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School of Architecture Urban Planning Construction Engineering
Faculty of Architecture
Department of Architecture and Urban Design

Augmented Flexibility in Architecture:

Architecture as Interface Between Physical and Virtual for Collaborative Mixed-Reality Environments

Supervisor: Prof. Simone Giostra
Co-Supervisor: Prof. Matthew McGinity

Author: Abdurrahman Furkan Balcı
Student ID: 10703962
Matricola: 940907

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This thesis is dedicated to them.

ABSTRACT

Augmented Flexibility in Architecture:

Architecture as Interface Between Physical and Virtual

For Collaborative Mixed-Reality Environments

The transformation in human life and living dynamics has accelerated in the last century, and this has caused the functional life of an architectural structure to be shortened compared to its structural life and the formation of dysfunctional and abandoned structures.

Flexible architecture is an approach to deal with this problem by increasing the functionality of buildings and extending their functional life. Mixed reality architecture, on the other hand, is a mixed reality approach that provides a flexible spatial topology covering physical and virtual environments, and in this respect, it contributes to the solution of the problem. However, neither the false promise of flexible architecture nor the inadequacy of application of mixed reality architecture in architectural practice has produced a solution to this problem. This thesis brings a new approach and a design/guideline to mixed reality architecture by redefining architecture as an interface that minimizes the conflict and incompatibility between virtual and physical and provides a solution to the problem of architecture's inability to respond to transformations with this *Augmented Flexibility*.

Augmented Flexibility will redefine human-space relationships and interactions and bring a new approach to the experience of space. The physical/tangible bits of the Augmented Flexibility are defined as hybrid affordances to be interfaces for mixed reality environments, providing a holistic experience for the physical and virtual layers. While this allows the space to be experienced in all its physical and virtual layers, it also enables distant spaces to interact with each other; in other words, architecture turns into a spatial communication tool that defines a space where present, remote, and virtual environments and their users can co-exist. Therefore, by transforming into a spatial communication and interaction tool, space gains the potential to become a media as it used to be. Architecture produces not only new types of spatial experiences and user interactions through mixed reality technologies but also enables physical space to be a part of the spatial internet by interacting with virtual and remote physical environments. This will create spatial possibilities for architecture waiting to be explored and put architecture in an irreversible process of change and development.

Keywords (ENG): Tangible Bits, Hybrid Space, Architectural Interface, Flexibility in Architecture, Mixed-Reality Architecture, Co-Existence, Adaptability in Architecture.

RIASSUNTO

Flessibilità Aumentata In Architettura:

L'architettura Come Interfaccia Fra Fisico E Virtuale

Per Ambienti Collaborativi Di Realtà Mista

La trasformazione della vita umana e delle dinamiche abitative ha subito un'accelerazione nell'ultimo secolo, e ciò ha determinato l'accorciamento della vita funzionale di una struttura architettonica rispetto alla sua vita strutturale e la formazione di strutture disfunzionali e abbandonate.

L'architettura flessibile è un approccio per affrontare questo problema aumentando la funzionalità degli edifici ed estendendone la vita funzionale. L'architettura della realtà mista, d'altra parte, è un approccio di realtà mista che fornisce una topologia spaziale flessibile che copre ambienti fisici e virtuali e, a questo proposito, contribuisce alla soluzione del problema. Tuttavia, né la falsa promessa dell'architettura flessibile né l'inadeguatezza dell'applicazione dell'architettura della realtà mista nella pratica architettonica hanno prodotto una soluzione a questo problema. Questa tesi introduce un nuovo approccio e una progettazione, o linea guida, all'architettura della realtà mista ridefinendo l'architettura come interfaccia che riduce al minimo il conflitto e l'incompatibilità fra virtuale e fisico e fornisce una soluzione al problema dell'incapacità dell'architettura di rispondere alle trasformazioni con questa *Flessibilità Aumentata.*

La flessibilità aumentata ridefinirà le relazioni e le interazioni uomo-spazio e porterà un nuovo approccio all'esperienza dello spazio. I bit fisici/tangibili della Flessibilità Aumentata sono definiti come affordance ibride per essere interfacce per ambienti di realtà mista, fornendo un'esperienza olistica per gli strati fisici e virtuali. Mentre ciò consente di sperimentare lo spazio in tutti i suoi strati fisici e virtuali, consente anche a spazi distanti di interagire tra loro; in altre parole, l'architettura si trasforma in uno strumento di comunicazione spaziale che definisce uno spazio in cui possono coesistere ambienti presenti, remoti e virtuali ei loro utenti. Pertanto, trasformandosi in uno strumento di comunicazione e interazione spaziale, lo spazio acquisisce il potenziale per diventare un mezzo di comunicazione come una volta. L'architettura produce non solo nuovi tipi di esperienze spaziali e interazioni con gli utenti attraverso tecnologie di realtà mista, ma consente anche allo spazio fisico di essere parte dell'Internet spaziale interagendo con ambienti fisici virtuali e remoti. Ciò creerà possibilità spaziali per l'architettura in attesa di essere esplorate e la metterà in un processo irreversibile di cambiamento e sviluppo.

Parole chiavi : Bit tangibili, Spazio ibrido, Interfaccia architettonica, Flessibilità nell'architettura, Architettura in realtà mista, Coesistenza, Adattabilità nell'architettura.

SUMMARY

Since the beginning of time, humans have transformed and improved their environment, tools, and lifestyles according to their needs and desires. This transformation in daily life and living dynamics has accelerated considerably, and the functional life of an architectural structure has been shortened compared to its structural life, thus causing the formation of dysfunctional and abandoned structures. This situation is one of the fundamental contemporary architectural debates, as it brings economic, ecological, and sociological problems. Popular approaches to this problem, such as functional restoration and adaptive reuse, are solutions to the problem after it occurs rather than a solution to the problem that caused the situation. On the other hand, the most pragmatic approach would be to develop an approach that would extend the functional life of the building and enable the building to keep up with the transformations without causing economic, ecological, and sociological problems.

In this context, enhancing the physical and functional flexibility of structures will prevent them from being reprocessed in order to maintain their function while also extending their functional life. In addition, mixed reality architecture is a mixed reality method that provides a flexible spatial topology encompassing physical and virtual worlds, and it contributes to the solution of the problem in this regard. However, neither the false promise of flexible architecture nor the inadequacies of mixed reality architecture application in architectural practice have resulted in a solution to this problem. This thesis introduces a new approach and design/guideline to mixed reality architecture by reframing architecture as an interface that reduces conflict and incompatibility between virtual and physical worlds and provides a solution to the problem of diminished functional life. Defining architecture as the interface between virtual and physical for collaborative mixed reality environments will increase the flexibility of space in physical and virtual terms, as well as create many new interactions and experiences. This interaction not only maximizes the flexibility of the space but also allows distributed spaces to interact in multiple ways, thus creating collaborative spaces. This will generate spatial possibilities for architecture waiting to be explored.

This research is about how mixed-reality technologies can 'augment' the flexibility in architecture by defining the architecture as an interface between virtual and physical and; how architecture should be designed so that present, remote and virtual spaces, users, and content can co-exist to provide the spatial needs of modern society.

The content of the research is as follows:

In the first chapter, the research was introduced, the fundamental questions to be studied and solved were determined, and the subject to be studied was summarized.

The second chapter, under the title of Flexibility in Architecture, in six parts, examines flexibility in architecture, what the theoretical and practical approaches are in this regard, and reviews a case study.

The third chapter, Architecture of virtual world, in 5 parts, examines the duality of virtual-physical notions, virtual architecture, and possible implementations of metaverse to architecture.

The fourth chapter introduces the concept of Mixed Reality Architecture. It examines Mixed-Reality technologies such as Augmented Reality, Augmented Virtuality, Tangible bits, and Mixed Reality boundary and their relationship with design through their contribution to architectural flexibility.

In the project chapter, the design concept is introduced, and design equivalents of the conceptual and theoretical expansions are made in the previous sections examined. All the physical and digital dynamics that make up the design are detailed, and their use is illustrated through sample scenarios and case studies with prototype studies.

In the last chapter, all studies are summarized concerning associated design, and its contribution to the literature is examined.

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1. INTRODUCTION

1.1. Research Questions and General Frame

Research Questions

- What kind of problems does the functional life of structures being shorter than their structural life lead to? How to fix these problems? How is this situation optimized?
- What is flexibility and adaptability in Architecture? What is the difference?
- Can flexibility of architecture optimize the inequality between the functional and structural lifetime of the architecture?
- What are Flexible Architecture approaches? How can it be improved?
- What is Virtual? What is Virtual Architecture?
- Are virtual spaces included in the future of spatial design?
- What is the role of the architect in the construction of virtual spaces?
- What is Metaverse? How should metaverse be interpreted from an architectural perspective?
- Can a relationship be established between physical and virtual spaces?
- What is, Mixed Reality? What are the concepts to apply it? What is the architectural approach to this field?
- How can architecture contribute to Mixed-Reality? What is Mixed-Reality architecture?
- What is the relationship between architecture and user experience & interface design?
- Can architecture be defined as an Interface? What does it mean to define architecture as the interface between the virtual and the physical? What is Augmented Flexibility?
- What is affordance? Could architecture be defined as spatial affordance in virtual environments?
- What is Hybrid affordance? What is its relationship with architecture?
- What is Computer-supported co-presence, and what can it contribute to architecture?
- How might mixed reality technologies allow for adaptive, flexible architecture?
- How to design architectural spaces for mixed reality, where present, remote and virtual people and content can co-exist?
- What kind of design/design guideline should be created to provide augmented flexibility? How it can be presented?

GENERAL FRAME

Main Aspect: Investigation of the contribution of an adaptive structure, defining *architecture* as a user interface between physical and virtual space to augment the flexibility of the space and thus to the functional life of the building.

This thesis will answer these questions and will produce a Mixed-Reality Architecture design as an Interface for a collaborative mixed-reality environment associated with adaptive structure and metaverse through mixed reality technologies.

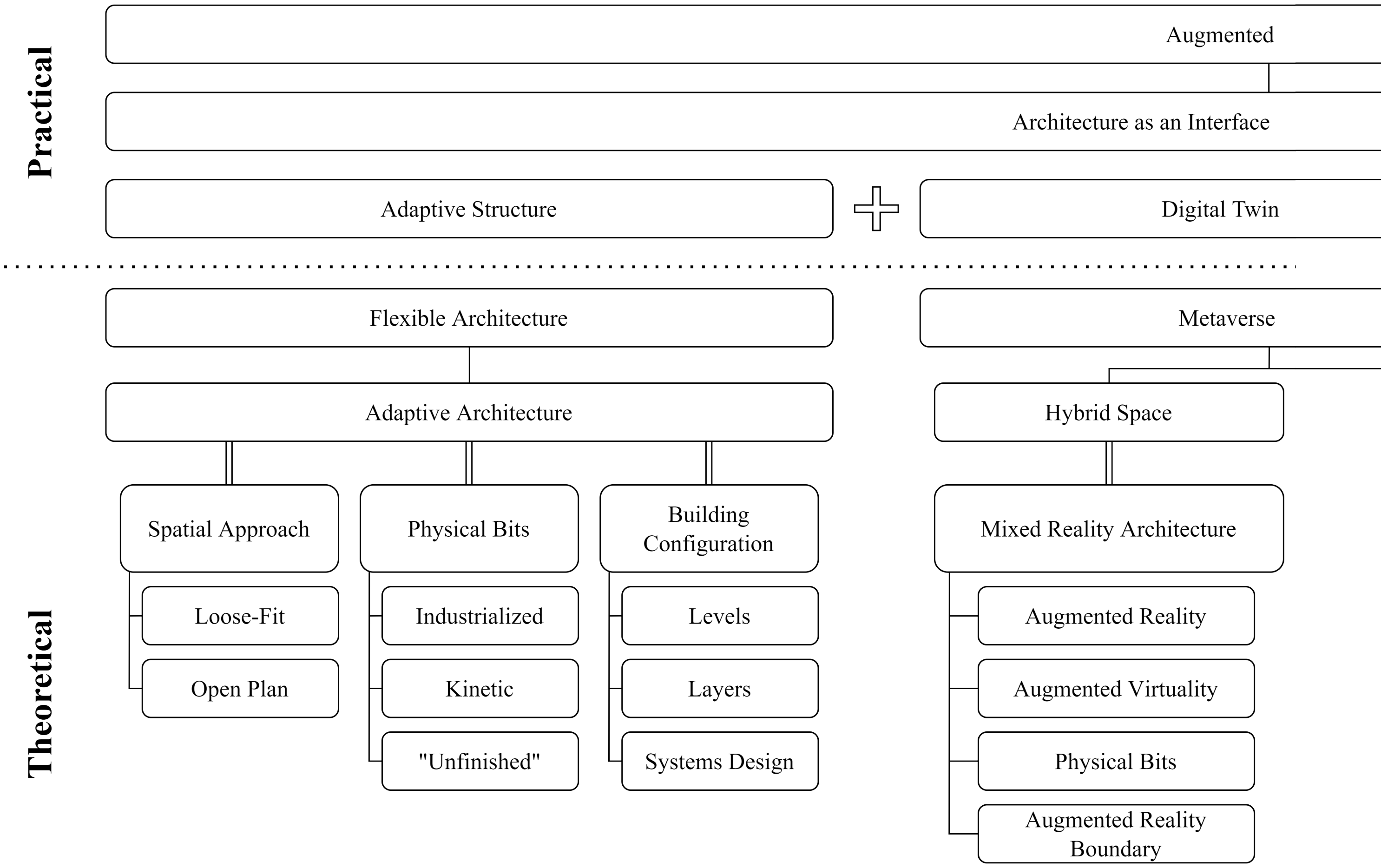
1.2. Outcomes of the Research

Architecture should be able to adapt to changing and developing conditions like a living organism. In this context, the functional sustainability of a building is as important as its structural sustainability. Therefore, there must be a mutual correlation between its functional and structural lifetime. Flexibility in architecture may be the key to getting this relation properly.

In order to increase flexibility in architecture, this study defines a digital layer to the layers of architecture in addition to its structural transformation capability. It provides an interface between physical and virtual by using the real-time adaptation feature of the structure. By using architecture as an interface, the space not only increases its physical and functional flexibility but also acquires virtual flexibility. This is called 'Augmented Flexibility'. In this way, the space gains the ability to expand and deepen virtually, as well as interact with other physical or virtual spaces that are separate from each other through Mixed-Reality Architecture. This concept turns this space into a collaborative mixed reality environment. In this way, many spaces can interact with each other, as well as directly or indirectly associated with the metaverse. Therefore, the design not only increases the flexibility of the space but also strives to move the definition of architecture beyond the physical.

As a result of the research, it can be observed that the flexibility of the space can be increased physically and functionally through an adaptive structure while defining an interface between physical and virtual space. Thus, augmented flexibility can be observed thanks to the interaction of many physical and virtual spaces in this way. This will not only add a different dimension to the flexibility of architecture but will also allow many new architectural experiences and interactions to be explored.

