by the needs of the user.[50] (Figures 2.10 & 2.11) Via this transformational design, the perception of space, even one of the basic terminologies belonging to architecture - room is being altered drastically.

[48] DesignBoom, TU Delft, https://bit.ly/3crT0uM

[49] Adaptive Environments, Cyber-Physical Furniture. https://adaptive environments.eu/project/cyber-physical-urban-furniture/

[50] DesignBoom, TU Delft, https://bit.ly/3crT0uM

Figure 2.10: Scenario in afternoon as a large living room

Figure 2.11: Scenario at night with separate sleeping rooms

Source: DesignBoom & TU Delft, retrieved from https://bit.ly/3crT0uM

2.3 A Discussion of the First Set of Cases

Starting from 1987 to 2022, each presented example of responsive application carries significance by its motivation, the intention of its designer(s) and its participation to the literature. To begin with, the Institut du Monde Arabe by Jean Nouvel is one of the most renowned examples of responsive architecture and has been groundbreaking in its time. It is a classic example of a responsive system with a certain purpose that is aimed to be met with a mechanical solution. However, as stated previously, the responsive façade of the Institut du Monde Arabe stopped functioning in six years after being built.[51] Maintenance schedule was not conceived when designing the responsive façade and operational issues emerged (Figure 2.12).

Figure 2.12: Damage on the motor force transmitting arm of the diaphragm actuation mechanism

Source: Mark Meagher, "Responsive Architecture and the Problem of Obsolescence"

Performance discrepancies between design intent and measured performance are frequently found in responsive façades.[52] This might be largely ascribed to the nature of them. There was no back-up system planned for this responsive body, and this causes unpredictability and fragility between design and the application of the

[51] Meagher, M. "Designing for Change: The Poetic Potential of Responsive Architecture". Frontiers of Architectural Research, 159 165, issue 4, 2015

[52] Attia, S. et al. "Adaptive Façades System Assessment: An initial review." In Advanced Building Skins, 1265-1273. Munich, Germany: 978-3-98120538-1, 2015.

façade. Similar to the idea of creating "control" on units as mentioned in Section 2.2, the control of the diaphragms -which are complex and in high quantity- requires extreme considerations and would require many parameters in such an example, rendering a mechanical solution as not reasonable.

The second case, Muscle Re-Configured, demonstrates how mutating the occupied space is possible by means of behavioral aspect. Whether the occupant is a human, a crowd, or simply an object that triggers the proximity sensors or applies pressure to the surface, the envelope itself re-configures the defined area and exhibits a behavioral approach. Conceived to reveal internal spatial responsive capacity[53], the strip defines itself and its borders according to the introduced parameters. By doing so, Muscle Re-Configured identifies itself as a three-dimensional space according to the participants behavior and becomes a hybrid of bodies, human and space.

The importance of the third case, Dune 4.2 by Daan Roosegaarde is that it purely seeks to investigate the relation established between nature and human. With no need for accomplishing or simplifying any daily life routine for people, Dune 4.2 introduces an environment which is intertwined with sensory devices, and it is a fusion of nature and technology. By altering the environment, the installation changes the perspective of how a person senses and experiences walking, which is a very fundamental part of daily life. Through the responsive landscape, the experience of walking becomes unpredictable in this altered area. Similar to Muscle Re-Configured, where the area is defined by the participant and the boundaries between the units are blurred, Dune 4.2 offers a similar approach by connecting the perception of the environment to the behavior of the participants. In case of such alteration, the state of the environment is tied to the participants and the units are perceived as one body.

[53] Biloria, N. "Spatializing Real Time Interactive Environments in 1st International Conference on Tangible and Embedded Interaction", USA, February 2007

As a very up to date example, Pop-Up Interactive Apartment project by the Robotic Building Lab of TU Delft is a fully adaptable and a dynamic space with the aim to maximize the potential of the free area utilization. Through the sensory units and the cyber systems, all of the 50-meter square can be altered, and the floor plan can be chosen among the provided options through the needs of the user and according to the time of the day.

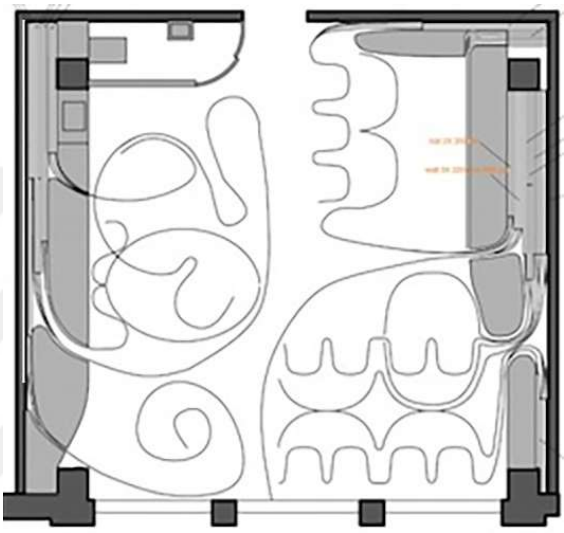

Figure 2.13: Conventional floor plan

Figure 2.14: Floor plan of Pop-Up Interactive Apartment

Source: Retrieved from https://bit.ly/3BeoFbY and Life Edited, retrieved from https://bit.ly/3TZhbBX

This maximization of the space utilization created a division: the conventional floor plan of an apartment unit shifted to the unknown, irregular, rather curved, childlike doodle. By leaving the grammar that architecture education covers, this unreadable floor plan of Pop-Up Interactive Apartment project is psychologically challenging since it lacks a certain quality of order. Moreover, turning back to the early modern era and the failed attempts of fully electric houses, it would be realistic to foresee the

failure of the full automation of domestic space. When considering the Institut du Monde Arabe and the solution which was brought to the responsive façade, the iconic example also illuminates the future of this project; in such cases where many parameters are considered and complex mechanical systems are included, the maintenance phase should be carefully conceived as well to discover the potential of space utilization and understanding what responsiveness offers on this particular example.

CHAPTER 3

UNVEILING THE STANCE OF RESPONSIVENESS WITH REGARD TO MACHINE VERSUS MECHANISM

Since its emergence, the notion of responsiveness has been interpreted extensively by intellectuals from several fields. Started as a "mechanism" that responds to people's needs, the notion of responsiveness has changed through contemporary approaches towards responsive machines by utilizing sensor-network technologies and computing strategies. The notion of responsiveness has thus evolved into a new understanding of the relation between the human and the machine. Therefore, a re-conceptualization of the term responsiveness is essential. This reconceptualization does not place the human and the machine as independent entities, but rather, emphasizes the interwoven and mutually interactive state of both parties. It seems important to focus on the definitions of both "machine" and "mechanism" in order to comprehend the altered use of such bodies throughout the process.

Practices on responsiveness in the early 2000s employed machines to establish the causal connection between various system components, people, and the environment. These machines' interrelated components made it easier for activities like sensing, processing, and actuation to take place, which previously defined the responsive quality of the environment. However, in the modern practice of architectural design, differing ideas about machines and the potential that the crossing of such ideas offer in responsive bodies may result in diverse experiences. When considering responsive bodies, the distinction between machine and mechanism needs to be analyzed thoroughly. Rather than adjusting a façade of the building according to the volume of light as explained in the example of Institut du Monde Arabe, architects and developers mainly focus on AI implementations

through using computer aided systems in order to provide the ability to respond to certain situations. However, a "kinetic response" or an "internal response" without the authority of computation should also be counted as a responsive system. To illustrate, the aim of the Smart Shade proposal made by Lance Hosey in 2005 is to control the sunlight permeability by making use of the different thermal tendencies of different materials[54]. The blinds are composed of zinc and steel, and they expand and contract according to the heat caused by the sunlight (Figure 3.1). As an internal response of the material, the sunlight that penetrates through the blind is being controlled with this proposal. That advanced internal response quality of such system which was accomplished through thermal characteristics of materials can also be provided simply by a hinged mechanism used in a façade which moves according to the direction of the wind. On a different setting considering the employment of wind power, "Strandbeest" is created as a kinetic sculpture by Theo Jansen, in which the wind is determined as the driving force of the mechanism. (Figure 3.2).

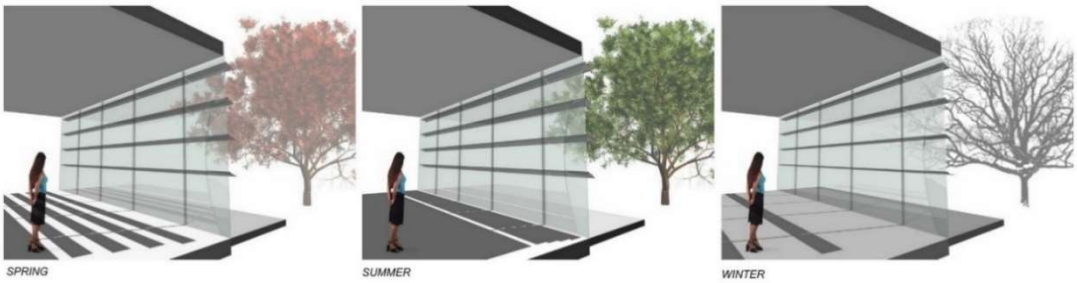

Figure 3.1: Smart Shade in Three Different Seasons

Source: Metropolismag. "Living, Breathing Buildings: Envisioning Architecture that Performs Like Natural Organisms", Retrieved from https://bit.ly/2WgfjJp on May, 2020.

"Cityhome", a gesture-based home automation system developed by the MIT Media Lab, in which case responsiveness is achieved based on computation, is an example

[54] Metropolismag. "Living, Breathing Buildings: Envisioning Architecture that Performs Like Natural Organisms", Retrieved from https://bit.ly/2WgfjJp on May, 2020

where the participant is taught to interact with the environment by making some pre-introduced gestures[55]. To elaborate, to activate the drawers, the user makes “push” or “pull” gestures (Figure 3.3).

Figure 3.2: Bruchus Primus **Figure 3.3:** Cityhome

Source: Bruchus Primus. retrieved from https://bit.ly/3LlivLs

An, Yijing. Exploring an Intelligent Responsive Architecture Through Gesture-based Interaction. The University of North Carolina, 2019

The movement of the participant is sensed, processed, recognized and actuated by the machine composed of various algorithms[56]. Both examples are considered as responsive. However, the significant difference between them is the involvement of the human. One of the responsive bodies, Cityhome, is designed as an environment to answer the needs of the user based on a pre-determined language composed of gestures, created in between the participants of the environment, the human and the machine. This determined language can be altered and developed through the needs,

[55] An, Y. “Exploring an Intelligent Responsive Architecture Through Gesture-based Interaction”. The University of North Carolina, 2019

[56] Ibid.

and new responses can be accomplished within the system. Therefore, when a pre-determined certain movement is introduced to the machine, Cityhome gives the anticipated response. Distinctively, Strandbeest is conceived as a mechanism, designed with the purpose to move in the presence of wind with no specific limits defined for the response determined in between two entities. The parameters of the response by means of direction, amount and stability is not identified, leaving only the response of "movement" as a result.

The background and the emergence of the term "responsive architecture" was introduced in Chapter 2, presenting diverse applications to emphasize the different perceptions on the notion. This chapter aims to examine the utilization of "machine" and "mechanism" terminologies in diverse fields and to distinguish between them in the case of responsiveness. By doing so, the thesis aims to emphasize the potential this difference offers in the transformation of the notion of responsiveness.

3.1 Mechanism and Machine: Definitions and Distinctions

Throughout time, machine and mechanism theories remained on the agenda of literature and have been thoroughly studied by scientists, philosophers, engineers and academics of various research fields. The emphasis in this study is on the accurate utilization of such terms in the field of responsiveness. The meaning of responsiveness is also perceived diversely since the emergence of the term and is still evolving. Looking back to one of the previous and relatively primitive conception of a responsive system, it is defined as a mechanism that provides output according to the provided input. To better understand the notion with the provided aspects, the use of mechanism/machine in the field will be scrutinized in this study.

There are three well known milestone conceptions while discussing the theory of mechanism: To put in order chronologically: philosophers Peter Machamer, Lindley Darden and Carl Craver defined mechanism as "…entities and activities organized such that they are productive of regular changes from start or set-up to finish or

termination conditions."[57] The definition made by Professor of philosophy Stuart Glennan emphasizes the behavioral aspect of a mechanism, by stating that "a mechanism underlying a behavior is a complex system which produces that behavior by the interaction of a number of parts according to direct causal laws."[58] Additionally, he suggests that what mechanism does is its behavior.[59] Lastly, according to Bechtel and Abrahamsen, a mechanism is defined as a structure performing a function in relation with the quality of the parts, operations and organization of that structure. They stated that "the orchestrated functioning of the mechanism is responsible for one or more phenomena."[60] To explain further, the definition suggests that phenomena are produced by the breakdown and reorganization of the things pertinent to the phenomenon.[61] Comparing these definitions, mechanisms should not be defined either as structures as Bechtel and Abrahamsen state, nor as systems as Glennan suggests. The terminology of "structure" offers the quality of inflexibility which is not applicable for mechanisms; however, mechanisms can also not be classified as "system" since the concept suggests a level of internal consistency that not all mechanisms exhibit.[62]

More recent descriptions made for responsive bodies refer to the arrangement of machines and the causal relationships established with the parts of the assembled

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[57] Illari, Phyllis & Williamson, Jon. 2011. "What is a mechanism? Thinking about mechanisms across the sciences". European Journal for Philosophy of Science. 2. 119-135. 10.1007/s13194-011-0038-2.