1.3. The Structure of Study



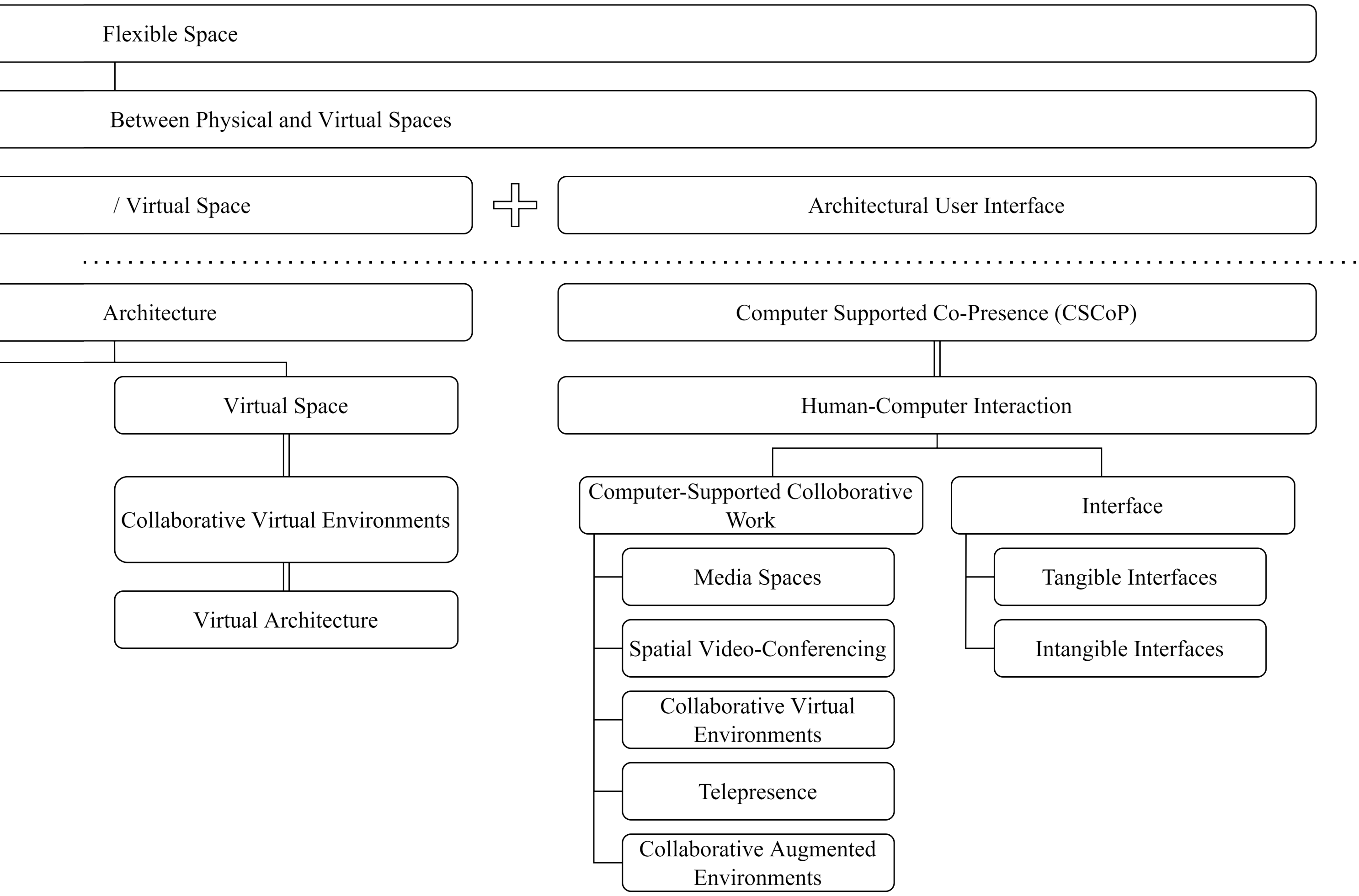


Figure 1: Flow Chart about the Structure of Study, illustrated by the author.

“The problem is temporary; thus, the solution must be as well. “

(Hertzberger, 1991)

2. FLEXIBILITY IN ARCHITECTURE

2.1. Introduction

Since ancient times, subjects such as flexibility in architecture and adaptability of the structures produced by architects to changing conditions have been the content of architectural thoughts. Today, with the acceleration of the transformation in daily living conditions combined with the architects' dream of a "future-proof" structure, flexible architecture has become one of the important research topics. However, before talking about flexibility in architecture, the terminology confusion that has occurred in this subject should be mentioned. When we look at the current research and daily architectural language, concepts such as flexibility, reconfigurability, adaptability, and polyvalence have multiple and often overlapping meanings that create massive confusion. Therefore, it is necessary to clarify this confusion.

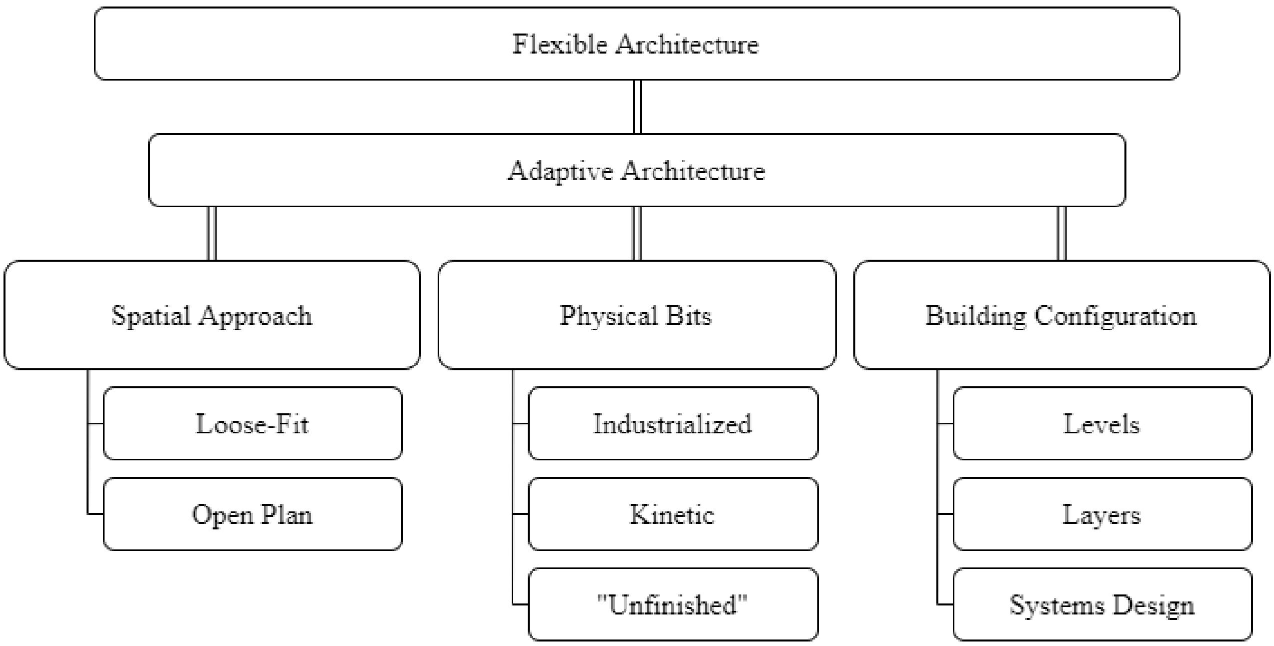


Figure 2: Flow Chart about the Terminology of Flexibility in Architecture, illustrated by the author

2.2. Terminology Study

In order to establish a consistent terminology on this subject, it is necessary to make an interrelated and comparative definition. In this context, flexibility in architecture is the feature of a building to adapt its spatial layout, functional content, and even its structure for transforming and developing situations and conditions. (Chaillou, 2019) Therefore, adaptability is a prerequisite for the structure to be flexible.(Schmidt III & Austin, 2016) In other words, the act of adaptation is the ability of the architecture to be flexible. We can position architectural flexibility as a framework definition for all these concepts from this perspective. [Figure 2] Therefore, we can explain the relationship between adaptation and flexibility in this way.

On the other hand, we need to bring a different perspective to clarify the term polyvalence, which is seen and used almost synonymously with these two terms. According to Hertzberger, who introduced this term to architectural literature, polyvalence is when a building can be used in multiple ways under several conditions and needs without changing how it was built. (Hertzberger, 1991) Although the expression gives some clues, it is still open to interpretation in a way that will be used with similar meanings to the other two definitions, and this causes confusion. In contrast, according to another expression of Hertzberger *'"Polyvalence" is the inherent capacity of an object to be reinterpreted for different uses over time'* therefore, polyvalence is not a physical adaptation of the space, but rather it is being open to interpretation in a way that the space will be used in different ways. (Hertzberger, 1991) Hence, the term introduced a dissociative variable into the subject. Whether the space needs physical transformation to show adaptation or not.

In this framework, if we divide adaptive structures into two categories; the ones that need a physical transformation on their physical bits and the ones that can be reinterpreted for different uses without physical transformation, the term polyvalence refers to this second spatial approach; Physical bits approach, on the other hand, refer to the physical or/and functional adaptation of the space through adaptation of its physical bits. The kinetic adaptation here may cover everything from the adaptation of the building elements to the partitions that determine the function in the building, to the reinforcements that support the action. However, it is necessary to expand this framework a little more to clear up the confusion. Reconfigurability, which is another concept used similarly to concepts such as adaptation and flexibility, is a self-explanatory word, and it is the layering of the building elements and the design of each layer in a way that allows reconfiguration in order to provide adaptation. Here, the adaptation is not open to interpretation like the spatial approach, polyvalence, and it is achieved by reconfiguring the pieces over the flexibility provided by layering, rather than the transformation of existing pieces as in the physical bits approach. Therefore, we can classify architectural adaptation under three headings: spatial approach, physical parts, and building configuration.

In summary, flexibility is the feature of architecture to adapt itself to the evolving conditions, and adaptation is the ability, a prerequisite for the structure to be flexible. In addition, adaptation is divided into 3 categories; the spatial approach in which the space does not need a physical transformation for adaptation but is open to interpretation for different uses, the physical parts approach which uses the movement or properties of the physical parts for adaptation, and the building configuration approach that allows the building to be reconfigured by stratification to ensure adaptation. [Figure 2]

Figure 3: Vitruvian Primitive Hut by Marc-Antoine Laugier from 1755

2.3. Flexible Architecture Overview

Since the beginning of time, humankind has produced various tools and clothes in order to adapt to their environment and changing conditions and have transformed the nature around them for this purpose. Architecture has also been one of his most effective and powerful tools (only spatial one) in this adaptation effort and has been the most critical element in the struggle for nature since prehistoric times. They created architectural spaces for themselves by transforming, crafting, and combining parts of nature such as caves, wood branches, plants, animal skins, and soil around them to meet their own needs. [Figure 3] According to Horning, “Prehistoric shelters were 'functional responses to local climate, the availability of materials and temporal requirements, nomadic, seasonal or settled.” In addition, the produced architectural spaces not only protect people from climatic conditions and predators but also produce functions that facilitate daily life.(Horning, 2009) These spaces consist of spatially wide singular openings (multifunctional spaces) shaped by environmental conditions in which many activities occur. We can see these openings as the most primitive versions of Herzberger's adaptive polyvalence design, which is open to interpretation to allow for different uses. In this direction, while the space itself provides the adaptation of the people to the environment, the adaptation of the space to the users and evolving conditions is inevitable.(Hertzberger, 1991)

The transition of human civilization from a hunter-gatherer society to an agrarian society began to give a much more diverse and more meaning to architecture. As the first civilizations began to grow, architecture produced different types of structures; temples, amphitheaters, bazaars, and public and cultural buildings. In addition, the development of new functions produced new building forms and types, while the building elements remained relatively simple, repetitive, and discrete. Thus, during the early period, many building functions remained static for many generations, meaning stabilized needs and functions matched the life of the building. (Schmidt III & Austin, 2016)

Throughout pre-modernism, the adaptation of the architecture with the traditional Japanese architecture's wa-shitsu approach, where the empty space is defined by the users (Schmidt III & Eguchi, 2014) and the English terrace houses, the Italian Renaissance palazzi and the Dutch canal houses, which exhibit a spatial generosity is often dominated by a single dominant room surrounded by subdivided auxiliary spaces that can be adjusted over time to develop and transforms until modernism.

Although the idea of flexibility in architecture can be observed in the examples of the past, it has only become explicit with the modernist movement. The Industrial Revolution was one of the significant catalysts that created an increasing rate of social change with new building materials, building types, and spatial standards, and together it led to new urban conditions and demands for buildings that could adapt to change.

Modernist architecture desires to express "truth" by revealing the structure and mechanical systems along with simple forms. This approach was embraced with the aspiration that architecture should express contemporary technology through new construction methods, new materials, and new ways of building techniques. The progression of framed construction has separated the structure from the elements that make up the spatial layout removed the load-bearing function of the walls and partitions, and in addition, entirely separated the outer shell from the structure with the development of lightweight cladding systems. This process removed the structural role of the architectural elements, allowing freedom in the design as well as enabling the architectural elements to be transformed to adapt through time. (Eisenman, 2014, p.)[Figure 5: Dom-Ino House]

Modernism's promise of abstract symbolism gives rise to the idea of "pure form" and the principle "form follows function." In other words, as Jencks put it, "what the building wants to be," meaning that the building itself could easily define its form through its function. (Jenks, 1999) However, according to Hertzberger, this approach led to overdetermined solutions, single-functional rooms, structures, and the built environment; and led to the division of functions in the pursuit of spatial efficiency. (Hertzberger, 1991) Therefore, this contradiction leads to the development of opposing approaches. Today, many approaches, such as the separation of the physical existence of the building and the actions of the users, the ownership of the space, constantly variable functions, kinetic architecture solutions, etc., also feed this discussion. (John Habraken, 2008; Schneider & Till, 2007; Town & Rabeneck, 1974)

2.4. Adaptive Architecture Design Approaches

Further in this section, we will briefly examine eight different adaptive architecture approaches in developed to reach flexibility in the architecture expressed by Schmidt & Austin in 3 categories as Spatial, physical bits and building configurations. [Figure 4]

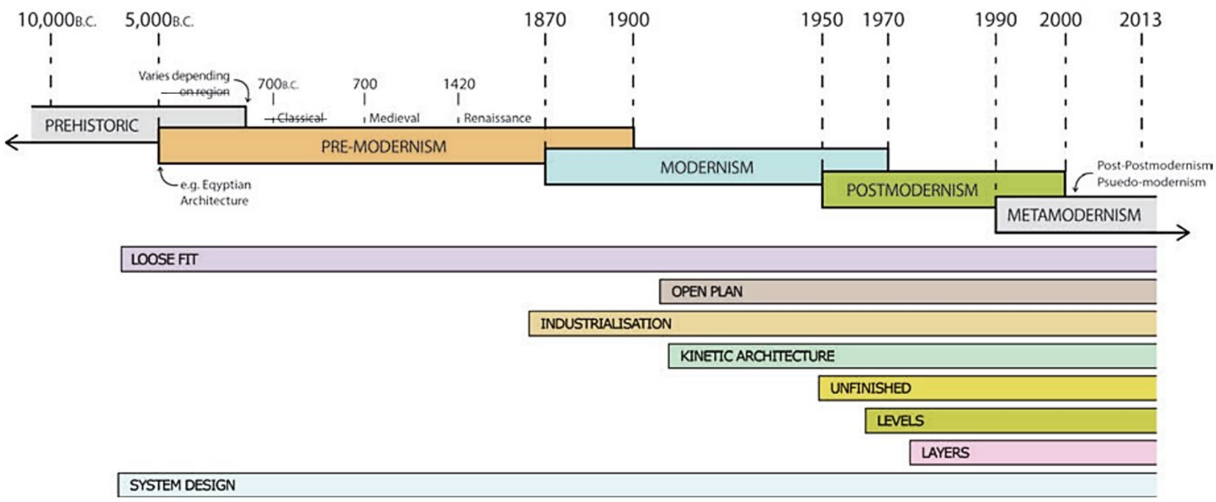


Figure 4: 8 approaches expressing the general adaptive architecture relative to a general point in time from which they emerged by Schmidt III & Austin from 2016

2.4.1. Spatial Approach

2.4.1.1. Loose-Fit

The loose-fit approach predates the rise of the modernist architectural era, expressing the capacity of a pre-modern building to adapt to changing conditions. Thus, the approach can be seen as an advanced version of the multifunctionality of traditional prehistoric architecture, which is concerned with providing ample "generic" space for possible functions and activities, rather than setting spatial standards for sharp predetermined functions.