[58] Glennan, S. "Mechanisms and the Nature of Causation." Erkenntnis (1975-), vol. 44, no. 1, 1996, pp. 49–71. JSTOR, http://www.jstor.org/stable/20012673. Accessed 14 Sep. 2022.

[59] Ibid.

[60] Ibid.

[61] Uçar, B. "An Inquiry into the Ontology of Responsiveness: Assessing Embodiment and Human-Machine Interaction in Responsive Environments", PhD. diss., Middle East Technical University, September 2011

[62] Illari, Phyllis & Williamson, Jon. (2011). "What is a mechanism? Thinking about mechanisms across the sciences." European Journal for Philosophy of Science. 2. 119-135. 10.1007/s13194-011-0038-2.

system, the human and the environment. Various approaches were made to define what a machine is, whether with an architectural, mechanical, or philosophical perception. Comparing these multiple perspectives and their implications on responsive bodies may reveal the true potential of the altered conception of the environment and the relation between the participatory units. Franz Reuleaux, who was a German mechanical engineer, famous with his significant work *The Kinematics of Machinery: Outlines of a Theory of Machines,* developed a theory which suggested that a machine is a kinematic chain of elementary links called "kinematic pairs"[63]. Renowned as the "father of kinematics"[64] he claimed that a machine is "a combination of resistant bodies so arranged that by their means the mechanical forces of nature can be compelled to do work accompanied by certain determinate motions."[65] According to Reuleaux, the term "machine" refers to a system that uses the mechanism(s) of its individual parts to displace an applied force and perform work to transform an energy input into an energy output.[66] Lewis Mumford elaborates on this concept in *The Myth of the Machine* by stating that a machine is "a combination of resistant parts, each specialized in function, operating under human control, to utilize energy and perform work." For Mumford, "The machine was a counterfeit of nature, nature analyzed, regulated, narrowed, controlled by the mind of men."[67] These definitions made by both Reuleaux and Mumford are not independent from the cultural and technological advancements and are closely related to the social conditions of their time. Specifically in Mumford's approach, the machine is conceived as a social formation inspired by Karl Marx.[68]

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[63] Militello, G. et al. "Structural and Organisational Conditions for being a Machine". Biol Philos 33, 35 (2018). https://doi.org/10.1007/s10539-018-9645-z

[64] Moon , F. C. (March 4, 2003). "Franz Reuleaux: Contributions to 19th century kinematics and theory of machines ." ASME. Appl. Mech. Rev. March 2003; 56(2): 261–285.

[65] Reuleaux, F. 2015. "Kinematics of Machinery". Arkose Press. p. 35

[66] Ibid.

[67] Mumford, L., 2020. "Technics and Civilization". The University of Chicago Press, p.52.

[68] Ibid. pp. 110-111

Putting more focus on scientific aspects, the machine is also defined as "an assemblage of moving parts, constructed for the purpose of transmitting motion or force, and of modifying, in various ways, the motion or force transmitted" by T. M. Goodeve, in his book *The Elements of Mechanism*.[69]. Mechanical engineer and architectural historian Robert Willis stated that machines are "to consist of a train of pieces connected together in various ways, so that if one be made to move, they all receive a motion, the relation of which to that of the first is governed by the nature of the connection."[70]

While machine is generally defined with its characteristic of multiplicity- being described as "a combination", "an assemblage" and so on-, mechanism is generally indicated with its "order" with descriptive terms used such as "orchestrated function", "regularity" and "causality". These definitions also highlight that during the utilization of machine, the components that establish the system can be organized in various ways since the conceptions of machine constantly emphasize the variety of arrangements and the possibilities that may emerge with a modification of the plannings.

As stated previously, these approaches towards machine and mechanism exhibit a certain diversity by means of flexibility for both terms. While machine presents a rather adaptable quality, mechanism is regarded as a frozen, stiff version of a machine, embedded with a mission to accomplish a specific task. Regarding responsiveness in architecture, previous conceptions that were made in order to schematize responsive systems were describing the performance of sensory networks as such: there were three main phases of the network that enables communication - response- which are sensing, processing and actuating[71]. In the case of mechanic

[69] Goodeve, T., 2017. "The Elements of Mechanism". 4th ed. hansebooks.

[70] Willis, R., 1841. "Principles of Mechanism". Oxford University, p.4.

[71] Uçar, B. "An Inquiry into the Ontology of Responsiveness: Assessing Embodiment and Human-Machine Interaction in Responsive Environments", PhD. diss., Middle East Technical University, September 2011

response, either system components, environment or human as participants provide a previously introduced input and the mechanism offers an output according to that input as a result. In most cases of mechanic response, presented output by the mechanism is equivalent of a function. In case of a machine response, provided input is processed by the controlling algorithm, the causal connections are made due to previously introduced parameters and the machine produces output as a response towards the provided input. If the algorithm changes, parameters are altered or the limitations are removed, hence the flexibility provided by the machine components creates a potential of mutability on the possible output. Since the presence of a controlling algorithm - or AI in the more recent and developed examples- is mandatory in machines, "processing" is inclusive in the machine response. This ability of being adaptive which is introduced to the responsiveness through the utilization of machine and along with the advancements in the technological field will be discussed in this present study under the concept of liveliness. The previously conceived equation of "output provided in response to an input" is seen to be replaced with a more holistic approach which is inclusive with what this thesis scrutinizes by means of liveliness and expression of behavior. The notion of "behavior", which is an imperative component while reconceptualizing responsiveness will partake in Chapter 4, along with the concept of "liveliness", while focusing on the inevitable transformation of the notion.

3.2 Deleuzian Idea of the Machine and the Rhizome

Gilles Deleuze considered himself as a part of a philosophical tradition that attacked and overturned society in order to provide new opportunities for practice and action.[72] According to Deleuze and Félix Guattari, every aspect of existence involves connections and interactions. Any object or body is the result of a series of "*assemblages*": A human body is an assemblage of genetic substance, thoughts,

[72] Colebrook, C., 2002. "Understanding Deleuze", Allen & Unwin, p. 11

acting abilities, and relationships with other bodies "passing from one to the other, opening one onto the other, outside any fixed order or determined sequence."[73] Instead of using the terms as organs and mechanics, Deleuze and Guattari used the term "machinic" in order to avoid pre-established connections to discover the potential of ever connecting notions. To illustrate, they described the organs as machines that are "plugged into an energy-source machine: the one produces a flow that the other interrupts." [74]

> "There is no such thing as either man or nature now, only a process that produces the one within the other and couples the machines together. Producing-machines, desiring-machines everywhere, schizophrenic machines, all of species life: the self and the non-self, outside and inside, no longer have any meaning whatsoever."[75]

The concept of the "machine", which was investigated thoroughly in Section 3.1 presents itself intensely in the studies of Deleuze and Guattari. They differentiate "machine" from "assemblage" as such: "a machine is like a set of cutting edges that insert themselves into the assemblage undergoing deterritorialization, and draw variations and mutations of it."[76] Furthermore, the philosophers indicated that the existence of "mechanical effect" is a hollow term since the effects created are machinic themselves: In their book *A Thousand Plateaus,* these effects are defined as machinic statements that define consistency. This dependence on machine creates "deterritorialization" as they call it, which unbounds itself and establishes new

[73] Deleuze, G., Guattari, F., 1980. "A Thousand Plateaus: Capitalism and Schizophrenia", University of Minnesota Press Minneapolis. p. 347

[74] Deleuze, G., Guattari, F., 1977. "Anti-Oedipus: Capitalism and Schizophrenia". Viking Press. p. 9

[75] Ibid.

[76] Deleuze, G., Guattari, F., 1980. "A Thousand Plateaus: Capitalism and Schizophrenia", University of Minnesota Press Minneapolis. pp. 333-334

connections which have the quality of variety: “Machines are always singular keys that open or close an assemblage, a territory.”[77]

To emphasize the distinction made in Section 3.1: a mechanism, according to their definition, is a self-contained movement that moves steadily, which never changes or creates new connections. A closed machine with a single purpose is a mechanism.[78] A self-contained organism like the human body -excluding the cognitive capacity- can be given as an example of a closed machine. The definition of organism itself is also similar; it is a bounded whole with a beginning and an end. These closed machines are thought of as mechanisms rather than actual machines.[79]

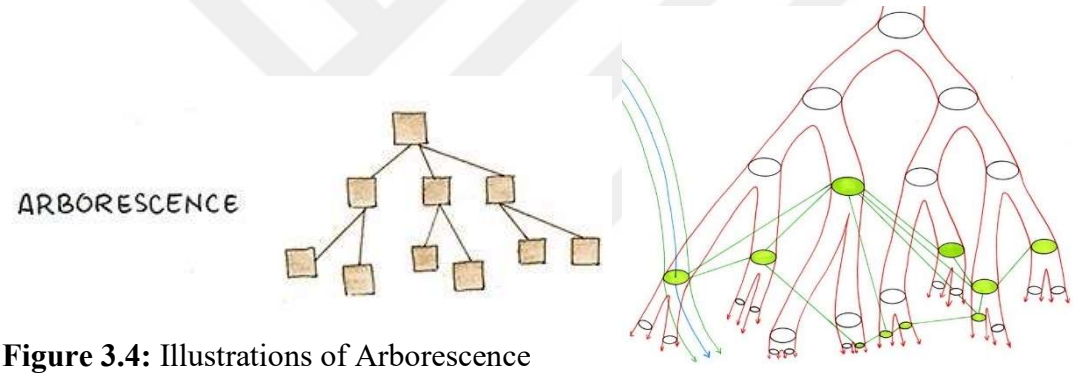

Figure 3.4: Illustrations of Arborescence

Source: Marc Ngui, retrieved from https://bit.ly/3eVQRJ9 and https://bit.ly/3qIi6cu

[77] Ibid.

[78] Deleuze, G., Guattari, F., 1977. “Anti-Oedipus: Capitalism and Schizophrenia”, Viking Press. p. 67

[79] Colebrook, C., 2002. “Gilles Deleuze”, Routledge, pp. 55-57

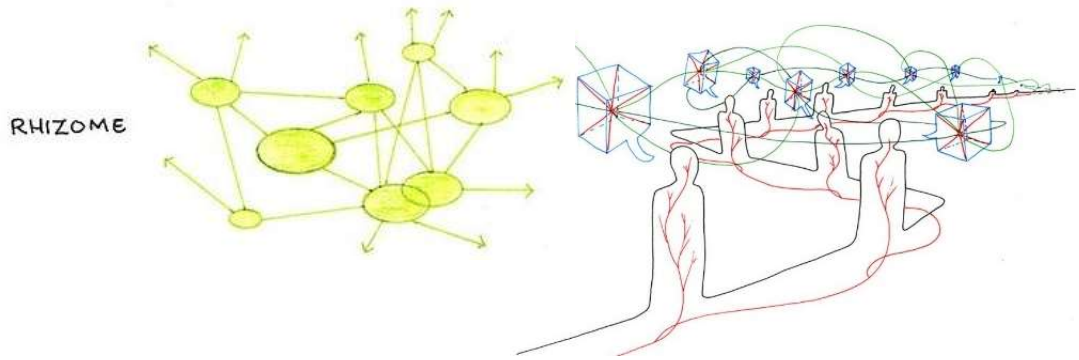

Figure 3.5: Illustrations of Rhizome

Source: Marc Ngui, retrieved from https://bit.ly/3eVQRJ9 and https://bit.ly/3dg96bL

For Deleuze and Guattari, unlike a mechanism, a machine does not have a closed identity. Instead of producing something dictated, production is created just for the sake of production itself.[80] Deleuzian thinking suggests that concepts of human, non-human and machine are equal. According to Deleuze, being a machine is about its connections; "it is not made by anything, is not for anything and has no closed identity."[81] The reason machines make new connections to what is not itself is to maximize themselves and to transform[82]. Mechanism and machine distinction can also be exhibited with the terminologies of *rhizome* and *arborescent* that Deleuze and Guattari introduced in their book *A Thousand Plateaus*. Originally French, the term arborescence represents a "tree-like" structure (Figure 3.4), expressing a hierarchical order in which every being has a seed, and this seed produces a unified trunk, subordinate branches, and the leaves.[83] Regarding this structure, they express: "We're tired of trees. We should stop believing in trees, roots, and radicles. They've

[80] Ibid.

[81] Ibid.

[82] Ibid.