The loose-fit approach minimizes the pre-determination of the function, allowing the user to determine the function of the space (or, according to Hertzberger, to be open to user interpretation). In addition, the generous dimensions and simple ambiguity of the space make it open to different potentials/uses.

2.4.1.2. Open Plan

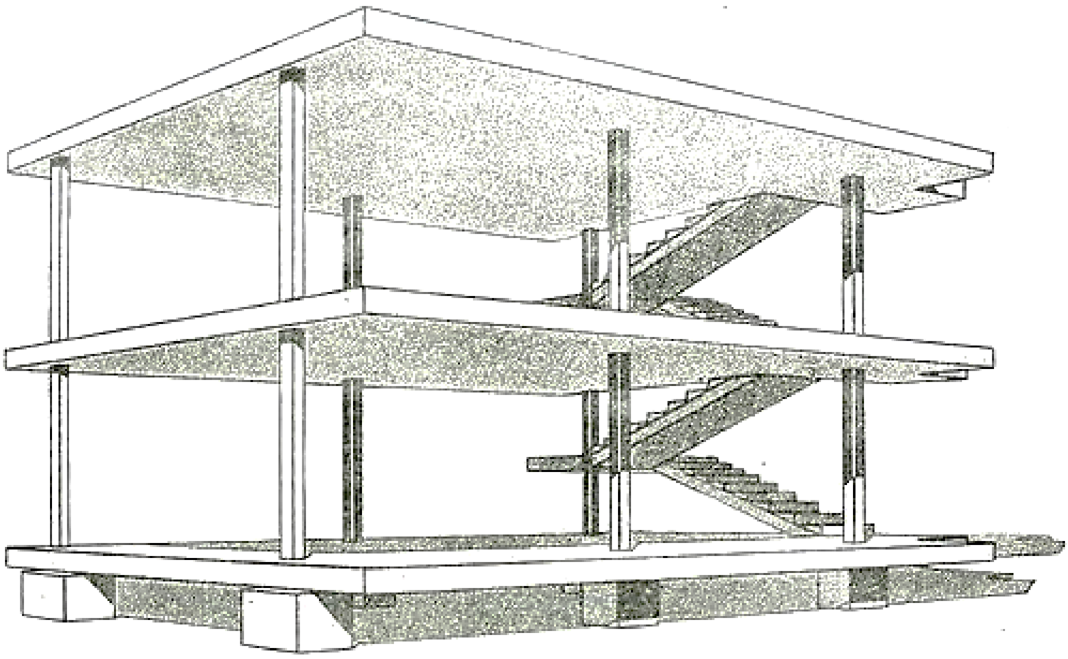


Figure 5: Dom-ino House by Le Corbusier

In 1914, Le Corbusier designed the Dom-ino House [Figure 5], a two-story building (floors, columns, and stairs) with partitions. Open plan, or in other words, Plan Libre, would allow the architect and/or users to determine the functions with ultimate flexibility through the complete separation of the structure and other architectural elements. Thus, non-bearing walls and partitions can make contributions that were not possible before to the design by acquiring additional tasks that support the functional requirements or spatial concept of the design.

2.4.1.3. Spatial Summary

The spatial approach to adaptive architecture is examined under two propositions. The first proposition is an ample space called Loose-fit, open to user interpretation, and the second proposition encourages flexible use of space by separating the structure and all other architectural elements. These two approaches do not contradict each other; they can also be used together or sometimes connect with the physical approach, which is the next one.

In summary, With the spatial approach, while obtaining loose spatial dimensions in spaces with functional freedom and user customization; On the other hand, we produce high capital costs and potential wasteful redundancy.

2.4.2. Physical Bits Approach

2.4.2.1. Industrialized Architecture

The desire of modern architecture to express "truth" by revealing the building structure and mechanical systems encouraged the expression of modern technology in buildings, and thus industrialized architecture offered accelerated construction, coordinated repeatable building systems (modular), and open, reusable, or transformable components between projects.

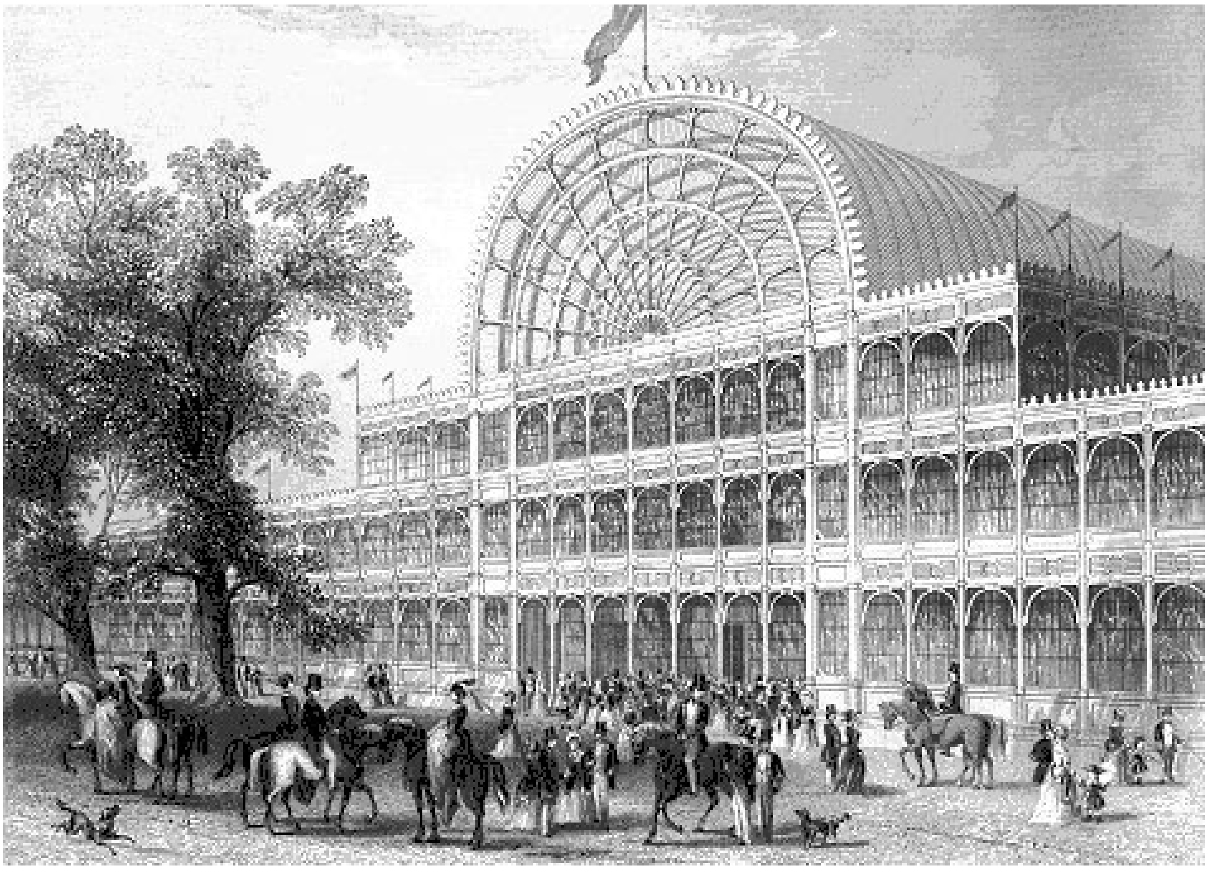


Figure 6: Crystal Palace by Sir Joseph Paxton

The movable or demountable bits of such buildings were intended to accommodate multiple functions – often without the necessary spatial standards- in a single spatial space. Thus, this approach to architectural adaptation is to try to do more with less. In addition, this approach associates architecture with architectural production methods and encourages the transfer of production technologies to architecture. Finally, these industrialized, standardized components promised the user freedom of choice and control over space, as these components were often movable or demountable.

The architectural space is kept as homogeneous as possible so that it can host any function, thanks to the versatility and customizability gained through specific movable or demountable physical bits. In this way, it provides freedom in function selection by increasing the user's control over the building and space.

2.4.2.2. Kinetic Architecture

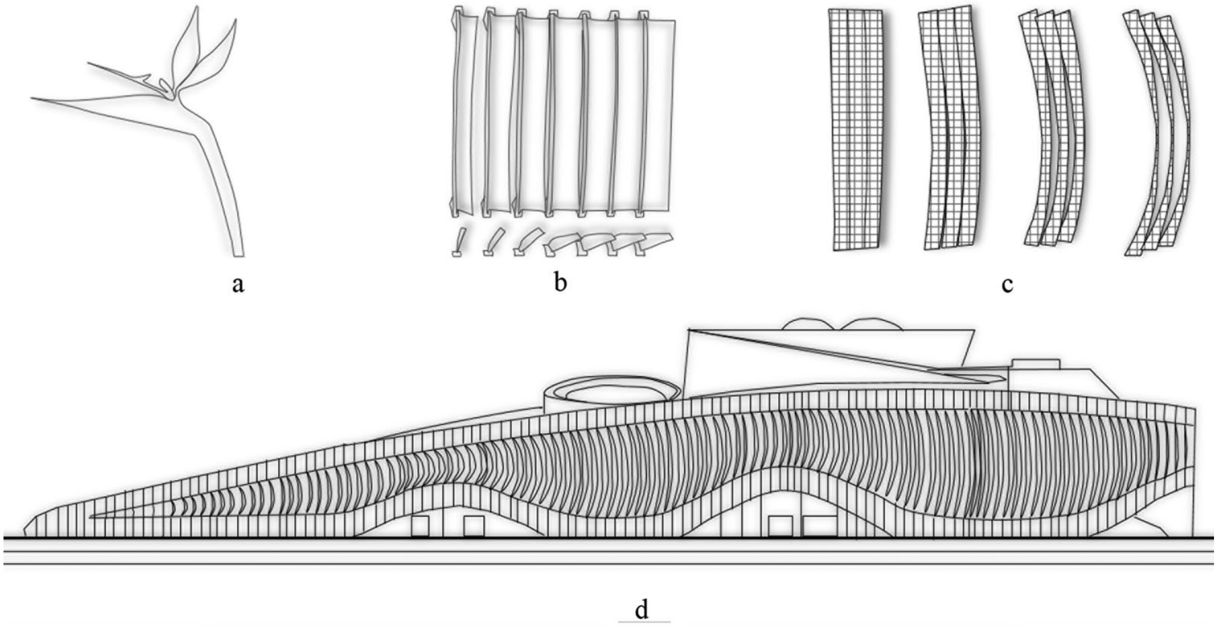


Figure 7: Thematic pavilion for EXPO 2012: (a) Bird-of-Paradise flower; (b) basic Flectofin principle; (c) project Flectofin louvers; and(d) Lamella façade – movement from closed to 60° opening by SOMA lima from 2012.

Kinetic architecture is the ability of the building to change its shape and position in order to adapt to changing and developing situations and conditions, from the smallest scale constituting the building to the building itself; and it is fed by the desire to move away from the concept of the building as a single monolithic object over time and to create a new unlimited libertarian architecture.

The structure consists entirely of or to a certain extent of movable, mechanical parts, or the elements that make up the structure can interact or change within themselves or with external parts. In the kinetic architectural ideal, all parts of the building have the ability to move and transform and the ability to adapt the physical or spatial characteristics of the building to changing situations.

Therefore, much so that there is the idea that the place is in constant evolution as if it were a living organism, and even that it is alive. According to Jencks, these structures argue that planning with the future (for multiple realities rather than a single reality) rather than planning for the future provides the user with a level of uncertainty and empowerment that would allow any activity to take place in a single spatial space and with this, architecture also plays a performative role where it can allow any activity in an adaptive structure by providing multi-interaction and real-time response speed and transformation. (Jencks, 2013)This is on the agenda of kinetic architecture.

2.4.2.3. "Unfinished" Design

In the "unfinished" design, the architect delegates the authority to the user to transform the space according to his current needs and conditions. The concept is based on the interaction between the user and the architecture, and the user becomes an active part of the architecture.

According to Hill, this approach is similar to software design, and the designer should design in a way that allows a two-way interaction between the user and the building. The building should "learn" the user's needs, and the users should "teach" what kind of adaptation to make. By making the user an active participant, this series fundamentally reconsiders the relationship and role between designer and user.(Hill, 2006)

Hertzberger likens architecture to a musical instrument that the users can play freely and with their own interpretations. (Hertzberger, 1991) On the other hand, Brand considers this as the designer handing over some of his architectural rights to the user, a surrender. According to him, some areas or layers of the spatial design should be entirely designed by the architect, and some layers should be incomplete but open for customization and accessible and usable by the users.(Brand, 1995)

2.4.2.4. Physical Bits Summary

This design approach has skewed from the use of technology through the development of industrialized components to today's adaptive and customizable parametric elements. Critics of adaptation through physical bits argue that it is possible to predetermine the transformation required for adaptation. However, the main issue here is that the architect produces suitable instruments that will involve the user in the design process, rather than predicting the future adaptation and transformation of the space and designing a suitable movement. The discussion focuses on whether the user is willing to interact with the building rather than the possibility of such an architecture. While this design principle increases the adaptation of the building to changing conditions and needs, it makes the building much more complex and requires user participation.

2.4.3. Building Configuration Approach

The building configuration approach examines the building in 3 different categories as levels, layers, or subsystems for a better understanding of the stratification of the structure. This stratification can help examine the effects of the structure's change during the adaptation process.

2.4.3.1. Levels

The strand of levels, or SI (support-Infill), equate the control levels of the individuals using the building with the environmental levels and determine the physical boundaries and social roles. For instance, Kendall (2009) examines the building on two levels; supports - design related to long-term use, public or shared service, i.e., urban, and environmental; and filling – shorter-term use, design of the user, that is, things that depend on the structure and the short-term user. For example, the façade types of all buildings on the street are determined by the authorities; however, the same authority has relatively less or no control over the interior of the buildings; or the building management has authority over the doors of the apartments, but the owners of the apartments have infinite flexibility on the inside.

The result is a system of levels that is more adaptive to the user's needs in the short term but also meets the long-term requirements on a larger scale. A balance between change and stability is provided by the stratification between the social and physical components of the architecture. This prevents the adaptation of the structure from harming the long-term needs or public structure while making short-term transformations.

2.4.3.2. Layers

The strand of layers suggest that building elements have different lifetimes that need to be built differently. Thus, a stratification is formed in the structure in a way that is proportional to the material and functional life. In this way, when a transformation is required for adaptation, it occurs only in the necessary layers, optimizing the cost and speed of the transformation.

The concept was first introduced by Frank Duffy, who argued that buildings should be measured in terms of time, not in material terms. According to Duffy(Duffy, 1990), the reconceptualization of buildings and the stratification of space improve our understanding of the initial and recurrent building costs.

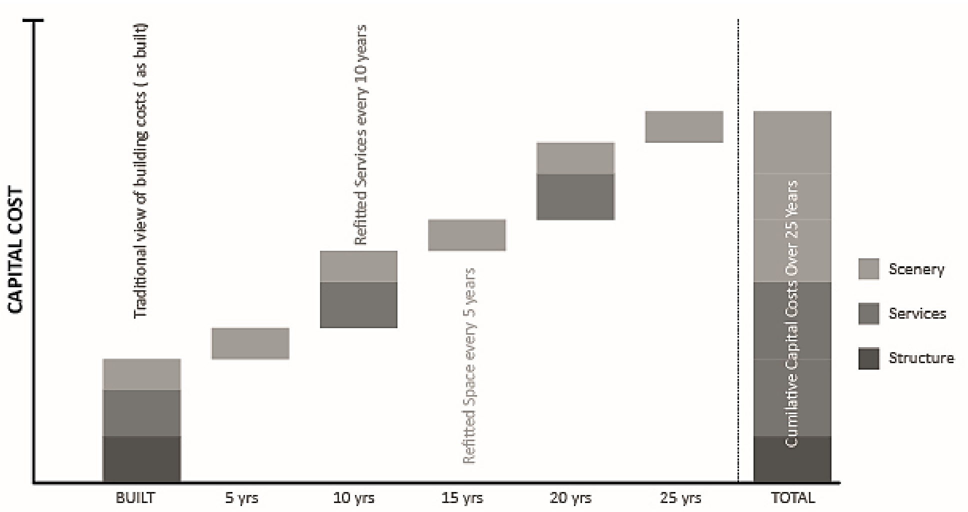


Figure 8: Duffy's reconceptualization of buildings and the stratification of space

Brand expanded on Duffy's concept by seeing the layers as a series of shear layers that change at different speeds. [Figure 8] As more layers are connected, more difficulties and adaptation costs will arise, so the design will be driven by slowly changing components. In fact, it is not only the architectural elements that define a layer but also the function of a collection of elements as a whole. (Brand, 1995)[Figure 9]

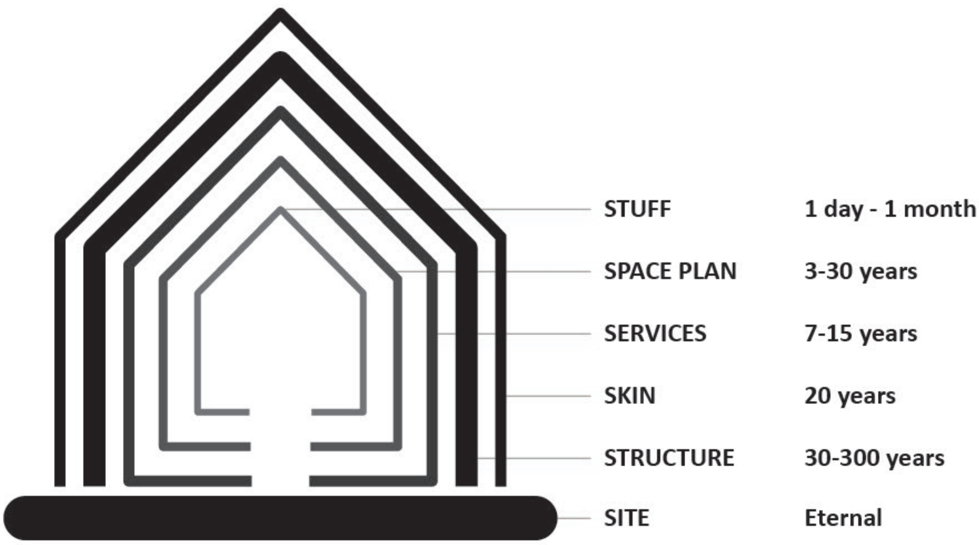


Figure 9: Brand's Shearing Layers of Change

2.4.3.3. Systems design

Throughout history, architectural theorists have developed many decompositional studies, definitions, and approaches to it, from the architectural elements of Vitruvius through the approach of Alberti, the decomposition of Walter Bogner, to the transformable parts of Schneider and Till, in order to understand, comprehend, improve, and express the architecture. (Alberti, 1988; Schneider & Till, 2007; Wotton, 1897)

The strand of systems design is that stratification over different functions increases the controllability and adaptability of complex design and systems. According to Alexander, systematically breaking down a complex design problem into smaller parts makes the problem more manageable. According to this approach, the object is decomposed into subsets of parameters; these subsets are analyzed and reassembled to meet all needs, leading to systematic design.(Alexander, 1964)

Today, this approach has evolved into parametric tools such as BIM that work with algorithms to control variables and create complex forms supported by advances in computer-aided design to manufacturing methods. BIM, i.e., building information modeling, is the foundation of digital transformation in the architectural engineering and construction industries while also aiming to code systematically, edit, manage, update, and monitor components from concept to use.

2.4.3.4. Summary of Stratification

The Building Configurations approach, i.e., levels, layers, and systems design methods, try to balance change and stability by subdividing the building into separate parts. In this context, the system design strand defines the different functions as a method of layering, while the layers strand defines the life cycles of the components that make up the structure. In addition, the levels strand divides the physical and the social into layers, arguing that flexibility cannot be achieved without the other. In summary, since the structure will be stratified and each layer will be handled separately for adaptation, the need for adaptation will be understood more clearly, and the adaptation time and cost will be reduced by concentrating the operation on a single layer.

“Architecture should have little to do with problem solving - rather it should create desirable conditions and opportunities hitherto thought impossible.”

(Price, 2003)

2.5. Case Study: The Fun Palace of Cedric Price

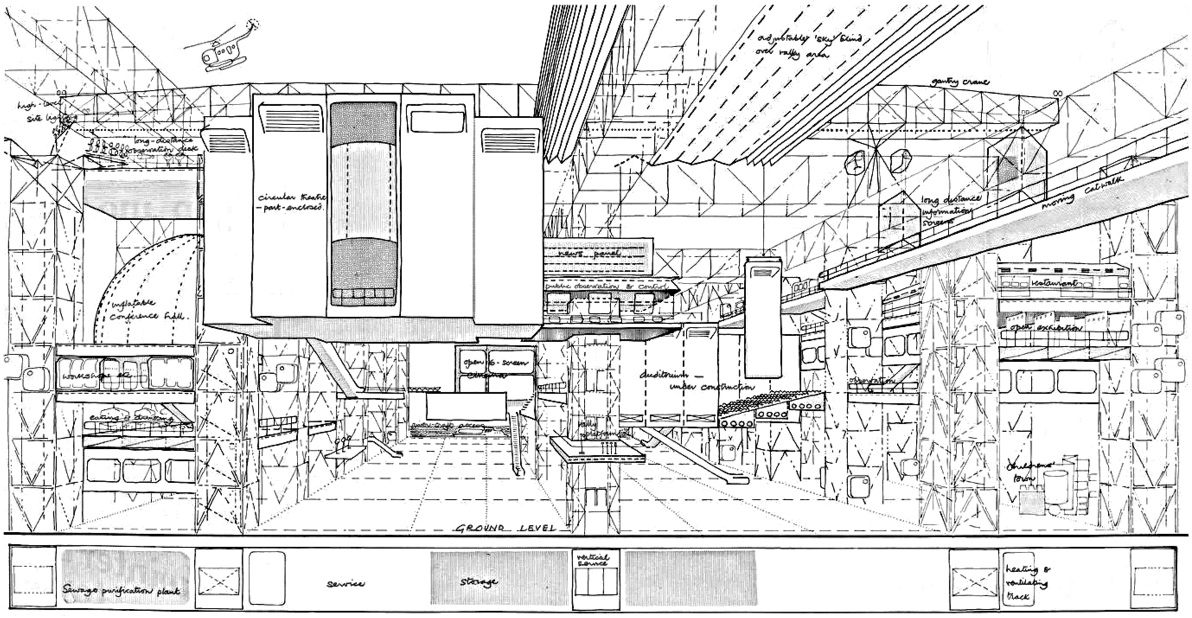


Figure 10: Fund-raising brochure for Fun Palace, Cedric Price Archives, Canadian Centre for Architecture, Montreal

> *"What is it?' Indeed, just what was the Fun Palace? It was an event, not a 'thing'"* *(Price, 2003)*

Cedric Price has given architecture a perspective brought by a unique synthesis of various contemporary discourses and theories such as cybernetic sciences, information technologies, game theory and even situationism and theater to produce a new improvisational architecture in order to adapt to the sociocultural post-war era, where change is continuous and accelerated. The Fun Palace is far from being a conventional architectural work in many aspects, rather it was a socially content and user interactive machine and was able to adapt to the changing socio-cultural needs and conditions of its time and place.

The design provides spatial spaces in its own way with using cranes and prefabricated modules in an improvised architecture for its users to escape from the daily routine or go on a journey of learning, creativity, and self-realization. In many ways, it was one of the most innovative and creative architectural proposals of its time, such as defining new roles for the user regarding the program of the space, carrying many discussions such as cybernetics and game theory to architecture.

The Fun Palace project started in 1962 with the collaboration of young architect Cedric Price and theater producer Joan Littlewood. Littlewood was dreaming about a new kind of theater; a pure performative theater experience beyond the stage, performers, and audience; She dreamed of a participatory, self-actualization theater where people could experience theatrical entertainment not as spectators but as participants. Price, on the other hand, was in research of an interactive, spontaneous, and improvised architecture at that time, and this gave rise to the idea of the Fun Palace project.(Price & Littlewood, 1968)

The existence of The Fun Palace was to respond to the ever-changing and developing demands and needs of individuals, rather than hosting exhibitions and events for a generalized public previously produced by the architect as a high-intellect. This also meant redefining roles upon design. It is a new and ambitious approach to architecture.

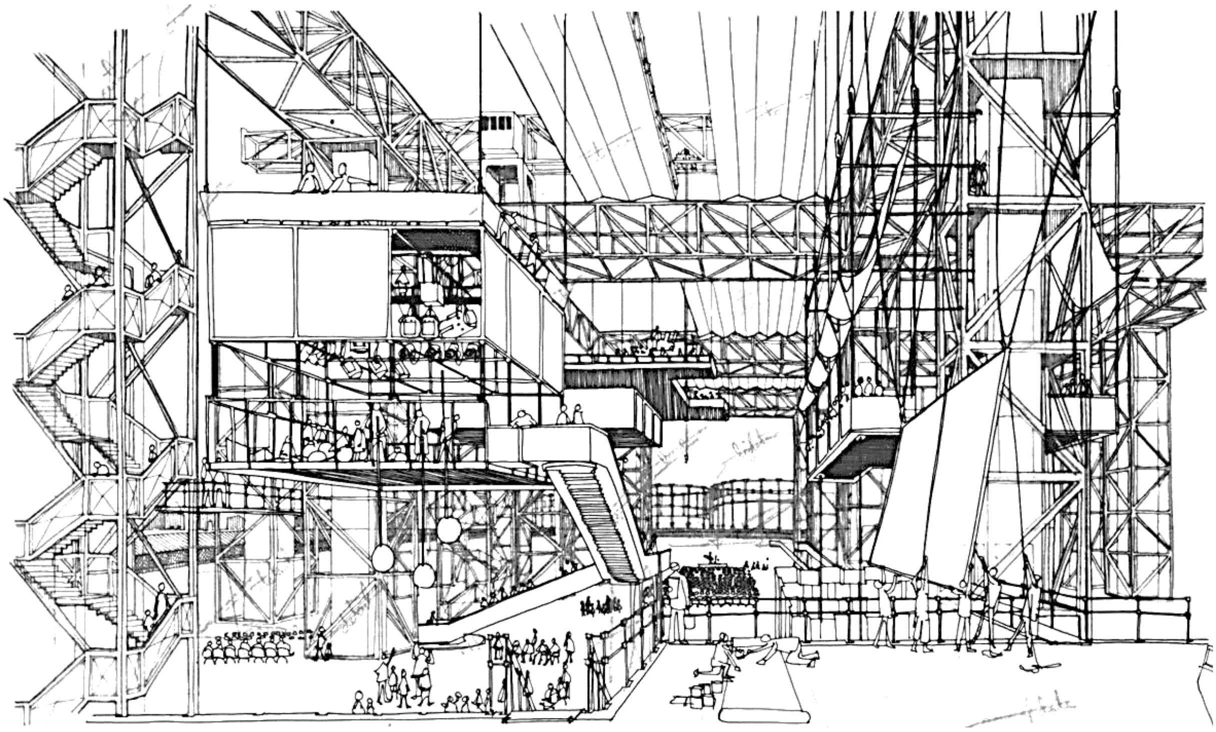


Figure 11: Interior Perspective of Fun Palace. Cedric Price Archives, Canadian Centre for Architecture, Montreal

As Cedric Price envisioned for his Fun Palace project, an architecture with an indeterminate form and an unspecified program was a stark contrast to conventional architectural practice. However, Price insisted on the impossibility of knowing beforehand the ever-changing and evolving needs and desires of users, so its structure must be adaptable to a constantly changing and fluid program. In addition, an initiative that is not limited to a specific program definition will open up unforeseen possibilities.

Despite the fact that improvisation, ambiguity, and open-endedness expand and excite one's imagination in many fields such as art, it is a very difficult task to find a practical way of design integration that will realize improvisation with architecture, especially with the technology of that period, with a familiar architectural approach. Therefore, instead of relying on mechanics and determined design methodologies, Cedric Price established a relationship between architecture and emerging fields such as cybernetics, game theory, and information technology, which are tools for modeling and systematizing chance and indeterminacy.

The Fun Palace project was developed with the contributions of consultants, including scientists, sociologists, and cyberneticists, formed by Cedric Price's vision for modeling chance and indeterminacy in architecture. While Norbert Weiner's cybernetics studies contribute to the short-term adaptation of daily activities that the project will provide; The mathematical game theories of John Von Neumann formed the basis for the long-term adaptive performance of the Project.(Mathews, 2006) In this way, the Fun Palace project, which moved away from conventional architecture, defined a "virtual architecture". A virtual architecture does not have a single program but can reprogram and reconfigure itself to accommodate an infinite variety of functions.