[83] Colebrook, C., 2002. "Understanding Deleuze", Allen & Unwin, p. 76-77

made us suffer too much. All of arborescent culture is founded on them, from biology to linguistics."[84]

Deleuze and Guattari suggest that the seed in the arborescent structure represents the "image of thought"[85], and this creates a barrier in the path to discover the potential that is only available by making new connections. The number of connections that can be made in the arborescent structure is limited and therefore, it is rather infertile. Deleuze explains it as such: "In a hierarchical system, an individual has only one active neighbor, his or her hierarchical superior.... The channels of transmission are preestablished: the arborescent system preexists the individual, who is integrated into it at an allotted place."[86] If the equation would be conceived for the responsive bodies using the presented terminologies, the "image of thought", which is the seed for the arborescent structure would be equal to the driving force, the purpose of the mechanism. When the instrument to function is removed from the equation, the meaning is lost, and the latter units that come after the function (seed), are baseless and at a frozen state as Deleuze and Guattari suggest.

Bruchus Primus by Theo Jansen was conceived with the idea of a beast moving with the power of the wind.[87] When the wind is removed from the equation, Bruchus Primus remains at a solid state. Since it is not able to perform efficiently under different circumstances, Bruchus Primus is not able to make new connections with provided parameters by the environment. The potential that it offers is previously defined and established.

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[84] Deleuze, G., Guattari, F., 1980. "A Thousand Plateaus: Capitalism and Schizophrenia", University of Minnesota Press Minneapolis. pp. 15-16

[85] Drummond, J. S., 2005. "The rhizome and the tree: a response to Holmes and Gastaldo". Nursing Philosophy, 6, Blackwell Publishing Ltd, p. 256

[86] Ibid.

[87] Jansen, T., "Strandbeest". Retrieved from https://www.strandbeest.com on 17th of September, 2022

Figure 3.6: Bruchus Primus by Theo Jansen

Source: Domus, retrieved from https://bit.ly/3QKE7lK

Deleuze and Guattari proposed the *rhizome* (Figure 3.5), which is not just a multiplying network of branches but also a chaotic root structure that connects every point to every other point and spreads out to form new directions.[88] The rhizome is one of Deleuze's many figures that describes movement along a single surface, which then stratifies or creates surfaces: no point elevated above any other, and no foundation or surface upon which movement and activity takes place, just movement and activity itself. In contrast, the tree grows upward, suggesting a hierarchical structure with a ground and elevated upper branches.

> "… unlike trees or their roots, the rhizome connects any point to any other point, and its traits are not necessarily linked to traits of the same nature; it brings into play very different regimes of signs, and even nonsign states. The rhizome is reducible neither to the One nor the multiple. …It is composed not of units but of dimensions, or rather directions in motion. It has neither beginning nor end, but

[88] Colebrook, C., 2002. "Understanding Deleuze", Allen & Unwin, p. 77

> always a middle (*milieu*) from which it grows and which it overspills."[89]

The rhizome is made entirely of lines, the lines of segmentarity and stratification serving as its dimensions and the line of flight or deterritorialization serving as the maximum dimension after which the multiplicity undergoes metamorphosis, or changes in nature. In contrast, a structure is defined by a set of points and positions, with binary relations between the points and biunivocal relationships between the positions.[90] Deleuze and Guattari states that, a rhizome is constantly in the center, between things, interbeing, or *intermezzo*;[91] the starting (seed) or the ending point of it is non-distinguishable. While the rhizome creates a unique alliance, the tree (arborescence) is only lineage. The verb "to be" is imposed by the tree, yet the conjunction "and... and... and... and" makes up the rhizome's structure. The verb "to be" is capable of being shaken and uprooted by this conjunction.[92]

The conception made for the machine by Deleuze and Guattari also aligns with the definition of rhizome. Since the *raison d'être* for the machine is to make new connections and to maximize its potential, the developed stage of a machine can also be recognized as a rhizome. The variation ability provided by the controlling algorithm of a machine enables the mutational potential of the output.

Cityhome by MIT Media Lab (Figure 3.7 & Figure 3.8) functions according to the introduced hand gestures and the expected outcome is provided according to those introduced parameters.[93] Since there is no driving force, as in "wind" on the Strandbeest example, Cityhome cannot misplace its characteristic of being a

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[89] Deleuze, G., Guattari, F., 1980. "A Thousand Plateaus: Capitalism and Schizophrenia", University of Minnesota Press Minneapolis. pp. 21-25

[90] Ibid.

[91] Ibid.

[92] Ibid.

[93] An, Y. "Exploring an Intelligent Responsive Architecture Through Gesture-based Interaction". The University of North Carolina, 2019

machine. Previously introduced gestures can be reintroduced, the controlling algorithm can be completely transformed, and these actions will not prevent Cityhome from being a machine. This example by MIT Media Lab expresses a rhizomatic behavior since the removal of introduced inputs cannot harm the functional existence of the machine itself. The algorithm makes it available to produce new connections, and the beginning or the ending point of the Cityhome cannot be distinguished, whether it is examined with a systematic approach considering input and output or examined with a behavioral aspect which will be explained further in Chapter 4.

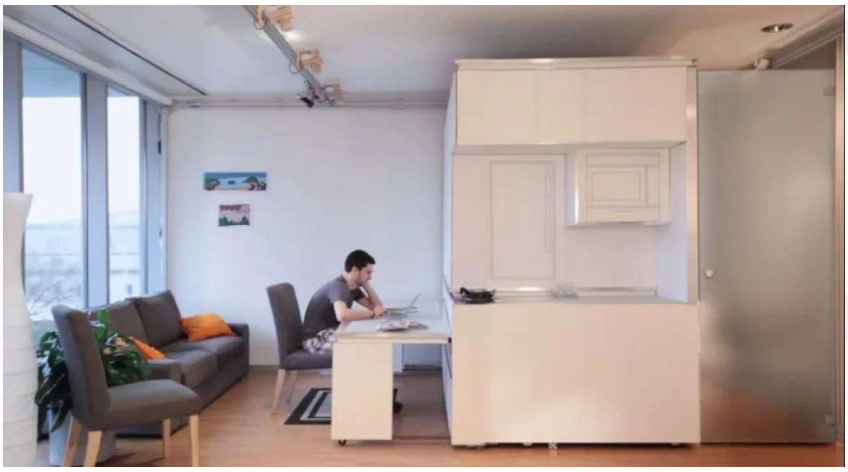

Figure 3.7: Cityhome as an Office

Figure 3.8: Cityhome as a Bedroom

Source: Building Design + Construction, retrieved from https://bit.ly/3qLpYdt

3.3 Negroponte's Architecture Machine

Many influential people like Nicholas Negroponte, Cedric Price and Gordon Pask were interested in the developing field of cybernetics and its applications in architecture throughout the 1960s and 1970s, which was a time

Figure 3.9: The Architecture Machine Group **Figure 3.10:** Nicholas Negroponte (left), K. Katz and S. Gregory at the exhibition of SEEK

Source: Cybetneticzoo, retrieved from https://bit.ly/3BOQf0D

of technological optimism along with the emergence of Industry 3.0.[94] In his concept of "*Architecture Machine*" architect and pioneer of computer-aided design, Negroponte envisioned what a fusion of cybernetics and architecture may produce in the future. Predicted as an intelligent environment that has the ability to learn and adapt over time, such a setting would react intelligently and suitably to its users'

[94] Steenson, M. W., 2014, "Architectures of Information: Christopher Alexander, Cedric Price, and Nicholas Negroponte & MIT's Architecture Machine Group", Volume 1. PhD. diss., Princeton University. p. 160

needs by creating a flexible cognitive model for them. In his published books *The Architecture Machine* and *Soft Architecture Machines*, as well as in essays and reports, Negroponte developed his theory on the practice of architecture machines using ideas from cybernetics and AI. He believed that architectural machines would be widespread in the future and the integration of machine and human would be so increased in density that "they won't help us design; instead, we will live in them."[95]

Most discussions on AI in the 1960s including early 1970s were influenced by Licklider's significant work, "Man-Computer Symbiosis".

> "Man-computer symbiosis is an expected development in cooperative interaction between men and electronic computers. It will involve very close coupling between the human and the electronic members of the partnership. The main aims are
>
> - to let computers facilitate formulative thinking as they now facilitate the solution of formulated problems, and
>
> - to enable men and computers to cooperate in making decisions and controlling complex situations without inflexible dependence on predetermined programs." [96]

Negroponte, influenced by Licklider, suggested that architecture machines were to be symbiotic. In his proposed argument, dissimilar species, processes, and the resulting intelligent systems would unite as associates. He defined symbiosis as "the intimate association of two dissimilar species (man and machine), two dissimilar processes (design and computation), and two intelligent systems (the architect and the architecture machine). By virtue of ascribing intelligence to an artifact or the artificial, the partnership is not one of master and slave but rather of two associates that have a potential and a desire for self-improvement".[97] The conception of

[95] Negroponte, N. "Soft Architecture Machines" (Cambridge, MA: MIT Press, 1975). p. 5

[96] Licklider, J. C. R., 1960, "Man-Computer Symbiosis". IRE Transactions on Human Factors in Electronics, Volume: HFE-1, Issue: 1. p. 4

[97] Negroponte, N. "The Architecture Machine" (Cambridge, MA: MIT Press, 1969). Preface

architecture machine was based on the intelligence of the machine and its cognitive capacity: to learn and adapt through the dialogue between human and the machine itself. He believed that this free-flowing dialogue would not only create a conversation but also a profound relationship between the system and the user. That suggested dialogue was predicted to be intimate[98], so that the context of the established dialogue would be incomprehensible in case if one of the parties would be absent, and the only way to produce ideas was through "mutual persuasion and compromise." [99] This suggested dialogue was specified as equally important as the product of this symbiotic relation. Architectural dialogue was not to be employed to program the design process, instead, the aim was to conceive such an interaction "that shifts between states of goal orientedness and states of playfulness … for the purpose of modelling the user."[100] The main purpose of architecture machine was not learning architecture, it was to learn about the user. Although the result expected was for the architecture machine to build a model of a dwelling for the user, the main aim was to render a model for the user and to produce the model of that user's model simultaneously.[101]

This conception of architecture machine born from the idea of computer integration to architecture is further discussed in Negroponte's book *Soft Architecture Machines*, where he stresses the idea that the machine which would be utilized in the architectural evolution should exhibit intelligent behavior[102]. Furthermore, he defends that "Intelligence is a behavior. It implies the capacity to add to, delete from, and use stored information."[103] The reason that he points out the necessity of the intelligence aspect is that without it, the machine would not be able to comprehend

[98] Ibid. p.13

[99] Ibid.

[100] Negroponte, N., Groisser, L., 1971. "Computer Aids to Participatory Architecture". Cambridge, Mass: Massachusetts Institute of Technology

[101] Ibid.

[102] Negroponte, N. "Soft Architecture Machines" (Cambridge, MA: MIT Press, 1975). p. 33

[103] Negroponte, N. "The Architecture Machine" (Cambridge, MA: MIT Press, 1969). p. 1

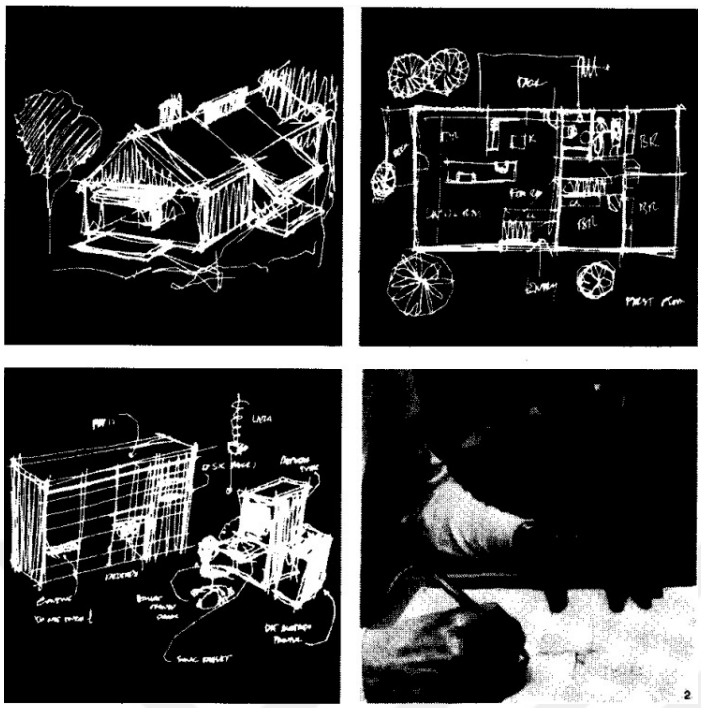

Figure 3.11: Drawings made on the Architecture Machine, to determine personalized drawing habits. Each figure is a computer display of every tenth point recorded by the Sylvania data tablet (bottom right).

Source: Negroponte, N. "From Soft Architecture Machines." The New Media Reader, Cambridge, MA: MIT Press. p. 354

what it would assist.[104] Negroponte suggests a crucial point with the previous elevator example that was given in Chapter 2. The elevator that learns and adapts according to the behavioral patterns of the user(s) stresses a significant point for this study, which is the "model of appropriate behavior."[105] This approach places the controlling algorithm of the machine as an authority in the environment that was meant for the human use.