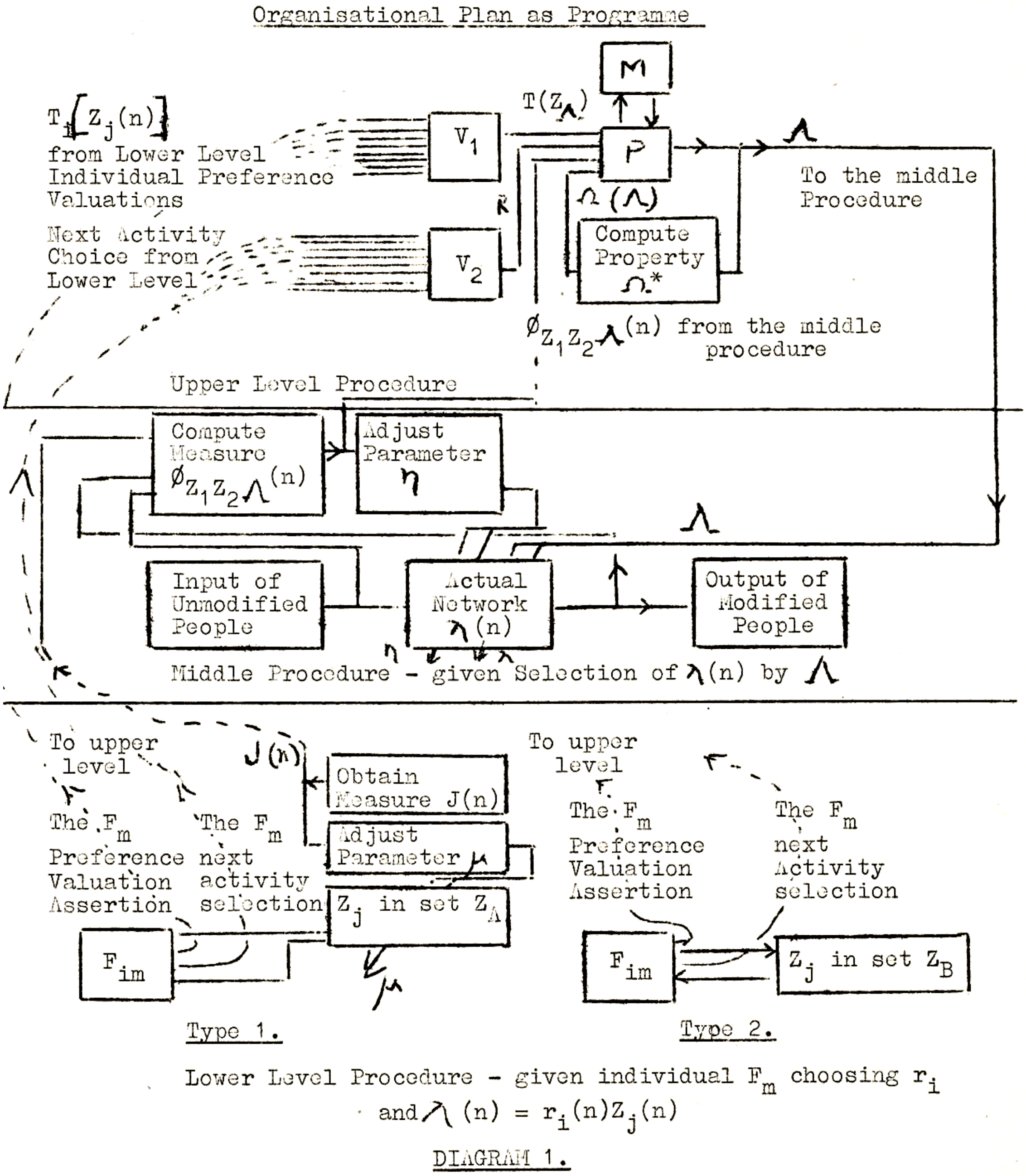


Figure 12: "Organizational Plan as Program", Cybernetic diagram of the Fun Palace program by Cordon Pask. Cedric Price Archives, Canadian Centre for Architecture, Montreal

In this context, cybernetics expert Gordan Pask introduced an algorithmic system that treats "human behavior as data". [Figure 12](Hobart & Smith, 2005) What makes building adaptation significantly more difficult is the numerical uncertainty and its effects of the organic elements (human and society) of architecture. Therefore, eliminating indeterminacy by using human behavior as data removes this challenge.

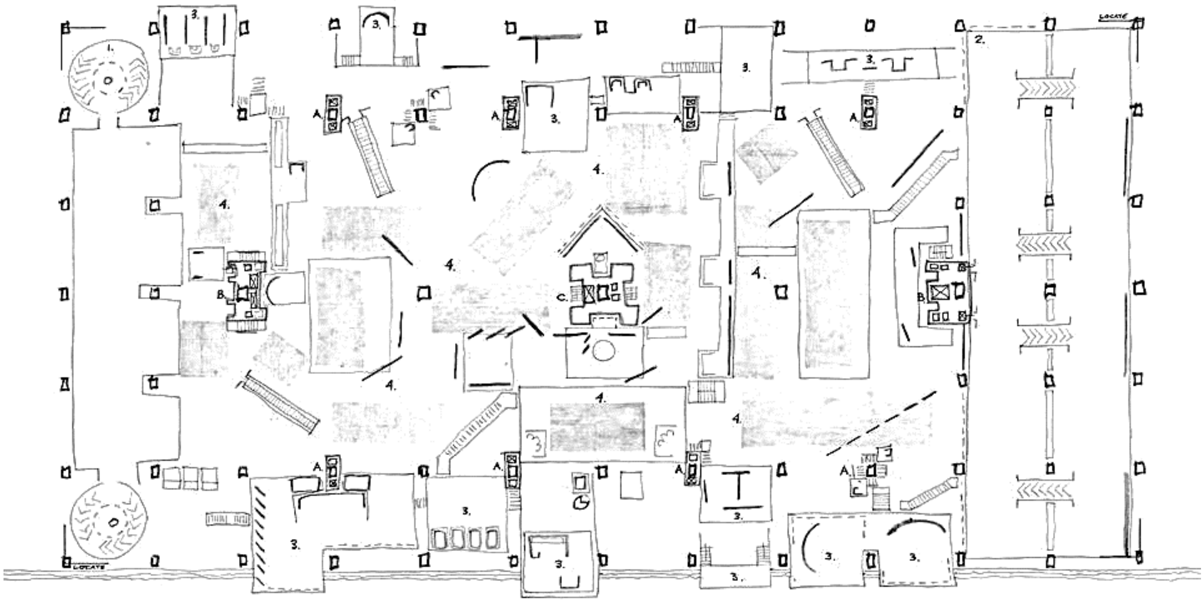


Figure 13: "Diagrammatic Plan", showing areas of variable activities. Cedric Price Archives, Canadian Centre for Architecture, Montreal

As mentioned, the Game Theory study of Fun Palace is about predicting and planning long-term adaptation strategies, while Cybernetics is about the short-term behaviors and daily activities in the Fun Palace. Therefore, Game theory not only responds to changing conditions, as in cybernetics, but also organizes the long-term configuration and strategy of complex systems that seem to be run by chance. In this respect, game theory does not have a temporal boundary like cybernetics. Game theory models the dynamic behavior of complex social and economic systems while explaining the indeterminacy and synergetic interaction of factors. Hence, game theory and cybernetics can be used together within a highly indeterminate system as thought for Fun Palace, thus they are not mutually exclusive.

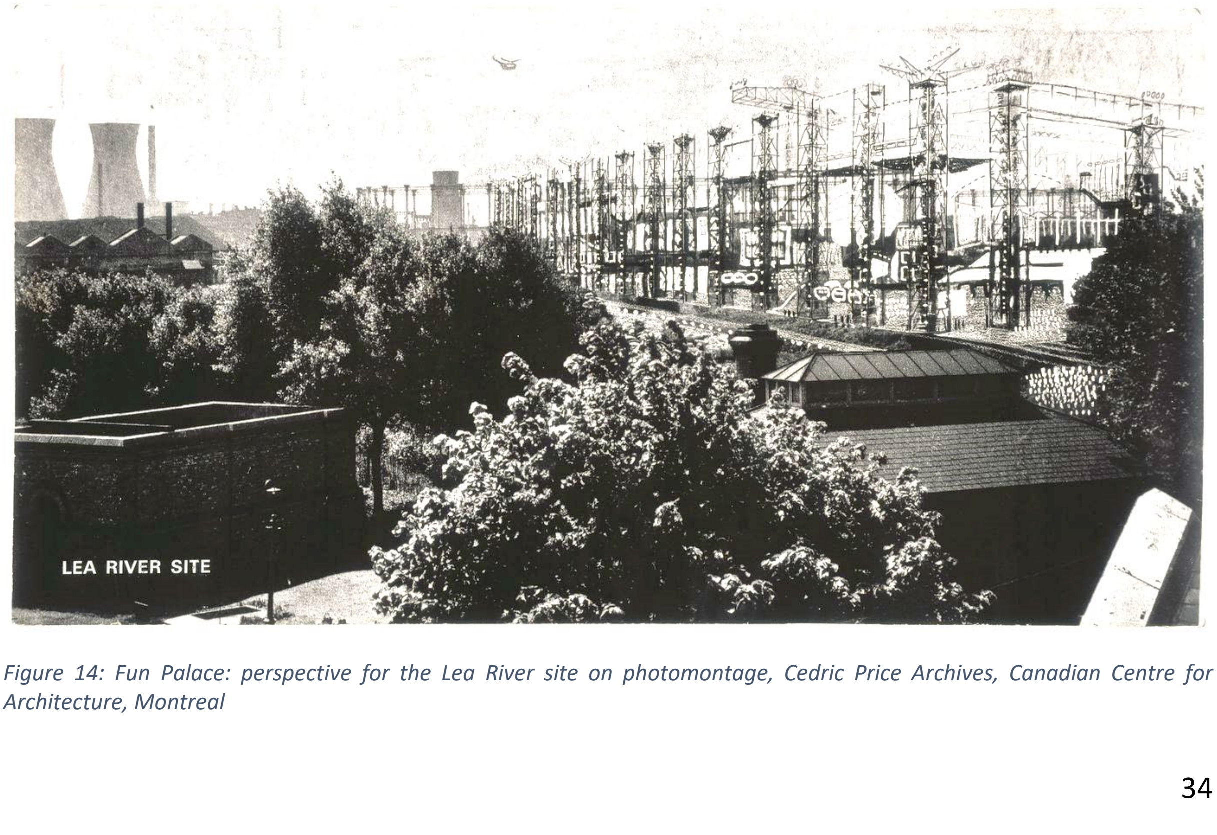


Figure 14: Fun Palace: perspective for the Lea River site on photomontage, Cedric Price Archives, Canadian Centre for Architecture, Montreal

The Fun Palace is an unprecedented architectural work as a synthesis of technology, cybernetics, and game theory; and Cedric Price's motivation for the Fun Palace was social, people-oriented, and in that respect the idea of individual liberation and empowerment focused architecture. Therefore, achieving this synthesis was not the objective, rather it was a tool. In addition, He defines architecture not as a encloser, symbol, or monument, but as an activity where human and space meet.(Price, 2003)

> *"The Fun Palace wasn't about technology. It was about people."*
>
> *-Cedric Price*

When Cedric Price's Fun palace Project is evaluated from the point of view of flexibility in architecture, many implications will emerge. Theorists and researchers develop several approaches to understanding complex issues. One of the most common approaches is to categorize and group similar designs and attitudes in a systematic way to develop a complete understanding. However, categorizing designs often helps us understand them better, but it does not do much because many designs may have features that cannot fit into a single category. As an example, it can be observed that the Fun Palace project has traces of almost all flexible architectural approaches.

Since the primary purpose of the Fun Palace project was to design a project that can adapt to changing and developing needs and conditions, it bears traces of almost every approach to flexibility and adaptation in architecture. For this reason, it is clear that Fun Palace is one of the most relevant case studies to comprehend Flexibility in Architecture.

In this framework, when the permanent components of the project are examined, it can be observed that these components are just the frame structure of the building that will later host the changes as if it were a blank canvas. The Fun palace project consists of large, wide, loose-fit architectural spaces that can be interpreted to adapt almost every program, function, and activity; It also bears traces of open-plan since the only thing that is permanent among the architectural elements that make up the building is the frame structure (like Dom-ino House). However, this observation is only the basis of a much more complex system.

Generally, it can be observed that researchers who examine the building in terms of adaptive architecture define the Fun Palace project as an "unfinished" design. Since this is probably the most inclusive definition, it can be a correct statement. However, it is quite an understatement.

As mentioned in the previous section, the physical parts approach of adaptive architecture consists of industrialized architecture, kinetic architecture, and "unfinished" architecture. The Fun Palace project can be defined as industrialized adaptive architecture, as it consists of the idea of combining and reconfiguring modular, industrial parts in order to accelerate the transformations within and to make them sustainable; Due to dynamic elements like cranes and winches that have become a part of the structure to realize these configurations and transformations, it also bears traces of the kinetic architecture. Besides, the Fun Palace is an "unfinished" design, as the most comprehensive and general definition, since nothing is fixed in the building except the structure, and it is a continuous change, a process of self-construction.

In addition, the building configuration approach was used to ensure the continuity of the adaptation in Fun Palace. It is built on the idea of layers that the elements that make up the building have different lifetimes to ensure the transformation and the continuity of the transformation in the building. In this direction, materials, construction styles, and technologies compatible with the activity life are used in projects such as the fun palace, where some activities are planned for ten days and some for ten years; This ensures the possibility and sustainability of adaptation. Furthermore, cybernetics and game theory determine transformation strategies, as they stand out as system designs; this also shapes short and long-term transformations by defining levels by acting as support and fill. The Configurable elements, on the other hand, are a systems design that provides the transformation and adaptation needed by all subsystems.

In conclusion, when the Fun Palace Project is examined, it establishes a connection with all the adaptive architectural principles and approaches defined in the previous section. In addition, with the virtual architecture defined by the project also sheds light on a concept beyond these approaches. This situation also shows that there is a fluid, intricate relations between these approaches and concepts due to the nature of Flexibility.

2.6. Developing Flexibility

Under the title of Flexibility in architecture, the necessity, possibility, approaches, and applications have been examined. Flexibility of architecture to adapt in order to respond to current needs and conditions brings a sustainable approach to economic and time optimization as well as its socio-cultural contributions to daily life. Every building is flexible to a certain extent, many approaches to this have been introduced in literature, nevertheless it has become a special solution by breaking away from architecture. However, flexibility has become a necessity rather than a useful approach.

Flexibility in architecture can be examined through spatial, physical, and building configuration approaches through adaptability. Adaptation in architecture inherently involves a kind of future-proof ideal. In this framework, an adaptive building defines a virtual architecture that will accommodate configuration and transformation by responding to future needs and conditions with its adaptation. And all of these adaptability approaches try to realize this idea of "future-proof" architecture with the virtual architecture with spatial possibilities they define through their own method.

In addition, adaptation can be the result of user structure interaction, communication. Therefore, to the extent that this interaction is designed and programmed, adaptation takes place. This situation, as will be discussed in more detail in the continuation of the study, gives rise to the fact that the architecture is an interface that needs to be designed for interactions with the user. Rather than creating an interface between the inside and outside of the architecture, as discussed in the past, the adaptive architecture defines an interface between the user and the virtual architecture in which the future function will be accommodate. In the next chapters, the inclusion of digital spaces, metaverse and mixed reality spaces in this discussion will broaden and deepen the notion of virtual architecture and will provide a clearer understanding of the interface that will be created by adaptive architecture.

In summary, the flexibility of the space is directly proportional to its adaptability, and that is directly proportional to the quality of the interaction between the user and the space. This study defines the architecture as an interface, designing the interaction between the virtual architecture and the user, and realizes the adaptation. The design of this interaction will be one of the biggest research issues that architecture will discuss today and in the future.

3. THE ARCHITECTURE OF THE VIRTUAL WORLD

3.1 Introduction

After the information technology revolution in daily life, people's use of the term "virtual" has become quite frequent in many fields such as art, technology, and philosophy. Moreover, the term "virtual" is often used as an antonym to the term "real", although it refers to things produced, designed, and experienced by computational technologies.

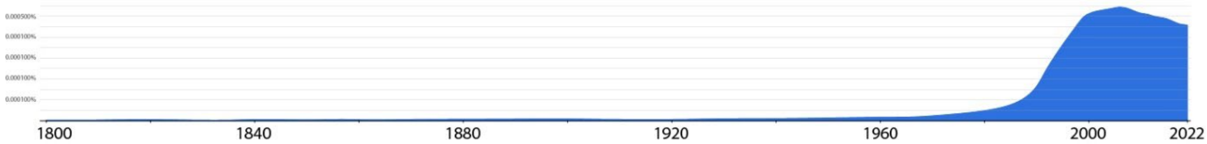


Figure 15: The use of the word "virtual" by time according to Google Ngram Data.

Similar to the terminology confusion experienced in the last chapter regarding architectural flexibility and adaptation, the term "virtual" contains a similar terminology confusion. It can mean many things, from the fact that something is "imaginary" or "hypothetical" or "simulated" by computer technologies to being such in essence or effect though not formally recognized or admitted. In fact, the word virtual was used long before the invention of computational technologies [Figure 15], and it has been the subject of study for many philosophers. (Bas, 2015) Therefore, it cannot be the right approach to confine the word "virtual" as the opposite of "real."

According to Deleuze, the term "real" is the opposite of "possible," and the opposite of "virtual" is the term "actual"; therefore, "virtual" is "the possibility that can be actualized."(Deleuze, 1988) In the previous section, when Cedric Price's Fun Palace described a "virtual" architecture, a description was made exactly like that of Deleuze's virtual definition. Fun Palace was a design focused on creating spatial possibilities for architecture that could be actualized in it. Therefore, the design of Fun Palace should not be described through its form and the program in which it was produced, like a conventional architecture, but it should be described by its "virtual" program that can be defined by the actualization of the spatial possibilities. Thus, cybernetics and game theory studies in the design process of Fun Palace were made for the production of "virtual" architecture, as defined by Deleuze. Price's Fun palace was conceptually a space-time matrix of virtual architecture that was designed to actualize what the parameter of architecture "program" needs as an affordance.

Moreover, according to Ettlinger (Ettlinger, 2007), the opposite of the term "virtual" is "physical," and, by ignoring the virtual vs. real dialectic, he says that the opposite of "real" is "simulacrum" because it superficially simulates the original. Therefore, when the subject is approached with the Hegelian dialectic, the concepts on this subject are redefined as virtual vs. physical, real vs. simulacrum.

Although simulacrum is known as an imitation or representation of a thing or person by definition, on the other hand, according to Baudrillard, "It is no longer a question of imitation, nor duplication, nor even parody. It is a question of substituting the signs of the real for the real".(Baudrillard, 1994) Therefore the simulacrum emerges its own reality: *the hyperreal*.

In this framework, a real perception, or a reality itself may be created by something virtual. Therefore, the fact that something is virtual does not interfere with the reality of the experiences or perceptions attached to it.

Figure 16: Plato's allegory of the cave by Jan Saenredam, according to Cornelis van Haarlem, 1604, Albertina, Vienna

The famous *allegory of the cave* in Plato's Republic depicts prisoners chained to a cave with their backs to the wall behind them, staring at a blank wall in front of them. [Figure 16] Since the prisoners have been there since their childhood, all they see are the shadows of the things carried by the guards passing by the fire behind the wall. Plato adds, "To them, I said, the truth would be literally nothing but the shadows of the images."(Plato, 1941) Therefore, prisoners think that the shadows on the cave wall are "real" and that the echo sounds they hear are "real" sounds. Therefore, Plato describes "reality" and "virtuality" in the context of relativity. The perception of reality and virtuality of a prisoner who leaves the cave and returns will constantly change in the process. Thus, this concept of relativity is directly related to user experience. In the continuation of the study, this concept of relativity will be considered when designing user experience, especially for the control of perception in mixed reality mechanics.

Returning to the confusion of the terminology around "visual", the duality related to the term virtual will be established as “virtual vs physical”, or “physical vs non-physical”, and the concept of these two together will be called hybrid or mixed. And within this framework, the approach to the reality of something will be carried out through the reality of its experience, and an architecture discussion will be carried out around user experiences that will produce virtual or physical realities.

3.2. Architecture & User Experience and Interaction Design

In the previous chapter, it was mentioned that regardless of whether something is virtual or physical, its reality will be defined by its user experience. In this section, the user experience and thus user interfaces will be expanded and their relationship with architecture will be examined.

According to Plato's cave analogy, reality can only be perceived as much as the perceiver's knowledge, and the perceiver's knowledge is also to the extent permitted by the designer. In this framework, the designer or architect designs a perception while designing the user experience. The perception design takes place within the framework of the interaction and experience between the design and the user.

Architecture is the design of the experience of space. From this perspective, the design of the space can be seen as a user experience design, and architecture has delegated the design of this experience to interior designers and product and user experience designers. However, when it turns to the design of virtual spaces, architecture will regain its function of experience design. This transformation in the approach should be interpreted as the transformation that architecture needs. The transformation that architecture has to go through in order to overcome the problems we mentioned in the previous section is the return of architecture to its essence, to the design of the experience, and thus the user space interaction.

The term "interaction design" is often used interchangeably with "user experience design", creating a misunderstanding. The large overlap between interaction design and experience design reinforces this confusion. All in all, Experience design is about shaping the experience between a "thing" and the user, and much of that experience comes from the interaction between the "thing" and the user. However, user experience and interaction design are not synonymous, rather user experience design is an umbrella term that also includes user interaction design. (Kolko, 2011)The main difference between user experience and user interaction design is how they approach user interactions. Interaction design focuses on the moment the user interacts with the "thing," and the goal is to enhance the interactive experience. However, for user experience design, the moment the "thing" is interacted with is only part of the experience process. Therefore, user experience considers all user-oriented aspects of a "thing." The term affordance is also very important in user experience and interaction design, as it defines the association between the user and the "thing". An affordance is, in essence, an action capability in the relation between user and a "thing".

> *The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. The verb to afford is found in the dictionary, the noun affordance is not. I have made it up. I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment. (Gibson, 2014)*

According to Don Norman, “An affordance is a relationship between the properties of an object and the capabilities of the agent that determine just how the object could possibly be used.” (Norman, 2013)Therefore, according to the approaches of Gibson and Norman, it can be said that affordance is a concept that defines the relationship with the "thing", the experience that includes the interaction before, during and after the interaction, through the perception, capacity, and continuity of this interaction. Therefore, the design of affordances is a key element of UX & UI design.

3.3. Interactive Spaces

At this point, I would like to take the discussion from the interaction and experience of "things" and the user to the focus of space and user. The conceptual expansions made before also cover this subject, but since this study was conducted with a focus on space, it would be more appropriate to draw the discussion on this ground. Therefore, the main focus will be on interactive spaces.

The concept of interactive space is a space that changes partially or completely based on the actions of an individual, group, or a "thing". These changes are defined through human-space affordances and can take place in a wide range from most essential components of space to graphical elements to changes even in virtual environments. Therefore, the fact that the space is virtual or physical does not prevent or encourage it to be an interactive space. The history of interactive space is as old as the history of human-substance interaction. However, interactive space history often refers to structural changes because they have more significant effects than non-structural changes within the space. Furthermore, this issue is at the center of the discussion of Flexibility in Architecture. Because to the extent that the user can interact with the space, user can stretch in form and function. While the fact that structural changes have a more significant impact, developing a more holistic approach to space would be a much more accurate approach to interactive space design and its affordances. Because space does not only consist of the structure, although the architect tends to deny it.

The advanced technologies of the era have always shaped interactive architecture and images of interactive spaces. Therefore, the contemporary way of understanding interactive spaces has begun to be defined through human-computer interaction, which became an important issue after the end of the 80s. According to Grudin,(Grudin, 1990) the evolution of computer technologies can also be seen as a "computer reaching out" where the human-computer relationship is not directly focused on the computer itself but instead incorporates more on the interaction with the user, his world, and the social setting, where the user is the focus. Therefore, it would be correct to see this process as the development of the social environment, thus the architecture itself.

In the age of computer-supported technologies and informatics, society is developing rapidly, as are the technologies that shape daily life. In the previous sections, we mentioned that architecture has difficulties adapting to this change and development. Interactive spaces can be a driver for architecture in providing this adaptation. Technological developments are making society faster and more connected than ever before in virtual layers, but this new field increases the need for social interaction and demands the derivation of new forms of interaction. Virtual layers also affect our physical environments. For instance, the distance between work and home, between real life and the media, is getting smaller day by day. Today, an individual is surrounded by screens and virtual images, and the individual's life alternates between virtual and physical realities. Therefore, this situation has become indispensable for architecture and other design fields.

The constantly transforming and developing the social structure of the society evolves the needs and desires of the society at the same rate and speed, which necessitates designers and architects to produce new tools within this framework and present them to the use of the society. Society needs to experience newer tools and technologies and new forms of interaction. The affordance of transforming the environment within digital tools that affect the physical world makes it a truly desirable new tool. The emerging needs and demands of the newly shaped society are also undeniable driving forces for the evolution of hybrid interactive spaces. Therefore, it would be correct to see this process as the development of the social environment, thus the architecture itself.

Recently, the development of technologies such as virtual reality and mixed reality made a breakthrough in the field of human-computer interaction. It took the interaction between human and virtual space out of mouse-keyboard interfaces and brought it to a much larger place waiting to be designed and explored.

Interactive spaces have always been experienced through two separate realities: virtual and physical. Being able to combine physical and virtual spaces will move human-computer interaction to an area that has not been experienced before, and will affect the perception of reality, and therefore will completely change architecture.

3.4. Metaverse

In the last section, it is mentioned that an experience caused by a simulacrum can be real even if the cause is a simulacrum, depending on user perception, and that the simulacra can even create its own reality. From this framework, virtual interactive environments, or even collaborative virtual environments as a more accurate discourse, should be examined. With the development of the Internet and related technologies, virtual environments have turned from simulations in which real, physical, or fictional worlds are experienced individually to collaborative virtual environments that have produced their own reality, where people spend most of their time and establish experiences and relationships that they do not have in the physical world. This process brought the experience, design, and production of virtual environments to architecture's agenda.

This chapter will examine these collaborative virtual environments, their architectural potential, the dynamics of their creation and experience, and the concept of the "metaverse" from a broader perspective. The main focus is on what kind of answers collaborative virtual environments bring to society's changing needs and desires, what position the architecture will take in this framework, and how it will be associated with mixed reality technologies.

The term “metaverse” was first used in 1992 by science fiction writer Neal Stephenson in his novel Snow Crash.

> *“On the back is gibberish explaining how he may be reached: a telephone number. A universal voice phone locator code. A.P.O. box. His address on half a dozen electronic communications nets. And an address in the Metaverse.*
>
> *“Stupid name,” she says, shoving the card into one of a hundred little pockets on her coverall.*
>
> *“But you’will never forget it,” Hiro says.”(Stephenson, 1992, p. 22)*

However, although this concept was introduced in 1992, it was forgotten for years, except for the fans of the book and sci-fi genre up to the present.

Metaverse consist of the words “Meta-” and “Universe”, meaning beyond the universe. It means a shared community of online worlds where physical reality and virtual reality can merge. Although it covers physical and virtual environments as a concept, the general perception is based only on the interaction of virtual environments with each other. The user experience and virtual-physical interface, renewed with the development of XR technologies, which have created new forms of interaction and socialization demanded by modern society in the Metaverse, offer new potentials to the society in this framework. However, since existing collaborative virtual environments already provide this experience, the innovation brought by the metaverse to this subject should be questioned.(Dionisio et al., 2013)

The most successful and popular example in this regard is the Project Second Life. Founded in 2003, the second life project promised its users a *second life* in a virtual world.(Ensslin, 2017) In the virtual world, almost everything could be done, from traveling, socializing, shopping, trading and even getting a university education. Its open-source structure also showed that the possibilities are increasing day by day and the limits depend on its users’ imagination. The game met its promises as much as the technology of that time allowed. In fact, this situation led to the recognition of the game by the Swedish government and the opening of an embassy within the game.(Bengtsson, 2011)However, Second life was not the only project with this concept. When examined, it can be seen that many projects with this concept have been developed.(Dionisio et al., 2013)

In this context, video games should be examined in order to understand the "virtual" society produced by collaborative virtual environments, their dynamics, and these new forms of interaction. MMO games for instance, as collaborative virtual environments with the highest number of users accessing for this review. All these games, from world of warcraft to second life, from Fortnite, Roblox and Minecraft, not only produced virtual worlds, but also created virtual economies and communities. By the end of 2022, this online video game market revenue is expected to reach US$208.60bn. (*Video Games - Worldwide | Statista Market Forecast*, n.d.)

Moreover, these games ceased to be just games a long time ago. In 2020, 12 million people watched a rap concert in Fortnite simultaneously. In addition, as a much earlier example, the concert given by the band MaNga in the game *Zombie Rock* in 2012 was a big step forward. Or the case of "Corrupted Blood Incident" in the 2005 game World of Warcraft could be taken. Due to a bug in the game, players with this corrupted blood "virtual disease" caused a great pandemic in the game while they were walking their avatars in the virtual cities of the game. No matter how many patches the game company made for 25 days, they could not find a solution to this problem.(Girish, 2019) In fact, this pandemic in the game affected such a large player base and aroused a voice; It was used by epidemic researchers to model human behavior under pandemic conditions in pandemic model development research. (Balicer, 2007)

As can be seen in all the examples given, the new society and life that the metaverse promises in a virtual universe already exists in other collaborative virtual environments. Therefore, this situation leads to questioning what is the difference between the metaverse and these.

In fact, the metaverse is simply a holistic concept where all virtual, mixed reality and physical realities can be related to each other, an event that occurs in one has an effect on the other, and a value created in one continues in the other. Therefore, it would be appropriate to define it as the internet of collaborative environments. However, the "metaverse" discourse that we follow from the media and the industry is not more than a slogan used by companies and individuals to make a profit, rather than this concept.

Coming back to the concept of metaverse in Neil Stephenson's snow crash novel. In the Metaverse there was a 65536-kilometer-long street that circumnavigated a planet as one long street on a digital planet. The Metaverse was originally imagined as an urban setting built alongside this long road. Later, this concept of metaverse reappeared as Oasis in Ernst Cline's novel and Stephen Spielberg's movie "Ready: Player One" adapted from it. In this metaverse, which began to be imagined in novels and later in movies in the 90s, users were using special googles, virtual reality glasses, in order to go beyond the universes. The same is thought for the metaverse that is being built today. In fact, Facebook, one of the social media giants, believes in this metaverse concept so much that it bought the oculus company by giving 2 billion dollars in 2014.(Kumar, 2019) Even changed the name of the company to META to refer to the metaverse.(Zuckerberg, 2021) Oculus was one of the pioneering companies that developed XR technologies. So much so that one fifth of Facebook employees are currently working on this technology and they plan to invest 5 billion dollars every year. In fact, after the last Facebook Connect event, they announced that they would hire thousands of people to work in AR / VR fields and started to take steps in this direction. (Zuckerberg, 2021) Because, according to Zuckerberg, the founder of the company, this will be the biggest innovation after the great revolution made by mobile devices to the internet.

> "This is a big topic. The metaverse is a vision that spans many companies – the whole industry. You can think about it as the successor to the mobile internet." *(Zuckerberg, 2021)*

However, such an innovation, of course, cannot be made with a single device by a startup or a company's efforts. So, for this concept to happen, all industry giants, companies, users, content producers, developers and designers must work together to create it. How this process happens or how it is coordinated and shared is probably a bigger problem than the technological ones. Fortunately, this is not the focus of this thesis.

Last May, the South Korean government announced the Metaverse Alliance.(Lee Jee Young, 2021) It is an initiative of local companies to promote the development of a national virtual and augmented reality platform and to unravel the ethics of virtual environments. While this is happening in the Far East. In the past period in the western world, according to data revealed in antitrust filings between Apple and Epic games, the game Fortnite generated $ 9 billion in revenue in 2018-2019.(*Epic Games, Inc. V. Apple Inc.*, 2021) At this point, it should be underlined that Fortnite is a free game. This income is generated as a result of Metaverse transactions, such as shopping for costumes and cosmetics, which do not give you any advantage in the game. Noticing these metaverse trends before others, epic games gave up on Fortnite as a game a long time ago and now they use the concept of metaverse as well. Fortnite wants to be the Metaverse. And they announced an investment of 1 billion dollars for this long-term goal they have set.(Duan et al., 2021) According to Matthew Weissinger, the defense side of the aforementioned antitrust lawsuit between Apple and epic games:

> *"It's one of the remarkable things about Fortnite, we're building this thing called the metaverse – a social place. "*(*Epic Games, Inc. V. Apple Inc.*, 2021)

So it is obvious why all the industry giants seek to build the "metaverse." However, as can be seen from the examples, none of these are different from collaborative virtual environments.