3.4 Cedric Price's Fun Palace

Approximately ten years before Negroponte came up with the term "responsive architecture", the architect Cedric Price and avant-garde theater producer Joan Littlewood were collaborating on a continually changing recreation facility, the Fun

[104] Negroponte, N. "Soft Architecture Machines" (Cambridge, MA: MIT Press, 1975). p. 33

[105] Ibid. p. 133

Palace. Cedric Price's idea of a responsive, improvisational architecture that could be altered according to the needs and wishes of the user was developed and refined based on Littlewood's vision of a dynamic, interactive theater. Price was more interested in the transitory and diachronically transformable structure of human activity and its implementation on architecture, rather than perceiving buildings as a static cultural symbol: [106] "The Fun Palace will be a playground for people of all ages. If to play is to employ oneself in the satisfaction of curiosity, variety, exploration, imagination, making decisions or attempting new skills, then the "Fun Palace" is a playground."[107]

Price determined that it should not have a definite form or floor plan because Littlewood's conception on Fun Palace did not include a defined program or set of activities. It would never be fully finished, as a matter of fact, in the traditional meaning of the word, it would not even be a building. Instead of creating a traditional structure to house Littlewood's and revolutionary programme, Price started to see a basic framework which the activities may expand and evolve around it.[108]

In his first concept from 1963, Price proposed a system of structural steel grids topped with cranes for the placement of modular components for Fun Palace. He drew a structural exoskeleton that resembled a shipyard and furnished it with mobile gantry cranes to relocate the different parts.[109] Price aimed for a space that could be altered and designed by the user through moving prefabricated building components via cranes. Later, he shared the initial concept for the Fun Palace with structural

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[106] Mathews, J. S., "An Architecture for the New Britain: The Social Vision o f Cedric Price's Fun Palace and Potteries Thinkbelt", PhD. diss., Columbia University, 2003. p. 9

[107] Ibid. p. 105

[108] Lobsinger, M. L., "Cybernetic Theory and the Architecture of Performance: Cedric Price's Fun Palace." Anxious Modernisms: Experimentation in Postwar Architectural Culture, Cambridge: The MIT Press, 2000. pp. 120-122

[109] Mathews, J. S., "An Architecture for the New Britain: The Social Vision o f Cedric Price's Fun Palace and Potteries Thinkbelt", PhD. diss., Columbia University, 2003. pp. 118-120

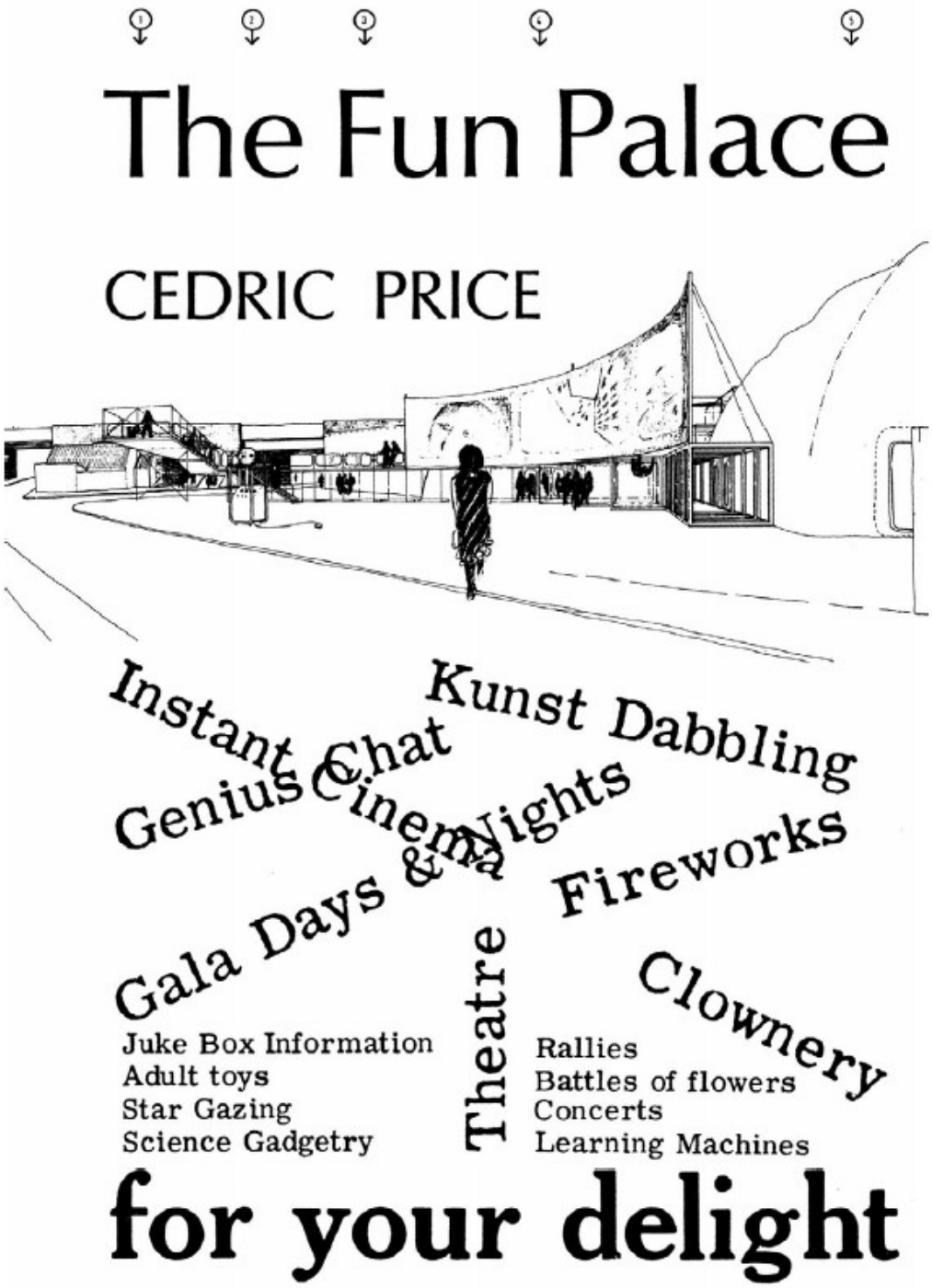

Figure 3.12: Promotional poster of Fun Palace

Source: Price, C., Littlewood, J., "The Fun Palace", The Drama Review: TDR Vol. 12, No. 3, Architecture/Environment (Spring, 1968), pp. 127-134 retrieved from https://www.jstor.org/stable/1144360#metadata_info_tab_contents

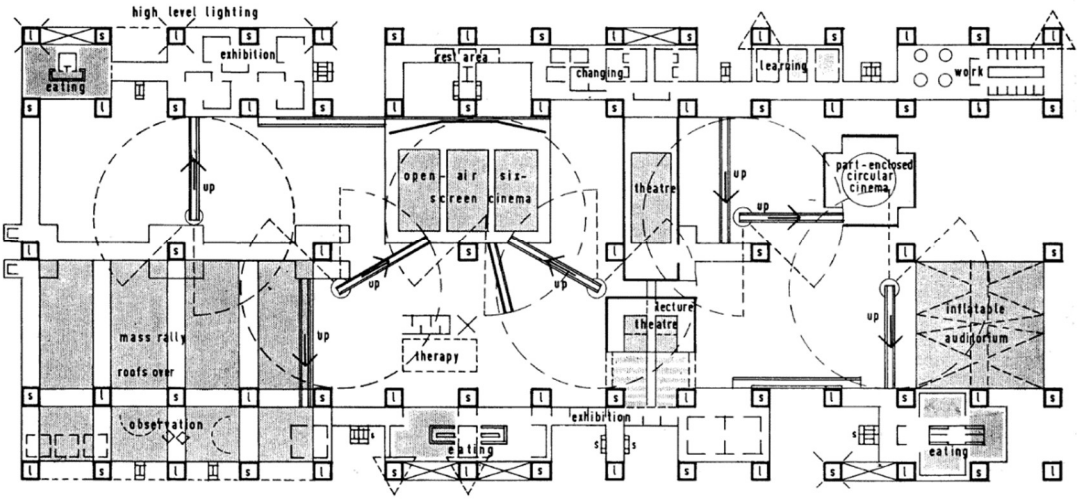

Figure 3.13: Final Plan of Fun Palace, 1963. This plan was developed by Cedric Price and engineer Frank Newby.

Source: Price, C., Littlewood, J., "The Fun Palace", The Drama Review: TDR Vol. 12, No. 3, Architecture/Environment (Spring, 1968), pp. 127-134

quality of the space and the vertical circulation was not planned well enough to allow the required flexibility. Newby suggested a more efficient structural system for the Fun Palace (Figures 3.13 & 3.14) consisting of two sixty-feet (approx. eighteen meters) side aisles neighboring the one hundred twenty-foot-wide (approx. thirty-six meters) central bay, formed by fourteen parallel rows of five fifteen-foot square (approx. one-and-a-half-meter square) service towers, spaced sixty feet (approx. eighteen meters) apart. A pattern of varying-sized interconnecting squares created the concept of the plan which offered both programming flexibility and stability. The square towers housed the mechanical and electrical units while leaving the bays clear of any enduring obstacles. The structural framework for Newby measured seven hundred and eighty feet long (approx. two hundred and forty meters) and three hundred and sixty feet wide (approx. one hundred and ten meters). Using two overhead gantry cranes mounted on tracks and spanning the total of two hundred and

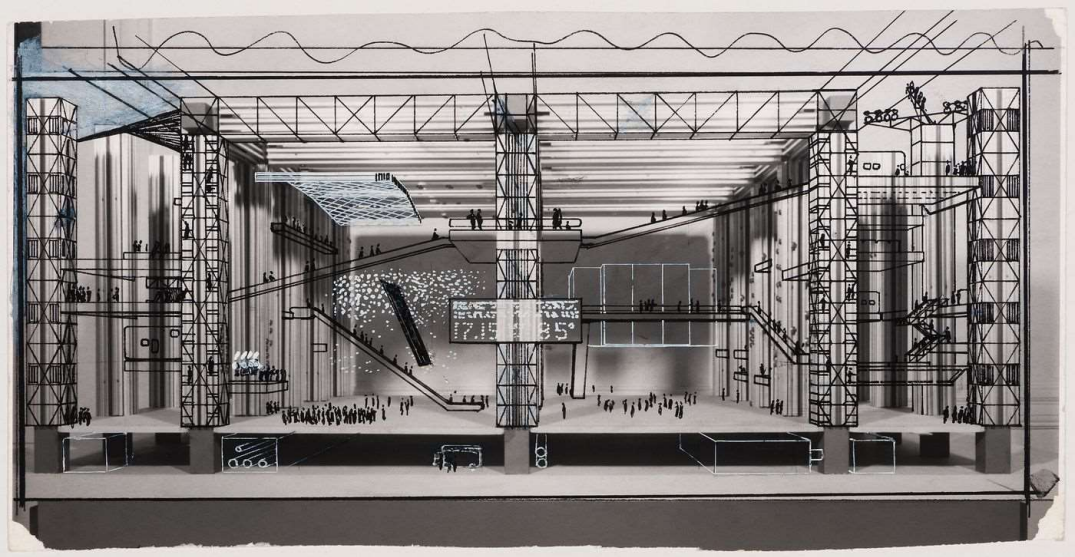

Figure 3.14: Fun Palace: Interior Perspective

Source: Canadian Centre for Architecture, retrieved from https://bit.ly/3drDjoh

forty feet (approx. seventy-two meters) of the two middle bays, it was no longer necessary to move cargo from one crane to another because they could now move along the whole length of the Fun Palace and access any location within.[110] Moving walkways and rotating escalators provided extra circulation in addition to the stair towers.[111] The majority of the center area was covered by a membrane roof that was suspended from a cable grid and had movable sky-blinds above it. Moving construction parts could be hoisted into place by the overhead cranes in the center bays between the roof and the ground level. Moveable decking might be placed in the side aisles as needed for auxiliary use. Plastic and aluminum inflatable standard modular modules that could be placed and moved anywhere inside the overall structure made up the interior structures and components.[112] Almost every

[110] Ibid.

[111] Lobsinger, M. L., "Cybernetic Theory and the Architecture of Performance: Cedric Price's Fun Palace." Anxious Modernisms: Experimentation in Postwar Architectural Culture, Cambridge: The MIT Press, 2000. p. 120

[112] Ibid.

component of the construction was supposed to be flexible, with the main structural frame acting as the only constant component. The bottom floor and the basement were the only "permanent" floors of the structure.[113]

> "It is more than expressive of spatial qualities, formal characteristics or structural necessities; but then, there really isn't much to describe in terms of the architectonic qualities or materiality of Fun Palace since, as Price laconically stated, 'It's a kit of parts, not a building,' adding that he doubted whether it would ever look the same twice."[114]

In order to provide for this dynamic characteristic, Cedric Price and Joan Littlewood included the cybernetician Gordon Pask to the team, who was the head of the British Cybernetics Foundation at that time.[115] Cybernetics was a relatively new notion, which was regarded as a "structural model of interaction between any sentient entities where no distinction was made between machines, animals, or humans."[116] Gordon Pask defined cybernetics as a discipline that derives its interdisciplinary character from perceiving terminologies out of their boundaries: "In each case its theme remains the same, namely, how systems regulate themselves, reproduce themselves, evolve and learn."[117] The potential that cybernetic control systems offer in order to reach the adaptive characteristic Price envisioned for the Fun Palace piqued his curiosity in particular. Price and Pask aimed to employ cybernetics to

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[113] Mathews, J. S., "An Architecture for the New Britain: The Social Vision o f Cedric Price's Fun Palace and Potteries Thinkbelt", PhD. diss., Columbia University, 2003. p. 121

[114] Lobsinger, M. L., "Cedric Price: An Architecture of the Performance." Daidalos 74, 2000. p. 24

[115] Mathews, J. S., "An Architecture for the New Britain: The Social Vision o f Cedric Price's Fun Palace and Potteries Thinkbelt", PhD. diss., Columbia University, 2003. p. 115

[116] Ibid. p. 117.

[117] Pask. G. "An Approach to Cybernetics" Hutchinson, 1968. p. 11

embed Fun Palace with the ability to self-regulate, mutate, and track users' locations, behaviors and actions electronically.[118]

The Fun Palace project, at its eventuality, was never realized. The conceptual project was mostly described as a kit of parts, never to be finished, and would not "last more than ten years, some things not even ten days."[119] Fun Palace had neither a fixed shape nor an underlying purpose in the traditional architectural sense. It was proposed as a "giant learning machine"[120] that aimed to integrate the space with technology and flexibility with the purpose of enabling people to adapt physically and mentally to the intangible experiences.[121] The development of the cybernetic structure of the Fun Palace project eventuated as perceiving human behavior as data for modelling of the utilization of space, therefore predicting the future expectations or to map the patterns of usage.[122]

3.5 Discussion on the Machine

Either perceived as a mechanism or a machine, the responsive quality of a body can be reached with both. Notions are ever-evolving entities, that are being affected from social, cultural and technological status of the time. Responsiveness was achieved via vernacular architecture prior to the emergence of the term "responsive architecture." The distinction between machine and mechanism is significant since

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[118] Lobsinger, M. L., "Cybernetic Theory and the Architecture of Performance: Cedric Price's Fun Palace." Anxious Modernisms: Experimentation in Postwar Architectural Culture, Cambridge: The MIT Press, 2000. p. 138

[119] Littlewood, J. "A Laboratory o f Fun," The New Scientist (May 14, 1964): pp. 432-433.

[120] Lobsinger, M. L., "Cybernetic Theory and the Architecture of Performance: Cedric Price's Fun Palace." Anxious Modernisms: Experimentation in Postwar Architectural Culture, Cambridge: The MIT Press, 2000. p. 126

[121] Ibid.

[122] Ibid. pp. 130-134

the thesis aims to pursue the evolution of the notion of responsiveness through human-machine interaction.

Both Negroponte's Architecture Machine and Cedric Price's Fun Palace are constituted between the 1960s and 1970s, while Deleuze and Guattari published the two volumes of *Capitalism and Schizophrenia* in late 1970s. It is crucial to realize that these people were pioneers in their fields and foresaw the future of human-machine integration and the path that responsive technology would go. Cedric Price's Fun Palace was conceived as "purely utilitarian and purposeful: a mechanical slab served as a provisional stage to be continuously set and reset, sited and resited"[123] but the involvement of cybernetics which was a concept ahead of its time, as well as the Fun Palace itself, led the project to evolve towards a human-machine hybrid, which realizes the human component as data and where machine was an authority, inseparable from the structure or the concept itself.

Distinctively, Negroponte envisioned the future of machine as an identity that not only shares the environment with the human, but further establishing the environment together with the human. He intended for a body where the distinction of human and machine cannot be made. Price, Negroponte and Deleuze represent a farsighted, holistic perception of the machine and the potential of transformational quality of it engenders. The mutual perspective that is being shared by them is that all emphasized the urge to self-improve[124] and the mutational capacity that machine possesses through making connections.[125] In her book, Steenson asserted that Negroponte believed "Such a machine would not only ingratiate itself to its human

[123] Lobsinger, M. L., "Cybernetic Theory and the Architecture of Performance: Cedric Price's Fun Palace." Anxious Modernisms: Experimentation in Postwar Architectural Culture, Cambridge: The MIT Press, 2000. p. 119

[124] "*...the partnership (man and machine) is not one of master and slave but rather of two associates that have a potential and a desire for self improvement.*" Negroponte, N. "The Architecture Machine".

[125] Steenson, M. W., 2017, "Architectural Intelligence: How Designers and Architects Created the Digital Landscape", Cambridge, MA: MIT Press. p. 171

partner by modeling its behavioral and linguistic particularities, it would become something more than either the human or the machine alone."[126]

These approaches, which are highly significant for the history of architecture, philosophy and cognitive sciences, are non-anthropocentric where the human, the non-human and the machine are non-hierarchized. Decentering the human from the general regard where responsiveness is a utility which aims to serve people's needs and to simplify the daily life, the potential that it offers enables the questioning of what a body is, understanding the transformation of the responsive body and the perception of 'behavior'.

[126] Negroponte, N. "Soft Architecture Machines" (Cambridge, MA: MIT Press, 1975). p. 133

CHAPTER 4

TRANSFORMATION THROUGH RELATION

The growth in the accessibility of mobile devices and the public employment of internet usage has led to the evolution of communication beginning with the late 90s. Increasing changes on how the information is processed resulted in the testing of the traditional perceptions of the world's physical and social status. Network technologies started quickly altering the world, redefining the functions of digital information and how people might access it. Effortless and faster information made a significant impact on the rapidity of advancements in technology.

Along with the exponential growth of computing and networking bandwidth, new paradigms of computing have emerged which are beneficial to the architectural field. Innovative technology embedded to the mobile devices and the consumer level prototypes have turned into powerful design tools by revealing the potential for communication and intelligence in everyday places and objects. Conceptual and institutional interest in reimagining "space" as a platform and media has evolved in parallel with such technical advances. The 21st century, along with the stated advancements, has become the period where the promise of infusing physical space with ubiquitous computational intelligence has been kept. Information and communication technology (ICT) has been the driving force behind the transformation of man-made surroundings into "smart" environments that interact with the human through sensors and digital devices.[127]

[127] Lee, J. H. et al., 2018. " Characterizing Smart Environments as Interactive and Collective Platforms: A Review of the Key Behaviors of Responsive Architecture", Sensors 2021, 21(10), 3417, p.2

Nicholas Negroponte, when conceptualizing the utilization of such technology into architecture, envisioned that:

> "The manipulative environment is a passive one, one that is moved as opposed to one that moves. In contrast, responsive, sometimes called adaptable, or reactive, means the environment is taking an active role, initiating to a greater or lesser degree changes as a result and function of complex or simple computations."[128]

The architectural perspective in the 1960s was about searching a new form of space which is flexible and is able to meet the changing demands of its occupants.[129] This attempt to reimagine the space which is capable of providing feedback was the symptom of the emerging notion of responsiveness. The qualities of adaptability and flexibility and the search to obtain those qualities to the recreated image of space called into question the very idea that the human body and architectural space are external to one another, resulting in the fictitious collapse of any separation between them. As a result, architects and the intellectuals of the modernist era frequently imagined homes as extensions of our sensory and biological systems.[130] Negroponte used reflexive and simulated behaviors in *Soft Architecture Machine* to develop a philosophy of responsive architecture.[131] He envisioned some instances of the first - reflexive- behavior through self-organizing controllers and the improvement of reciprocal dialogue between the human and the machine, while also realizing that it was still difficult to picture the gesture-based behavior as applied in the Cityhome example by MIT Media Lab.[132] For the simulated behavior, Negroponte suggested

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[128] Negroponte, N. "Soft Architecture Machines" (Cambridge, MA: MIT Press, 1975). p. 132

[129] Colombino, L., "The House As SKIN", European Journal of English Studies, 2012, 16:1, p. 25

[130] Ibid.

[131] Ibid.

[132] Lee, J. H. et al., 2018. "Rethinking and Designing the Key Behaviours of Architectural Responsiveness in the Digital Age", Learning, Adapting and Prototyping - Proceedings of the 23rd CAADRIA Conference - Volume 1, Tsinghua University, Beijing, China, p. 360.

that it could be effortlessly achieved within a "simulatorium" building.[133] The theoretical framework that underpins these two sorts of behaviors not only takes on the role as a guideline to generate responsive architecture, but also makes it possible to comprehend how recent evolution has led to a diversity of architectural responses.

4.1 Transition from Hard to Soft Architecture

The perception of the environment, space utilization and the theory of architecture is necessarily transforming through time and with the technology at hand. Beginning in the 21st century, a deliberate effort to redefine the notion of space and to reengage with architecture has caused a significant and comprehensive revolution in architectural education. The self-declared "death of theory" by separating hard and soft architecture[134], and a rebirth in computation-based and material-related research within the discipline go hand in hand with this interest in practice and reveals a greater concern regarding political, social, and environmental matters.[135] Numerous architecture schools have initiated specialized post-professional degree programs in material, computational and robotic research as a result to explore disciplinary boundaries. Beside from the precursors of these interdisciplinary programs as MIT's Media Lab and Design Research Lab at the Architectural Association, more recent post-professional programs are added to the list, including Robotic Building Lab at TU Delft, Responsive Environments and Artifacts Lab (REAL) at Harvard GSD, the Bartlett at UCL and so on.[136] These programs, which are actively extending disciplinary discourses and practices, declare an interdisciplinary agenda. By mostly

[133] Ibid.

[134] Lee, J. H. et al., 2018. "Characterizing Smart Environments as Interactive and Collective Platforms: A Review of the Key Behaviors of Responsive Architecture", Sensors 2021, 21(10), 3417, pp. 3-18

[135] Velikov, K. et al., 2012. "Thick Air", Journal of Architectural Education, 65:2, pp. 69-79

[136] Ibid.

being lab-based as opposed to studio-based, they place a strong emphasis on invention and exploration through computation and robotics.

The interaction between the human and the machine has transformed itselft from a consumer-supplier relationship into one which is mutual, where both parties are affected from each other. The established relation of the human to technologically facilitated surroundings simultaneous with the rising interest in cybernetics and mobility led to the notion of an extension of the "body". [137] This extension arose the inquiries on effect of participants to one another and the desire to discover the boundaries of this intertwined state. The "in-relation" state, which is now happening out of awareness caused by the spread of everyday objects embedded with cybernetics, resulted in an environment where components that exist in that environment are being altered continuously. As a common example from daily life, the smartphones are optimized for the best interest of the user with the developing technology. To illustrate, a smartphone measures the amount of environmental light through the light sensitive sensors and arranges the screen brightness accordingly. Regarding responsiveness, this language created between the human and the smartphone introduces itself as a reflexive behavior in this scenario. In case of a faulty arrangement of the brightness provided by the phone, the user takes action by predicting that an application that affects the brightness of the screen may be working at the background and preventing the sensor process and the user can turn of that aforesaid application.

Excluding the impact that the COVID-19 pandemic had on computer ownership - which has become compulsory for educational purposes and some remote work models-, interest in computers is now decreasing, but computation is now widespread since it became smaller, faster and more affordable.[138] Extensiveness of the internet is now considered as a major component regarding communication, and

[137] Ibid.

[138] GlobalWebIndex, "How Device Usage Changed in 2018 and What it Means for 2019" retrieved from https://blog.gwi.com/trends/device-usage-2019/ on September 27, 2022.

it is at a point where the absence of the internet would result in dire circumstances. Along with this integration of cybernetics to everyday objects, the psychological and physical limits of the "space" have started to blur and the notion of space itself is now a hybrid including digital environments.[139] This merging of digital and physical made a significant impact on architectural theories and ideologies. The idea of utilizing computation and the promise of a flexible and adaptive architectural behavior brought the need to discover the expanse of space in architectural discourse. "Cybernetics and information networks; the beginnings of the ecological movement; political protest; the space race and its technological spin-offs; control and choice and the right to individual happiness" were five key topics cited by Steve Parnell, that initiated the transition from hard to soft architecture which became evident with the emergence of these new themes in architectural culture based on an analysis of the architectural publications from the late 1960s and early 1970s.[140] Shelter idea, which used to be conceived as a "hard" shell was therefore challenged with "soft architecture" and the potential that it carries. While hard architecture yields the responsibility of providing "shelter" and therefore obtaining a utilitarian perspective, what is defined as soft architecture is dedicated to rediscover what architecture represents as an opposing paradigm. Visionary groups such as Eventstructure Research Group and Haus Rucker Co marked that paradigm shift happening in the architectural discourse by stepping out of the conventional boundaries of the field and putting an effort to reveal the softness of architecture by introducing pneumatic architecture (Figure 4.1).