In fact, what has changed is not technology, but society. Society gained new habits, forms of interaction, and behaviors to spend time in these collaborative virtual worlds. So, this is no longer a concept and is closer to realization than ever before. Although architects have long insisted that the construction of virtual environments is not the subject of architecture, the primary task of the architect is to design the experience of physical, virtual, or mixed space and the forms of social interaction that will take place within it. Thus, the construction of the metaverse, or more accurately, the concept of multiple collaborative environments, is the construction of the spatial internet.

3.4.1. Semantic Web&Metaverse

The world wide web is the W3 project developed by Tim Burners-Lee at the CERN lab in Switzerland. I think it would be sufficient to look at the first web page established by Tim Burners-Lee to make the definition.

> *“World WIDE WEB*
>
> *The WORLDWIDEWEB (W3) is a wide*area hypermedia[1] information retrieval initiative aiming to give universal access to a large uni,verse of documents.*
>
> *Everything there is online about W3 is linked directly or indirectly to this document, including an executive summary[2] of the project, mailing lists[3], policy[4], november’s W3 news [5], frequently asked questions [6].”(Berners-Lee, n.d.)*

The first two paragraphs of this web page explain what the W3 project is and its methods. It is the first generation and first form of the internet, Web 1.0. It connects computers that had until then been singular, disconnected from each other. It is an internet version where most users are consumers, websites are static pages, and the displayed DATA uses the server filesystem rather than the database system.(Cormode & Krishnamurthy, 2008)

The Internet should be recognized as Web 2.0 is known and used today. Tim O'Reilly first used the concept of Web 2.0 in 2004. According to Tim O'Reilly, the compact definition of Web 2.0 is as follows:

> “Web 2.0 is the business revolution in the computer industry caused by the move to the internet as platform, and an attempt to understand the rules for success on that new platform. Chief among those rules is this: Build applications that harness network effects to get better the more people use them. (This is what I’ve elsewhere called “harnessing collective intelligence.”)*(O’Reilly, n.d.)*

Web 2.0 is a movement based on the idea of ensuring the participation of visitors to the site in order to improve the web service and collaborating with other sites and visitors for the same purpose. With the widespread use of mobile devices, these web 2.0 dynamic websites started to emerge. As access became faster and easier, it started to be fed with user-generated content with participants.(O’Reilly, 2009)

In this study, the main reason for examining what Web 1.0 and Web 2.0 are how web 3.0 is the continuation of an intellectual continuity and what it is, and in addition to this, its relationship with the metaverse, if any. The only change in the transition from Web 1.0 to 2.0 was the replacement of a static server with platforms. Nevertheless, in both cases, centralized structures are needed, intermediaries. In its most basic form, the Internet is the interconnection of multiple computers. So, do computers need an agent to connect to each other? Web 3.0 is the model of the Internet that does not use an agent to connect with each other—a decentralized internet with peer-to-peer communication.

According to the definition of Tim Berners-Lee, the creator of the Internet, Web 3.0 or with his definition the semantic web in his words:

> *“I have a dream for the Web [in which computers] become capable of analyzing all the data on the Web – the content, links, and transactions between people and computers. A "Semantic Web", which makes this possible, has yet to emerge, but when it does, the day-to-day mechanisms of trade, bureaucracy and our daily lives will be handled by machines talking to machines. The "intelligent agents" people have touted for ages will finally materialize.” (Berners-Lee & Fischetti, 2008, Chapter 12)*

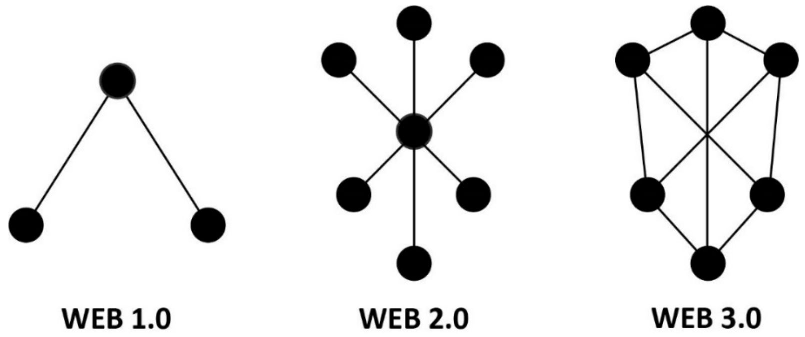


Figure 17: Diagram of WEB phases

When the concept of decentralization is used, blockchain technologies come to mind. Unlike Web 2.0, Web 3.0 is a decentralized internet concept that provides peer-to-peer connectivity that blends old-generation web tools with cutting-edge technologies such as artificial intelligence and blockchain. [Figure 17] As is known, social media platforms are entirely free. This situation causes the revenue model of service providers to be questioned. Revenue models are built entirely on the data its users share with them.(Enders et al., 2008)The reason for the emergence of new fields such as data mining and data analysis is these platforms that web 2.0 offers people. Therefore, the product these companies sell is the users' data, that is, the users themselves. Therefore, the security of users' data is questionable.

> *“It was one of those pictures which are so contrived that the eyes follow you about when you move. BIG BROTHER IS WATCHING YOU…” (Orwell, 1954)*

The future of the Internet, the idea of the metaverse, which is seen as the spatial Internet, and if there will be virtual environments where people will spend time in the future, our presence in these environments will similarly turn into a salable and shareable data. Consider that Big Brother in Orwell's 1984 is just the set and doesn't even need cameras. For this reason, one of the most crucial debates on architecture will be the lack of the notion of privacy.

At this point, there are two critical movements about the future of the internet. One of them is metaverse, and the other is web 3.0. They should not be seen as two separate concepts.

The change that will happen to the internet; can be realized by providing the infrastructure by Web 3.0's peer-to-peer connection and UX&UI concept of the metaverse. Just as mobile devices have accelerated the transition from web 1.0 to web 2.0, technologies such as augmented reality, virtual reality, mixed reality, or smart glasses can facilitate the transition to spatial internet.

In this context, the spaces of the future can be multi-collaborative virtual environments that are equally accessible to designers and users, with open source code, information is semantically classified, personal data and privacy are secured, have a secure infrastructure, and communication is made through verifiable methods for the formation of a social structure.(Kibet et al., 2019)

If all these are provided, the security of our personal data and privacy can be ensured, and a democratic internet can exist. This situation can bring organizations to the DAO (Decentralized autonomous organization) phase. Which can cause Metaverse may also lead to the formation of an algocratic system which governance by computer algorithms. (Aneesh, 2009) Perhaps in the light of such trials, its reflections in the physical world in the future can be seen.

3.4.2. NFT & Metaverse

In the previous section, it was mentioned that Dapps in Web 3.0 systems convert each action data into a value and that these values may have a role in the setup of the system we are illustrating. Based on this, it was mentioned that the concept of Non-fungiable token could correspond to these values. Therefore, let's take the concept of NFT's.

According to the Cambridge dictionary definition, a fungible is "replaceable" while a token is something that has a symbolic value and is something that people give to each other. (McIntosh, n.d.) The definition of "Fungible token" seems to describe a currency as a combination of these two words. It is also possible to define cryptocurrencies in this way - assuming the tokens are digital. From this point of view, if we focus on the "replacable" side of the word fungible, we can see that the non-Fungible tokens differ from cryptocurrencies that they are non-replacable, unique. Therefore, they cannot be replaced or duplicated by something that is identical. As a more inclusive definition;

NFT, a non-fungible token, is a data unit stored in a blockchain, confirming a unique digital asset. NFTs are easily verifiable through their blockchains and are not interchangeable. (J. Fairfield, 2021) However, access to the original file in question is not limited to the owner of the NFT. Besides the fact that access to the file is public, NFTs are tracked on blockchains to provide the owner with proof of ownership other than copyright.

At this point, the focus of the discussion should return to the redefinition of concepts such as the production of unique digital assets, their ability to be traded as they are in the real world, and digital ownership.

For a long time, we have been in a transformation where the actions we have taken in our daily lives have been replaced by digital in virtual environments and our lives have started to become digital. However, although this revolution has begun to change almost every area of our lives step by step, it has failed to build on the value of digital things as it is with things in the physical world. According to Joshua Fairfield, this was the way the digital world works:

"While this digital shift has been building for some time, the rivalrousness and uniqueness that gives value to items in physical space has been hard to reproduce online. Every image online can be copied by right-clicking on it and saving the file. Every file sent is sent by making a copy. The kind of value we attach to our unique homes, works of art, collectible trading cards, and even personal data has gone entirely unrealized in a digital environment where copying is the breath of connectivity."(J. Fairfield, 2021)

Despite the fact that users are starting to form emotional attachments to digital things (a character in an MMO game, an island to own in Nintendo's Animal Crossing game, or the social media account of a lost relative); Technology and law have so far failed to develop systems for creating unique digital assets. NFT notion offers a solution to this problem.

At this point, it would be the right approach to clarify the definition of the problem and not lose focus. What makes a usual asset valuable? What makes an object valuable is that it is one of a kind. In the physical world, we evaluate the value of an asset through its Rivalrousness and uniqueness properties. (J. Fairfield, 2021) Rivalrousness is a phenomenon where one has something, and the other does not. When someone gives what he has to someone else, it now belongs to someone else, and that person no longer has it. This is much more effective on rare items. (J. A. T. Fairfield, 2017) Uniqueness is a more extended version of this phenomenon. If someone has something unique, it has no equivalent and cannot be changed. To illustrate, all Chicago Michael Jordan jerseys are rivalrous for each other, but Jordan's jersey used in "The flue game" match and signed by him would be unique and rivalrous because there is no other signed jersey from that specific match.

Cryptocurrencies and ledgers -open-source, public and totally secure decentralized data of who owns what- provided the first step of this solution. Cryptocurrencies brought rivalrousness to the system, but not uniqueness. Because they were fungible. If someone has a cryptocurrency, one can transfer it to another, and the one no longer has access to it. But one can get it again from another or someone else. Because all crypto coins of the same type are identical.

This is exactly why NFT came into existence. As the name suggests, non-fungible tokens add uniqueness to the system. Therefore, they are special and necessary for the system. In the construction of a decentralized system, decentralized values and assets are as important as decentralized currencies.

For example, on the most prominent digital game platform, Steam, users can buy and play video games that they have in their accounts. However, it does raise some questions on licensing and ownership. To illustrate, steam accounts cannot be sold to anyone else in any way. The video-games in these accounts cannot be bought and sold similarly. When the owner dies, it does not pass on to the owner's heirs or cannot be transferred to someone else. In this situation, it would be difficult to say that the so-called owner has a steam account. Rather than ownership, it looks like a non-transferable lease of service for a certain period (lifetime). If anyone sells or trades their account and the system discovers this, that account will be frozen and closed indefinitely. Social media services can close the accounts of people they want, block their access, and remove them whenever they want. Similar things apply to online game accounts. In summary, the things owned in any digital environment or platform are left to the initiative and conscience of the platform owner and the service provider. So, technically no one other than the platform owner owns anything except responsibilities for the content it produces.

Therefore, just as NFTs protect and define people's private property, virtual assets, and unique values, NFTs must also define what architects and designers create and design in the virtual environment, such as intellectual property. Therefore, in the following chapters, while discussing the role of design tools in virtual and mixed reality environments in design, NFT can be used to define the intellectual property of the values to be produced in the design or the architecture to be built in virtual and mixed reality environments if deemed necessary or if the metaverse and Web 3.0(Semantic Web) concepts are realized.

In fact, these developments, and even the fact that these discussions are being held, show the existence of society in virtual environments and that a new social system is in the process of building suitable for this new environment.

3.5. Developing Multi Collaborative Virtual Environments

Throughout this chapter, we focused on the technological developments that have taken hold of the last period and the changes in our daily lives with their influence. In order to understand the concept of hybrid space and mixed reality that will be explained in the next chapter and the project design phase that will be illustrated in the final chapter; It is vital to understand and comprehend this change, development, and concepts.

It can be observed that architecture adapts to technological developments like every other profession and situation, or at least there is progress in this direction. However, when the development of architecture in the last 1000 years is compared with the change in the last 20-30 years, we can see that this is quite limited compared to the change in other aspects of life. Technological developments have not pushed us to redefine architecture, nor have they affected architecture to the same extent. Although several conceptual approaches are beginning to emerge, this is far from being a transformation that takes over all areas of architecture. However, these changes are limited to redesigning design and representation tools and adding new ones rather than how we define or realize architecture. Therefore, the transformation is somewhat limited compared to what is expected. Nevertheless, this study has been tried to shed light on the points where transformation can reach and talk about potentials with a design proposal.

Today, from 3D virtual worlds, we can talk about designers and "architects" who design virtual spaces. In this context, there are many studies with 3d virtual worlds. Although I have to choose the examples from video games, since the majority of them are video games, it is not even sincere to see that these studies will be replaced by things with different functions as decentralized virtual worlds and next-generation virtual worlds are built.

Before bringing the focus of the discussion to the desired point, let us take the virtual worlds in video games, even focus on open world-based games developed by Ubisoft as an example. Explaining what an open-world video game means here will be very useful for understanding the subject. Virtual worlds created in video games were designed to be constrained so that the running hardware was not overburdened and for optimum use of resources. However, with the strengthening of the hardware and the development of methods that will ensure the most optimal use of resources, it has been made possible to create virtual worlds, which are not limited, as open worlds. These developments allowed the creation of towns, cities, and even continents within virtual worlds. (Nenad, 2018)

Following these trends, in the Assassin's Creed video-games developed by Ubisoft, which we examined as an example; To summarize, there is gameplay where the player can go to the past and experience the history by simulating the lives of people who lived in the past, by using the DNA extracted from the ancient ruins through technology in the game. Many periods and geographies can be experienced, from ancient Egypt to ancient Greece, from Renaissance Florence to French Revolution Paris, from Victorian London to the colonial Caribbean. Here is where I want to focus without deviating from the topic; Ubisoft company used architectural historians and sociologist to recreate the cities and geographies that existed in the past, but the people who created the virtual world and designed it were not "architects." Although architectural realism is vital in the effort to experience this fictional history, 3D artists without an architectural education created virtual worlds. So why aren't virtual worlds designed by architects? Especially in a situation where the experience of space, of urban dynamics is one of the main elements of the product being sold, why are architects the people who will only be consulted on historical realism but sit aside while creating the virtual world? Or why don't the people who create these virtual worlds called architects, or at least virtual architects? Because obviously, they are doing the work that architects can see fit to do. Although architects and 3D artists use almost the same tools when designing these virtual structures, the things produced, and the focus are quite different.

The situation I would like to shed light on with this example is that the digital revolution and transformation we live in have a limited impact on architecture, and architects do not design the spatial and environmental experiences offered to users in virtual worlds. This discussion is not that architects will design virtual environments much more successfully or that the dictionary definition of the architect includes designing virtual spaces; the fact that the architect or architecture does not take a role in this field, maybe even cannot.

With the development of building technologies, the architect's role has recently begun to transform into the design of the spatial experience rather than the production of the physical structure in every sense. Therefore, the design of virtual worlds, metaverse, augmented reality architecture, and mixed reality spaces will be one of the most critical roles of the architect in the future, if not his sole duty. This study is only one of the millions of steps taken in this direction.