According to Parnell, the expansion of architecture towards the stated fields happened as such:

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[139] Lee, J. H. et al., 2018. "Characterizing Smart Environments as Interactive and Collective Platforms: A Review of the Key Behaviors of Responsive Architecture", Sensors 2021, 21(10), 3417, pp. 3-18

[140] Parnell, S. "Architectural Design, 1954-1972: The architectural magazine's contribution to the writing of architectural history". PhD. diss., University of Sheffield School of Architecture, November 2011, p. 293

> “First in terms of the very material of architecture: it is no longer considered to be formed of hard materials like bricks, concrete, glass, and steel, but is more integrated into its environment and ecological. Inflatables and softer materials, including ‘air walls’, were literally considered as building materials. Second, the previously hard boundaries of what constituted architecture, the profession and the role of the architect in the building process, were softened by talk of participation, community architecture, "architecture without architects", and squatting. Third, there was more talk of ‘software’ and less of ‘hardware’.”[141]

Figure 4.1: Pneutube by Eventstructure Research Group

Source: Jeffrey Shaw Compendium, retrieved from https://bit.ly/3SkkX7J

[141] Ibid.

4.2 Responsiveness in the 21st Century

The human and responsive architecture have been mostly considered as in a one-way relationship, which was deducted from previous principles and discourse that shapes an architecture with a utilitarian perspective, focusing on how space may serve for the benefit of the human. However, with the expansion that is being observed in the field, the reciprocal communication between architecture and the human have been revealed, from human to architecture (H2A) and architecture to the human (A2H).[142] The latter has not yet been fully explored because of utilitarianism, whereas the former has received much investigation with an emphasis on smart environments and context awareness. In this sense, advances in cybernetics and networking technologies have the potential to enhance A2H communication through various sensory responses, such as kinetic, auditory, and visual simulation. A2H, an approach which emerged as a representation of the discipline's extension to other fields has been on the focus of artists and architects who aim to emphasize the expansion of space and its relation to the human.[143]

Architects like Philippe Rahm, Philip Beesley, New Territories and others in the field have made an effort to investigate this newly brought "extension" scenario through somatosensory experiments based on A2H communication. The control of individual boundaries of bodies, and the negotiations among the institutions of power that decide the complex trade-offs associated with extensions into environments and ecologies are some of the topics that were attempted to be discovered in these contemporary explorations.

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[142] Lee, J. H. et al., 2018. "Rethinking and Designing the Key Behaviours of Architectural Responsiveness in the Digital Age", Learning, Adapting and Prototyping - Proceedings of the 23rd CAADRIA Conference - Volume 1, Tsinghua University, Beijing, China, p. 360.

[143] Ibid.

4.2.1 Hylozoic Ground

Hylozoic Ground, which was designed by Philip Beesley in association with engineer Rob Gorbet and biology expert and chemical engineer Rachel Armstrong, was exhibited at the 2010 Venice Architecture Biennale as a live sculpture environment which aims to discover the physiological expansion of the human body to the environment by enhancing empathy and exchange.[144] The sculpture which is akin to a living system via embedded machine intelligence, organ-like components and Shape Memory Alloys can be defined as a "suspended geotextile"[145] that collects hybrid soil from substance obtained from the participants and the surrounding, and enables caressing, breathing and swallowing motions along with hybrid metabolic changes[146].

The title of the project is derived from "hylozoism", a word coined in the 17th century which is a perception of "all matter … alive, either in itself or by participation in the operation of a world soul or some similar principle"[147]. Similar to the Deleuzian idea of anti-anthropocentricism, Hylozoic Ground is an attempt to unveil the equal participatory roles of the human and the nonhuman and aims to reveal the liveliness of an environment by establishing a homeostasis, "the tendency towards a relatively stable equilibrium between interdependent elements"[148] within the metabolism of the body.[149] The responses of Hylozoic Ground are provided through hives of kinetic valves and pores in peristaltic waves which act as a living and breathing member that

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[144] Markopoulou, A. "Design Behaviors: Programming the material world for Responsive Architecture" PhD. diss., Universitat Politècnica de Catalunya, January 2020. p. 131

[145] Beesley, P. "Hylozoic Ground: Liminal Responsive Architectures". Toronto: Riverside Architectural Press, 2010. p. 14

[146] Ibid.

[147] Encyclopedia Britannica. "Hylozoism" Retrieved from https://bit.ly/3hwLBbr on June, 2020.

[148] Retrieved from Oxford Languages.

[149] Markopoulou, A. "Design Behaviors: Programming the material world for Responsive Architecture" PhD. diss., Universitat Politècnica de Catalunya, January 2020. p. 131

Figure 4.2: Hylozoic Ground by Philip Beesley

presents behavior (Figure 4.2). The responsiveness of the body is provided through integrated devices which have a similar duty as pores and hair follicles found in an organism's epithelial skin layers. Thin sheets formed into outward-branching membranes representing arboreal mimicry (Figure 4.3) constitute breathing

apertures. Each unit possesses acrylic tongue stiffeners connected to tendon-like units which enables upward curling motions to create upwards movement for the surrounding air. Embedded sensor lashes at the bottom terminals provide cupping and pulling motions.[150]

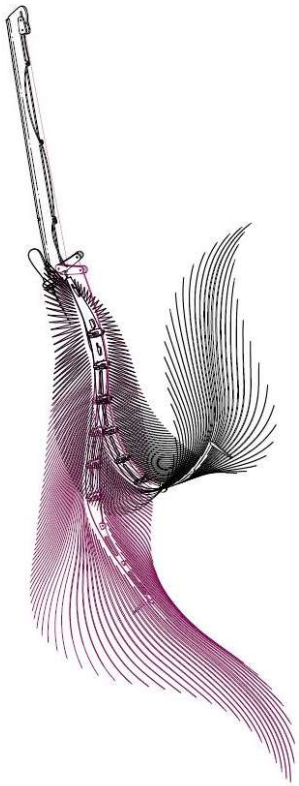

Figure 4.3: Frond-Like Members

Along with the sensory equipment, the environment inhabits several incubators that are packed with synthetic protocells (Figure 4.4) and artificial chemical cells (iChell) which are able to self-assemble throughout the chemical synthesis process. Incubators are triggered by the light and vibrations caused by the movement and the presence of the participants.[151] Protocell development which depends on the participant-generated stimuli and the surrounding is influenced by these lights that carry small amounts of energy. Since synthetic protocells also respond to and are affected by carbonate, when CO_2 levels rise due to the exhalations of numerous visitors, the morphologies change in relation to the participant amount. Therefore, the exchange taking place in the intricate matrix of the Hylozoic Ground is reciprocal.[152]

Philip Beesley describes the installation as "an immersive environment," and comments about the experience as "it's about being inside something, not being on

[150] Beesley, P. "Hylozoic Ground: Liminal Responsive Architectures". Toronto: Riverside - Architectural Press, 2010. pp.17- 19

[151] Ibid.

[152] Markopoulou, A. "Design Behaviors: Programming the material world for Responsive Architecture" PhD. diss., Universitat Politècnica de Catalunya, January 2020. p. 35

top of it and owning it, but being swallowed by it, with a sense of vertigo."[153] Representing an environment where the parties are co-dependent to each other in order to exhibit behavior, Hylozoic Ground points out a crucial point for this study which is the question of liveliness or what is required to be a living body. The unpredictable pulsing, caressing and swallowing behavior presented by the environment and the action of breathing (Figure 4.5) brings into the question of how a body can be perceived as alive. In reference to what was described in Chapter 3 of this study, Hylozoic Ground represents in 2010, the ideas conceptualized by Deleuze and Guattari on the machine in the late 1970s, which they described as possessing the ability to adapt constantly, establishing connections in order to transform and maximize itself and producing for the sake of production by abandoning pragmatical implementation of responsiveness. Wolfe describes what Hylozoic Ground represents as follows:

Figure 4.4: Detail of a Protocell

> "Hylozoic Ground generates another kind of 'queasiness' or vertigo—the vertigo associated with what is now being called 'posthumanism': the need to move beyond the comforting philosophical categories and certitudes of the humanism we have inherited from the Renaissance and the Enlightenment, to a more nuanced and complex vocabulary that allows us to deftly process the imbrication and enfolding of bodies, machines, codes, discourses, and spaces that we

[153] Wolfe, C. "Queasy Posthumanism Hylozoic Ground", Hylozoic Ground: Liminal Responsive Architectures". Toronto: Riverside Architectural Press, 2010. p. 57

> increasingly encounter in our own historical moment—and in Hylozoic Ground." [154]

This all-embracing ground reveals the permeability of the subjective boundaries of both human and non-human and the intricate nature of the individuality. Through A2H and H2A communication which occurs simultaneously in Hylozoic Ground, Beesley's aim to abandon the architectural lexicon for the sake of inventing a space as an extension between the human and the machine resulted in "a model system of a synthetic ecology undergoing an evolutionary process."[155] Participants of the environment may see how the environment first appears and can also see how their actions alter the environment in a variety of ways as a spatial experience[156]. They eventually participate in and contribute to the formation of this ecological representation of liveliness.

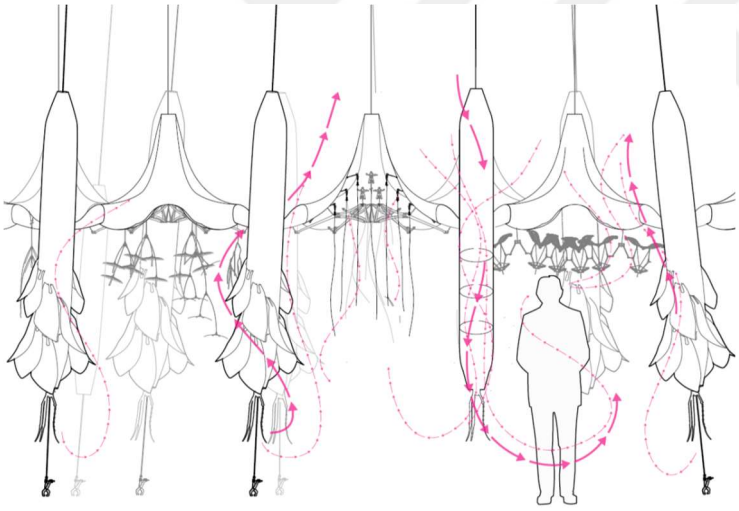

Figure 4.5: Breathing cycle diagram

[154] Ibid.

[155] Armstong, R. "Hylozoic Ground Chemistries & Unanswered Questions in the Origins of Life", Hylozoic Ground: Liminal Responsive Architectures". Toronto: Riverside Architectural Press, 2010. p. 127

[156] Armstrong, R. "Vibrant Architecture: Material Realm As a Codesigner of Living Spaces". De Gruyter Open, Berlin, 2015

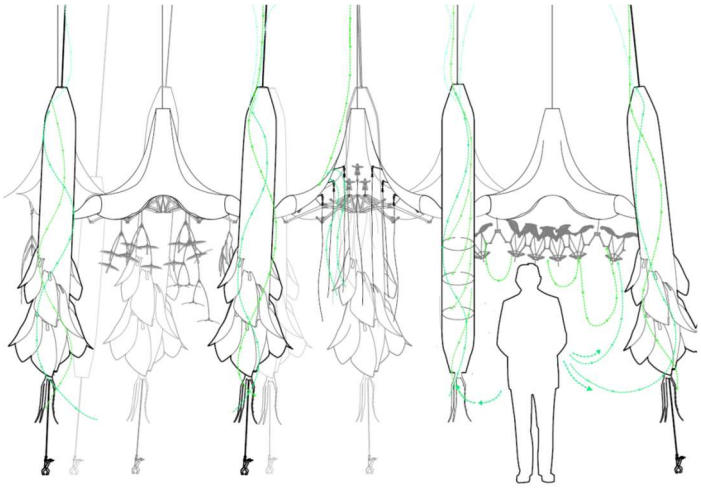

Figure 4.6: Visualization of programmed series of motions initiated by participants.

Source for all images in this section: Beesley, Philip. "Hylozoic Ground: Liminal Responsive Architectures." Toronto: Riverside Architectural Press, 2010.

4.2.2 Hormonorium

Although the reason of the emergence of responsive architecture can be considered as the optimization of the environmental conditions according to the participants actions, needs or desires, the experiments made in the field of responsiveness engender another side of the relationship. When encountered with a drastic change of circumstance, the human body tends to alter the optimal conditions and tries to adapt to the brand new environmental condition. To illustrate; when the temperature rises, the average amount of sweat produced increases in order to balance the body temperature. In case of low temperatures, human body intrinsically reacts by shivering, goosebumps and so on to alert that the metabolism is not in the homeostatic state.

Philippe Rahm and Jean-Gilles Decosterd in collaboration with Prof. Urs Scherrer from Department of Internal Medicine, CHUV Lausanne and Dr. Anna Wirz-Justice, expert on chronobiology from University of Basel experimented with such responses

Figure 4.7: Fluorescent tubes in Hormonorium

Source: World Architecture website, retrieved from https://bit.ly/3Czews9

the human body gives to an "altered" environmental condition with the *Hormonorium* project exhibited in 2002, at the Swiss Pavillion of the Venice Biennale. The objective of the proposed design is to present a space that creates blurred boundaries among body and environment. In the words of Rahm, "Understanding the physicochemical mechanisms that govern organisms brings about a change in how we understand space, and longer resorting to semantic, cultural or plastic media for the making of architecture."[157]. The environment mimics the climatical conditions of high mountains by affecting participants' skin, respiration and the visual senses. By placing 528 fluorescent tubes under the transparent plexiglass floor which allows the passage of the UV lights, (Figure 4.7), UV –A and UV-B enable the environment to make changes in the hormonal levels of the participant. The Hormonorium was a tanning environment since UV-A was

[157] Rahm, P. "Hormonorium" Retrieved from https://bit.ly/2yDtS0x on May, 2020

present, while UV-B allowed for vitamin D production.[158] The physical boundaries of the room are blurred with the manipulated amount of UV light which radiates white light.[159]

The light radiation is not blocked by the eyelids, eyelashes, or the head's natural inclination since it is inverted and emanates from the ground, as in the case of snow. Between 5000 and 10,000 lux of intense light stimulates the retina, which sends signals to the pineal gland that reduce melatonin release, since it is a hormone that is stimulated by darkness.[160] (Figure 4.8) This atmosphere enables the experience to feel a decrease in fatigue, a likely rise in sexual desire, and management of our emotions by reducing the level of this hormone in the body. The temperature of the environment was set between 15–16° C. To fully manipulate invisible atmospheric

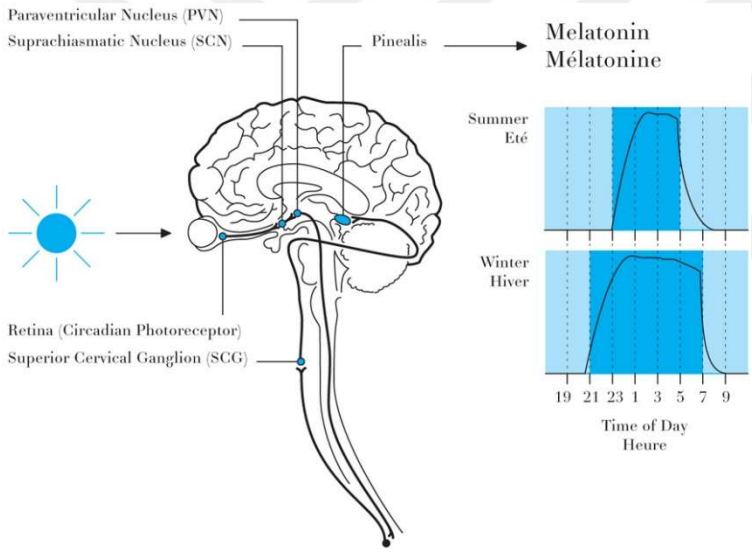

Figure 4.8: The Diagram of the Effect of Hormonorium on Melatonin Levels

Source: Philippe Rahm website, retrieved from https://bit.ly/3MiKHiH

conditions in a way so that the experience is similar to sudden transfer into an alpine region, the nitrogen level is increased and this leads to a reduction in the oxygen levels of the environment from 21 percent to 14.5 percent.[161] This oxygen level

[158] Förster, D. "Aesthetic Experience of Metabolic Processes", meson press, 2019. p. 65

[159] Plewke, A. "Philippe Rahm: Part 1". Retrieved from https://bit.ly/3blSico on May, 2020

[160] Cardinali, D. P. et al. "Cellular and Molecular Mechanisms Controlling Melatonin Release by Mammalian Pineal Glands", Cellular and Molecular Neurobiology , Vol. 7, No. 4, 1987. p. 324

[161] Rahm, P. "Hormonorium" Retrieved from https://bit.ly/2yDtS0x on November, 2022

corresponds to the level which is available at as high altitudes as 3000 meters. According to Philippe Rahm, altitude sickness can strike at a height of about 2000 meters, and under these circumstances symptoms may arise quickly, since the unexpected exposure to such an environment was not preceded by any time for acclimatization.[162] The reduced oxygen level of the environment engenders a slight hypoxia which presents itself as a "*confusion, disorientation, or bizarre behavior, but also a slight euphoria through the production of endomorphine.*"[163]. In case of spending aproximately twelve minutes in the *Hormonorium*, a strengthening of the cardiovascular and respiratory systems is observed. The increase of the EPO (Erythropoïetine) which is a protein-based hormone and hematocrit levels causes a growth on the delivery of oxygen to the muscles and strengthening of the cardiovascular and respiratory systems, therefore resulting with an improvement in the physical capacity up to ten percent.[164]

The somatosensory-triggering setting of Hormonorium draws attention away from the architectural world and toward the individual's own body. Architects Rahm and Décosterd created an atmospheric continuum using temperature, humidity, and light in order to highlight the many modalities of perception that track climatic changes and their effects on the experience. Alteration of space is accomplished by rebelling what architectural discourse offers. Instead of targeting visual perception and adjustment of the space by means of hard architecture, Hormonorium triggered an area of endocrine, where living and non-living extends to each other by moving beyond the dimension which is visible to human eye.[165] The established "infra-functionalist architecture, a place whose visibility expands into the upper and lower wavelengths of the light spectrum, into the invisibility of the chemical compositions

[162] Förster, D. "Aesthetic Experience of Metabolic Processes", meson press, 2019. p. 65

[163] Plewke, A. "Philippe Rahm: Part 1". Retrieved from https://bit.ly/3blSico on May, 2020

[164] Ibid.

[165] Armstrong, R. "Vibrant Architecture: Material Realm As a Codesigner of Living Spaces". De Gruyter Open, Berlin, 2015. p. 51

of the air"[166] penetrates through the human skin, which is considered as the most fundemental and undeniable boundary of an individual.

The architecture that Philippe Rahm and the visionaries who are determined to discover the transformation of the archtiecture and how it establishes a relationship with the human therefore unfolds to the environment and by doing so, the human body and the space become one, intertwined. In this scenario, the human and the manipulated atmosphere are unstable machines that change in proportion to their connections with one another. It is not argued that bodies turn into literal machines; rather, it is suggested that by thinking of them as machines, their individual potentials and bounds might be expanded.[167] During this in-relation state, the dialogue between the human and the space remains faithful to the Deleuzian concept of *rhizome*. Where human starts or where the manipulated atmosphere ends is not distinguishable and each unit transforms itself through connection, hence, constituting a unified "body". The A2H communication is purely experienced under the human skin, to the eye, it is nothing more than visitors sitting in a simple white room with several basic one type furniture (Figure 4.9).

New materials, techniques, and forms of social organization may be liberated to create new means of architectural creation by subverting the expectations of architecture. These are necessary for the growth of really subversive types of material creativity that allow for the convergent entwining of artificial and organic processes. By integrating technology smoothly and coherently with natural processes, these alternative modalities of architectural creation dismantle the conventional division between architecture and human and alter the in-relation state of both parties into post-natural ecologies.

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[166] Plewke, A. "Philippe Rahm: Part 1". Retrieved from https://bit.ly/3blSico on November, 2022

[167] Uçar, B. "An Inquiry into the Ontology of Responsiveness: Assessing Embodiment and Human-Machine Interaction in Responsive Environments", PhD. diss., Middle East Technical University, September 2011. p. 169

Figure 4.9: Hormonorium with visitors
Source: Philippe Rahm website, retrieved from https://bit.ly/3MiKHiH

4.2.3 Altered State

As an adaptive living organism, humans tend to correspond to the environmental conditions as fast as possible in order to survive. Supporting the Deleuzian idea of a machine, the human body modifies the conditions with hormone-machine, skin-machine and so on[168] according to the input provided by the surroundings and gives

[168] Deleuze and Guattari present their conception of the machine as such: "Everywhere *it* is machines—real ones, not figurative ones: machines driving other machines, machines being driven by other machines, with all the necessary couplings and connections. An organ-machine is plugged into an energy-source-machine: the one produces a flow that the other interrupts. The breast is a machine that produces milk, and the mouth *i* machine coupled to it. The mouth of the anorexic wavers

the safest output possible through another machine. Taking that into consideration, thinking about responsiveness leads to the recognition that it is not only applicable to architecture or the environment but that responsiveness is a human feature, both physical and psychological.

François Roche, who is the cofounder of the collective New-Territories which is a polymorphous architectural organization, has been experimenting on the psychological effects of altered environments on the human with the aid of machines called "psycho-scapes"[169]. Roche's approach to these experiments is based on his understanding of machinery, which he describes in the following words: "*machines have been always pretending to do more than what they were programmed to do*."[170]. He believes that this "pretending" is in their nature and that they have the ability to break free and threaten us[171]. Such nature alternates phantasms, frustrations and fears. The confusion between what they are created to accomplish and what people project on the machine creates a potential to re-'scenarize' the operating processes of the architectural field. Since what people expect and what the machine is programmed to do differs from each other, this blurriness creates a sort of schizophrenia, which Roche perceives as a tool that makes machines "agents of blur logic, of a reactive and reprogrammable logic."[172].

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between several functions: its possessor is uncertain as to whether it is an eating-machine, an anal machine, a talking-machine, or a breathing machine (asthma attacks). Hence we are all handymen: each with his little machines."

Deleuze, G., Guattari, F., 1977. "Anti-Oedipus: Capitalism and Schizophrenia". Viking Press. p. 1

[169] Budor, D. "Architectural Psychoscapes: Francois Roche" Retrieved from https://bit.ly/2BaROcG on June, 2020.

[170] Roche, F. "(Science) Fiction, Ecosophical Apparatus and Skizoid Machines: Animisim, Vitalism and Machinisim as a Way to Rearticulate the Need to Confront the Unknown in a Contradictory Manner". AD: Ecoredux. Vol. 80 No. 6 (November-December 2010): 64-71

[171] Ibid.

[172] Ibid.

Figure 4.10: Altered State

"Altered State", designed by François Roche and Camille Lacadee in collaboration with Carsten Höller (Figure 4.10 & 4.11) for the Donau Festival 2013 in Austria is one of the case studies of #mythomaniaS, established with four machines that release chemical fog, containing ingredients -pheromones of a pregnant woman's urine. [173] By approaching the conception of space with A2H perspective, the design idea is to disrupt perception, to break boundaries between real and unreal, logic and illogical by disseminating a cocktail of human pheromones Androsta-4, 16-Dien-3-One (A5) and Estetraenol (E1). This foggy matter released by "four petrified dancers" described by designers causes physiological and psychological altered states like euphoria, melancholia, hysteria, phobia, philia, joy, delusion, delirium, anxiety, amnesia and so on. By causing such states, the environment prepares the participant to a shamanistic ceremony which leads to an "emotional delivery"[174]. Regarding the aim of the installation, François Roche stated their purpose as:

[173] new-territories. "#digitaldisobediences: s/he would rather do Fiction MAKER", new-territories / Frac Orleans / Tars Gallery / theMet, August, 2018, p. 188

[174] Ibid.

> "It's engaging an emphasis of the acephalous body, released from its rational jail and limits, by rationalities, as a strategy to reach a line of subjectivities escaping, crossing real and unreal, logic and illogic, through the viscera, the arterials, and the headless desirable machinery of the human body."[175]

#mythomaniaS, developed by New Territories, is a series of case studies to form environmental-architectural psycho-scapes as laboratory-shelters for examining and dissecting the alleged splits between body and mind, psyche and environment, realism and myth.[176] The aim of the study is to prove that "the human being is no longer a bio-ecological consumer but a psycho-computing animal that emerges co-dependently with its environment in a hyper-local haecceity ("this-ness")."[177] Lacadee and Roche fashioned *mise-en-abymes* in which specific scripted parapsychic tales and architectural structures blend in an effort to restore resilience by combining architecture, Deleuze and Guattari's schizoanalysis, machine conception and deterritorialization.

[175] Ibid.

[176] Lacadee, C. et al. "#mythomaniaS". Retrieved from https://bit.ly/3RL5P2f

[177] Ibid.

Figure 4.11: Altered State

Source for all images in this section: Camille Lacadee website, retrieved from https://bit.ly/3T4lOt7

4.2.4 Urban Algae Canopy

London based architecture practice EcoLogicStudio introduced Urban Algae Canopy project at the 2015 Milano EXPO. Conceptualized as an interactive pavilion with three layered ETFE (Ethylene tetrafluoroethylene) architecture skin system integrating living microalgae cultures -Spirulina in this instance-, Urban Algae Canopy offers an architecture in which the maximization of the capacity of both parties (the architecture and the human) are established through relation.[178] Microalgae also oxygenate the air and can absorb CO_2 from the urban environment ten times more efficiently than large trees. Moreover, the pavilion produces 2 kg of oxygen per day, which is a rate that requires 25 large urban trees to accomplish.[179] Spirulina are harvestable photosynthetic machines, they include nutrients that are essential to the human body, such as minerals and vegetable proteins.

Figure 4.12: Urban Algae Canopy

Source: EcoLogicStudio

[178] Wilkinson, S. et. al. 2020. "Algae Building: Is This the New Smart Sustainable Technology?" Data driven Multivalence in the Built Environment, Springer.

[179] EcoLogicStudio, "Urban Algae Canopy". Retrieved from https://www.ecologicstudio.com/projects/expo-milano-2015-urban-algae-folly on October, 2022.

The photosynthetic activity of the algae, which was influenced by the carbon dioxide released by visitors and weather conditions, determined the development of the algae and therefore the air quality and shade inside the canopy.[180] In order to intensify the impacts of visitors' respiration, the algae growth was also physically linked to the number of visitors: The movement of the visitor is monitored by motion sensors and affects the rate at which the algae fluid is pumped through the facet by hydraulic pumps, along with extra nutrition that is automatically adjusted. If the number of algae in a specific facet rises, the facet gradually darkens and releases more oxygen into the canopy, and also dynamically producing a shadow.

Figure 4.13: Urban Algae Canopy

Source: EcoLogicStudio website

The installation demonstrates the A2H and H2A relation between human and ecological architecture by using atmosphere as a mediator. Visitors' breathing produces carbon dioxide, which increases the nutritional supply for the photosynthesis cycle of the algae. As a result, the volume of participants has an impact on the growth of the algae. In return, algae flow and the production density focuses on the occupied area therefore providing air quality and comfort to the visiting agent.[181] Through the introduction of emergent differentiations that cross various sensual thresholds, such as the speed at which the algae move, the intensity

[180] Förster, D. "Aesthetic Experience of Metabolic Processes", meson press, 2019. p. 107

[181] Ibid.

of the light, and the quality of the air, the aesthetic milieu mediates metabolic interrelations in this environment. These emergent differentiations must meaningfully relate to the topic being perceived in order for them to be experienced. Potentially common metabolic pathways between a particular visitor and algae, between other visitors and algae, and between visitors are involved in these newly discovered correspondences. It also takes into account the surrounding environment, the weather outside the planned apparatus, and the digital technology that acts as a bridge between these many agencies.[182]

4.3 Twenty Years of Responsiveness

Since Negroponte offered the term "responsive architecture", computers have advanced in speed, size, affordability, and they have gained the ability to be integrated into extremely small objects. The developments on ICT therefore spread to each aspect of the standard daily life. This integration to everyday objects, structures and surroundings enabled ubiquitous computing where everything is globally networked and eventually evolved into Internet of Things (IoT).[183] IoT is defined as "a system that incorporates various computing devices, actuators, wireless sensors, routing protocols, and applications that can independently share data and commands across networks in order to provide intelligent services."[184] It is a term used to describe the state of simultaneous data storing and sharing by billions of objects that are connected to the internet on a global scale.

Integration of IoT with everyday objects reflected itself through art and architecture as well. These fields now exist in new informative and interactive surroundings,

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[182] Ibid.

[183] Lee, J. H. et al., 2018. "Rethinking and Designing the Key Behaviours of Architectural Responsiveness in the Digital Age", Learning, Adapting and Prototyping - Proceedings of the 23rd CAADRIA Conference - Volume 1, Tsinghua University, Beijing, China, pp. 360-361.

[184] Maraiya, K. et al. (2022). "IoT and Its State of Art Applications: A Survey." Saudi Journal of Engineering and Technology , Volume 7, p. 211

which is defined as “thick air”, an invisible sensor cloud.[185] To illustrate, many interactive installations encourage visitor participation in the interactive creation of the artwork and architecture. The spectators participate actively in the responsive body rather than being a passive one. They portray a parallel process of self-organizing behavior in architecture by being both audience and artists. This results in a reciprocal communication where “process replaces product in importance, just as system supersedes structure”.[186] What is stated as “responsive output” in the former examples of responsive bodies has translated itself and is referred as “behavior” in most of the articles written after 2010s that were referenced throughout the study.

As architecture became a form of behavior, software and soft architecture outmoded hardware. Sensing – Processing – Actuating, which was considered as main phases of the network that facilitates the communication (which was also stated as such in section 2.2.2 of the thesis) was therefore no longer able to provide for the real time response in this environment of dense data.[187] Latest implementations of ICT and IoT on architecture is being processed through fog computing (similar to cloud), which is a decentralized computing environment where data, computation, storage, and applications are distributed between the data source and the cloud.[188] Fog computing brings the benefits and power of the cloud closer to where data is

[185] Lee, J. H. et al., 2018. “Characterizing Smart Environments as Interactive and Collective Platforms: A Review of the Key Behaviors of Responsive Architecture”, Sensors 2021, 21(10), 3417, p.3

[186] Ascott, R. "Behaviourables and Futuribles," in Kristine Stiles and Peter Selz, eds., Theories of Modern Art (Berkeley, CA: Univ. of California Press, 1996).

[187] Gupta, H. et al. “iFogSim: A Toolkit for Modeling and Simulation of Resource Management Techniques in Internet of Things, Edge and Fog Computing Environments”, *Softw Pract Exper.* 2017; 47: 1275– 1296.

[188] Yousefpour, A. et al. ”All one needs to know about fog computing and related edge computing paradigms: A complete survey” Journal of Systems Architecture, Volume 98, 2019. p. 292

produced, alters a flexible platform to meet the data-driven needs of operations and used for stabilizing the system simultaneously.[189]

Living Landscapes (Figure 4.14) exhibition which took place in 2021 demonstrates how the understanding of space and the control of the human on it has differed with ICT development and IoT. The exhibited artworks raise the question related to the ownership of the data and the belonging of the space through "fluid liquid real time

Figure 4.14: Living Landscapes

Source: Stanza website, retrieved from https://www.stanza.co.uk/livinglandscapes

data space", as in cloud of the data, which envelopes the environment.[190] Some of the artworks in the series investigate worldwide data pollution and others track Wi-Fi activity in the city using fog computing, AI and Machine Learning. Wi-Fi activity is triggered by any data that has been broadcasted through the usage of phones and

[189] Ibid.

[190] Stanza. "Living Landscapes". Retrieved from https://www.stanza.co.uk/livinglandscapes on October 2022.

computers within one kilometer range and simultaneously alter the artwork.[191] This exhibition represents the occupancy of the ICT on city space through data implementation and therefore illustrates the liveliness of the environmental body integrated with cybernetics.

These case studies reveal how the understanding of space has drastically changed with the technological developments which increased its speed gradually specifically in the last twenty years. Visionaries that are seeking to unveil the potential that the in-relation state holds perceive the previously defined notions and bodies in an unconventional way. By defying the Anthropocene which is deeply rooted in various disciplines, artists such as Rahm, Beesley, Roche and so on surrender the control on the space which is a notion that got used to being manipulated by architects and artists who are dependent to the so-called theory. Utilitarian perspective regards a physical body, an environment, a building and so on, as a commodity that can be shaped by the architect who is entitled to do so. With the Deleuzian idea of machine and *rhizome*, visionaries who challenge the conformist approach towards architecture, remove the human from the center of the equation and configure an equalitarian body in which all parties establish the in-relation state. Through the non-anthopocentric approach, the boundaries between the parties fade away, opening a different perspective that has a immense potential of discovery, spesifically regarding the notion of liveliness and what can be considered as being alive.

[191] Ibid.

CHAPTER 5

CONCLUSION

The study carried an investigation on the key aspects of the utilitarian approach in responsive architectures and the earlier conceptions through rule-based applications that aimed at manipulating space for the sake of human interest. Taking the case of vernacular architecture as the ancestor of responsiveness, the research presented a chronological inquiry by defining the modernist utilitarian approach for space automation in the early 1920s as a starting point for the initial pursuit to achieve responsive architecture. The involvement of the notion of responsive architecture to the lexicon of the discipline has been introduced in the study, and the limits of the conceptualization of the notion in early interpretations has been related with limited technology. Consequently, the thesis surveyed the development of responsive architecture within the anthropocentric perspective and related the motives of this one-way development to an interest in utilitarianism, together with restricted technological resources.

The first set of case studies presented in the study illustrated how diverse implementations of responsiveness were introduced gradually through non-conventional applications of the computer-aided systems starting from the late 80s along with the developing technology. These advancements, specifically in the field of computational techniques and with greater cognitive capacities, enabled experimenting on and expanding the limitations of previously defined borders in the anthropocentric approach. Although most of them were executed before the groundbreaking advancements in responsiveness, which Industry 4.0 introduced starting from 2011, these implementations questioned the stance of the architect, the machine, the participant and their relations with each other. Although each approach

and each study are authentic, the aim to test the role of the parties that produce the responsive body seems certain and mutual. Through the adoption of new strategies that reevaluate and change the already established relationships between various parties, these strategies paved the pathway to challenge the predetermined roles of the architect, the participant and even the role of the environment itself.

It has been discussed that the shift from conventional approaches to non-anthropocentric ones was introduced through the acknowledgement of the potential that machinery offers to a redefinition of responsiveness. In this regard, the thesis examined machine perceptions of divergent disciplines and prepared the framework of the machinic approach in terms of an interactive entity of a responsive body. Acknowledging the Deleuzian Machine on the matter, the rhizomatic quality of responsiveness is achieved by machines that define the responsive body by surpassing the boundaries of a mechanism and maximizing their potential through making new connections, with an enhanced ability to ever-transform.

The debates on the role of the architect within the formation of responsive bodies and the radical shift with computer-aided systems and machinic approaches have been traced in the thesis as well. As Negroponte forethought when first conceptualizing responsive architecture in 1960s, the framework which is defined through the machine on responsive bodies removes the architect from the equation and the association established between machine and participant becomes more direct and active. Through the computing capacity integrated to a reconceptualized responsive architecture, the *model of appropriate behavior* recognizes the participant as a generator of behavioral patterns. The *Architecture Machine* of Nicholas Negroponte offers a reciprocal interactive body, in which the units generating the responsiveness are indistinguishable from one another. The study additionally provided insight on this responsive perspective with one of the first examples that offered an interactive environment in the architectural discourse: The *Fun Palace* project by Cedric Price and Joan Littlewood has been presented as an attempt to search for a flexible, adaptable and an ever-transforming structure with the intention to provide for the changing needs of the user. By emphasizing the integration of

cybernetics to the machinic approach in the iconic example, the thesis suggested the metamorphic progress of the conception of *Fun Palace* to a point where the human is started to be regarded as data in order to predict the transformative pathway of the responsive body, rather than the user of the system.

Through the Deleuzian conception of machine and *rhizome*, the *Architecture Machine* by Negroponte and Cedric Price's *Fun Palace*, the study emphasized the interaction between the participant and the machine which converts to being more fertile by means of potential outcomes of behavioral response and freeing the responsive body from the restrictions predetermined by the utilitarian approach along with the architect as an administrative unit. By doing so, the understating on the boundaries of each unit, how they generate relationships with one another and questioning the concepts of the human and the machine in an atmosphere where the human is decentralized have been scrutinized in order to establish a better understanding of the established in-relation state.

Along with the 4th Industrial revolution, advancements in cybernetics and the increased cognitive capacity of machinery enabled the integration of advanced computation to daily life. Within the post-humanist context, the attempts to reveal the potential of human-machine interaction have been brought up to the architectural agenda, exhibiting parallel development to the earliest conceptions of responsive architecture. Since the early 21st century, non-conventional approaches focused on the applications which perceived space manipulation as a reciprocal matter between the parties that establish responsive bodies. The study demonstrated how the contemporary implementations of responsiveness considerably altered the concept of space and the embedding of liveliness quality to the new definition of the notion. This liveliness aspect has been traced among the scrutinized case studies, which share an equalitarian atmosphere concerning the human, non-human and the machine.

Responsiveness is now seen to be versatile in its nature and the status of the notion has moved from answering the needs of people to a concept which enables the

dissolution of principal boundaries between the entities that generate a responsive body. From its pragmatic use to its more empirical use, as illustrated in the contemporary case studies in this thesis, the in-relation state between the machine and the participant translates itself as an interaction where all parties develop behavior. Where human is decentralized, an equalitarian atmosphere is established where the is no hierarchy between the human, non-human and machine. By doing so, each parties welcome the transformation aspect. Where kinetic responsiveness is limited with internal behavior based on the mechanism, the in-relation state, which can be defined as the *rhizomatic* capacity of a body, is obtainable through the machinic approach integrated with computation. This non-hierarchized, rhizomatic body exhibits an intricate in-relation state where the dissolution of principal boundaries are possible and non-conventional responsive bodies are now proposing a new definition of space, which is interactive and excludes the purpose of serving any request, condition or alteration. The shift on the perception of responsiveness is now contributing to the discovery of a new potential and the redefinition of boundaries.

Although the early applications of responsive architecture were more pragmatic and addressing human comfort through environmental control, this instrumental understanding is seen to change as the human and the machine are becoming intertwined in a mutual relationship as a result of the increasing cognitive capacity provided by the technological advancements. However, the utilitarian approach which significantly influenced responsive architecture can be claimed to maintain its existence since utility is an important aspect of responsiveness in architecture.

Future research on the notion of responsiveness and the in-relation state discussed in the study can focus on an aspect that is not included in this thesis. The research should continue to be inclusive of the non-anthropocentric perspective since the technology at hand is on the verge of a new industrial revolution. Since one of the

pre-determined aspects of the emerging Industry 5.0 is "human-centric"[192], contemporary attempts that will focus on architecture to human (A2H) direction of the reciprocal relationship in terms of space manipulation and liveliness may lose track among the upcoming utilitarianism. The further explorations on responsiveness and HMI should abandon utilitarianism and benefit from the fusing of digital and physical systems in order to sustain the post-humanist approach.

[192] Huang, S. et al. "Industry 5.0 and Society 5.0—Comparison, complementation and co-evolution" Journal of Manufacturing Systems, Volume 64, July 2022, Pages 424-428, p. 424

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