In this context, the architect's role in the production of virtual space is of vital importance for the future evolution of the architectural profession.

In order for this process to happen, perhaps the design process of the virtual space should first transition to the production of hybrid spaces and then to the production of the virtual space itself, in order to create the necessary production culture for the architect, rather than a direct transition from the design of the physical environment to the design of the virtual environment. Therefore, in the next chapter, conceptual expansions will be made on the design through the concepts of hybrid space and mixed reality architecture.

This chapter states that the metaverse, multi collaborative virtual spaces, points to a whole containing hybrid and physical spaces. The architect should produce his own role in the production process of this whole and even play an essential role. Contrary to the rest of the process, this situation and many other studies can be realized.

In conclusion, the internet has not yet completed its natural evolution, and it is changing, developing, and even evolving day by day. A metaverse is a future form of the internet that is predicted to carry out this evolutionary process in today's world. The spatialization process of the internet makes the architect one of the leading roles in this evolutionary process, although s/he is not willing. Spaces of the future; even if it comes to life in whatever form, virtual, physical, or somewhere between, architects and architecture began to evolve and transform to respond to this situation. The stakeholders of this change will support this situation in almost every direction, and the participatory structure of the internet pushes us all to be stakeholders in our own way.

The spatial spaces of the future will have a decentralized, egalitarian, sharing, and participatory structure built on a decentralized data network provided by Web 3.0, with the user experience and interface elements suggested by the metaverse perception that has become popular these days. The socio-economic dynamics of the spatial spaces of this future will also be established, liberated, and democratized with cryptocurrencies and NFTs, which are the products of the same decentralized approach. This study proposes an architectural approach suitable for this future spatial space model.

4. MIXED-REALITY ARCHITECTURE

4.1. Introduction

According to Schnädelbach, “Architecture can be described as structuring patterns of co-presence.” (Schnädelbach, 2007)Therefore, architecture affects who we interact with and with whom we do not in our daily life. This is a two-way process in which architecture expresses but also shapes society and the norms and rules of social interaction. As the intentions of this thesis, this definition of architecture is also not a definition that puts architecture within physical boundaries. On the contrary, it makes technologies that enhance co-presence, such as virtual reality and mixed reality, one of the research topics of architecture. In this chapter, mixed reality technology, computer-supported co-presence and their relationship with architecture will be examined.

4.2. Mixed Reality Technologies

As mentioned in the previous section, with the popularization of the metaverse concept, there has been a growing interest in techniques combining real and virtual environments used for the creation of mixed-realities – spatial spaces where participants can engage in an integrated interaction with physical and virtual environments.(Milgram & Kishino, 1994) In this framework, collaborative mixed reality technologies can enable users distributed in multiple physical and virtual spaces to interact and communicate with each other. Therefore, mixed reality is the focus of this research in the production of a reality where virtual and physical spaces overlap, as it provides co-presence.

In this framework, various approaches have been produced to create a shared mixed reality, including augmented reality, augmented virtuality, tangible bits, and mixed reality boundaries.(Benford et al., 1998)

Augmented reality is the definition of reality that involves adding a digital layer (e.g., text and graphics) to a physical scene. This physical scene can be a local environment where the virtual layer is delivered via a head-mounted display or devices such as a tablet phone. Alternatively, it could be remote environment captured by a camera and the camera input could be enriched with digital overlays. However, while the layer added in one is spatial, in the other it is 2-dimensional. The first concept designs of collaborative augmented reality are the *Shared Space* system(Billinghurst et al., 2000), where users share the objects they create in virtual layers on a physical desktop, and the *Studierstube* system(Szalavári et al., 1998), where virtual objects are also displayed in a physical environment. Both of these systems use head-mounted display hardware. In addition, in the concepts based on remote scenes are inherently shareable as the video display elements are typically located in a shared physical space.

In contrary, *augmented virtuality* is the definition of the reality that, places representations of physical objects in a virtual scene. These can be views of the faces of users' avatars in the form of texture videos, like in the *FreeWalk* system(Nakanishi et al., 1996), or likewise with a small difference in the Spatial VR app today. In addition , augmented virtuality can be given, which placing the objects in the physical environment to match the objects in the virtual environment and augmenting the virtual reality experience with physical objects(Zuniga Gonzalez et al., 2021)[Figure 18]. Alternatively, the DATA of the things in a remote physical environment can be captured by sensors and produced as graphic, text or audio to create augmented virtuality.

Figure 18: Augmented Virtuality study, Left: Real life environment. Right: Virtual Reality Environment.

The *tangible bit* approach(Ishii & Ullmer, 1997) involves the use of tangible interfaces to interact with the virtual environment and layers. To illustrate, the Clearboard system(Ishii & Kobayashi, 1992), in which physical models are moved on a tabletop to manipulate a virtual map projected onto it. It can also be combined with the use of virtual layers such as light, sound, airflow to give more information about the background information.

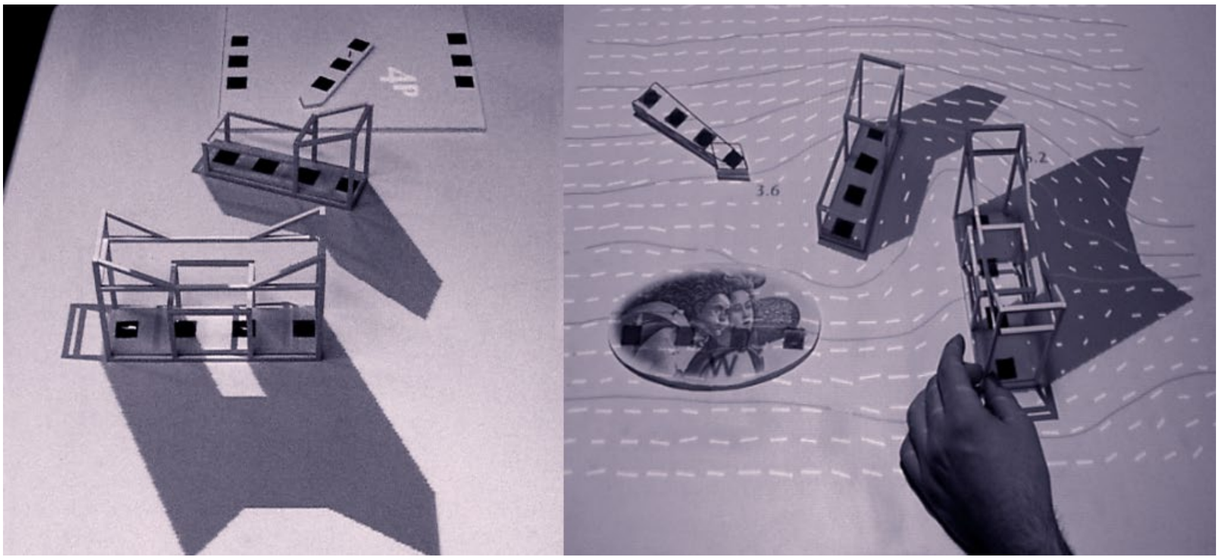


Figure 19: Tangible bits by Hiroshi Ishii: a) Urp and shadow simulation. Physical building models casting digital shadows, and a clock tool to control time of day (position of the sun). b) Urp and wind simulation. Wind flow simulation with a wind tool and an anemometer.

The *mixed reality boundary* approach is defining a virtual transparent boundary between distributed virtual and physical spaces to combine their experiences.(Benford et al., 1996) In this approach, the physical and virtual environments are not overlayed, but are brought together to enable interaction. Users of the shared physical space can see and interact with the adjacent virtual space, while users of the virtual space can see and interact the physical space through mixed-reality boundary surface in the virtual space. The difference of this approach from other approaches is that it gives equal weight to physical and virtual environments. At the same time, with the use of multiple mixed reality boundaries, the space can interact with more than one physical or virtual space.

This thesis study is concerned with the mixed reality architecture approach, which examines the shared mixed reality production approaches from an architectural perspective. The design concept will be based on a new approach influenced by and interpreted this mixed reality architecture approach. It will be developed by examining the relationship between the concept of mixed reality architecture and mixed reality production approaches and its relationship with computer-aided spatial communication tools, which will be examined in the next section.

In this framework, Mixed-reality architecture is an architectural approach to mixed-reality technologies. (Schnädelbach, 2007) It involves dynamically linking and overlapping multiple physical and virtual environments to support the social interaction of users who are not in the same physical environment. The mixed-reality architecture consists of mixed-reality architecture cells (MRACells) that create co-presence through their interactions. MRACells are defined as spatial units consisting of one physical and one virtual spatial cell, the smallest architectural space possible, joined together by a Mixed-Reality Link. [Figure 20] To illustrate, in a conference speech made to the physical and virtual environment, physical and virtual architectural cells connected to each other via a mixed-reality link can interact with to the speaker in the virtual environment. In this example, users in the physical environment can see the speaker in the virtual environment with the help of the projector in the room through the mixed reality connection, which is used as the mixed reality boundary between two mixed reality architectural cells. At the same time, by rendering the camera input in the physical environment in the virtual environment, the speakers and the audience in the virtual environment can interact with the audience in the physical environment. [Figure 21](Schnädelbach et al., 2003) In this way, both places can listen to the conference and interact with each other.

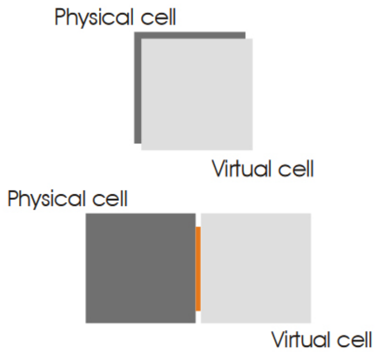


Figure 20: MRLinks: Overlaid & Boundry

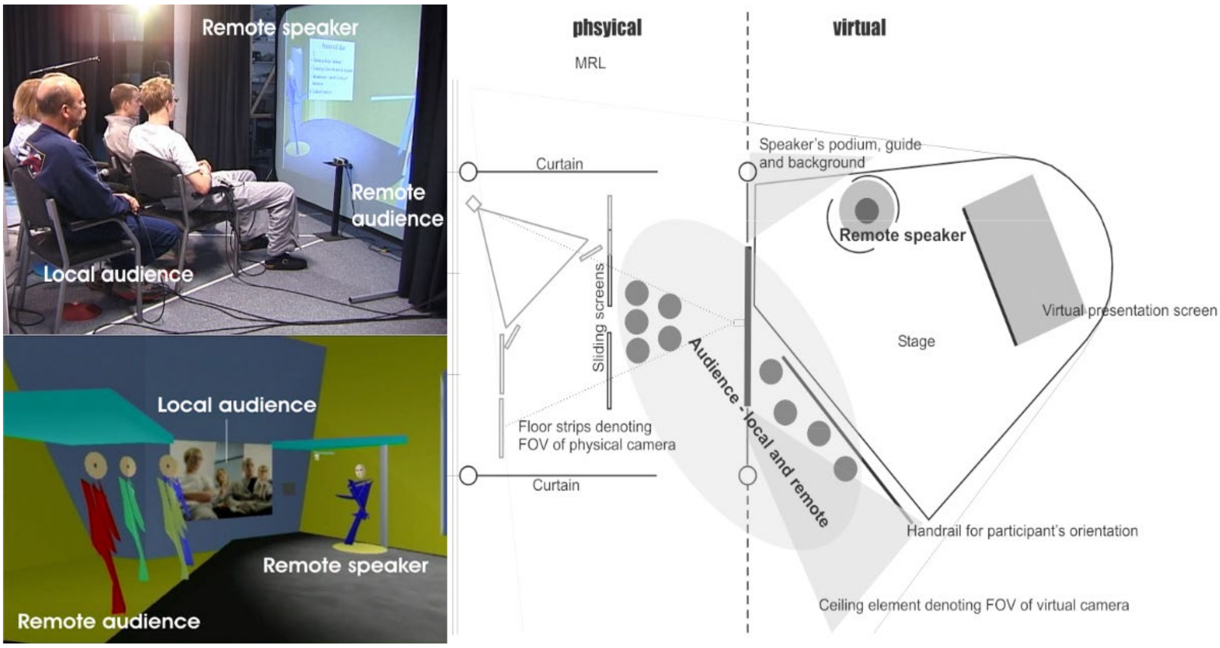


Figure 21: MRA for the remote presentation

Although architecture is the prerequisite of social interaction for a very flexible and rapidly changing society, it is quite static and inflexible. This flexibility of society, especially from the point of view of transcending the boundaries of space is provided by communication technologies in many different forms through social interaction. However, due to the fact that these technologies were ignored in the architectural field for a long time, they were not considered until the popularization of topics such as virtual reality, mixed reality and metaverse in architecture. Therefore, in the next section, we will examine the communication technologies that provide this flexibility, computer-supported co-presence.

4.3. Computer-Supported Co-Presence

Throughout this article, it has been mentioned that buildings have difficulties adapting themselves to changing conditions. During the Covid-19 period, people have had much time to face this reality because they have started to spend more time indoors and even started to get to know their homes, themselves, and their housemates. In this process, issues such as long-distance relations, remote working systems, and distance education came to the fore. Unfortunately, architecture had difficulties producing solutions to these and even prevented this in some cases.

On the other hand, computer-supported collaboration systems helped us face these problems. However, these solutions also made us compromise some organic events and relationships that spatial environments provide us. Therefore, examining the spatial approaches of computer-supported collaboration systems is essential for analyzing what kind of contribution architecture can make to this experience. In this framework, space sharing through co-presence has entered into current architectural debates.

Technologies that create distributed environments where participants can take advantage of spatial data, such as containment and movement to enable productive communication, are called shared space technologies. It provides solutions to some of the needs deemed necessary for collaborative work. These needs can be summarized as; providing a permanent, secure, and organized context for ongoing work; providing peripheral and focused awareness of colleagues' work-related activities; being able to accommodate random encounters and events through spatiality and the construction of a metaphorical context that will enable remote work systems to imitate the traditional work environment.

According to past studies, it is observable that the spatial approaches of Computer Supported Cooperative Work (CSCW) can be examined in 5 categories. These are media-spaces, spatial video conferencing, collaborative virtual environments, telepresence systems, and collaborative mixed reality environments. [Figure 22]

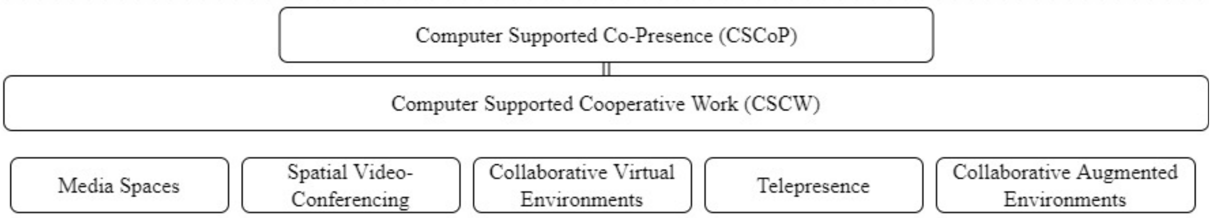


Figure 22: Computer Supported Co-Presence Diagram, illustrated by the author

Media spaces are electronic media environments that will enable colleagues to work together when they are not in the same place or cannot be in the same place at the same time. (Stults, 1986) [Figure 23] In its most primitive form, in these environments, users can create and share real-time visual and audio elements and environments that they can view at different physical locations or times.

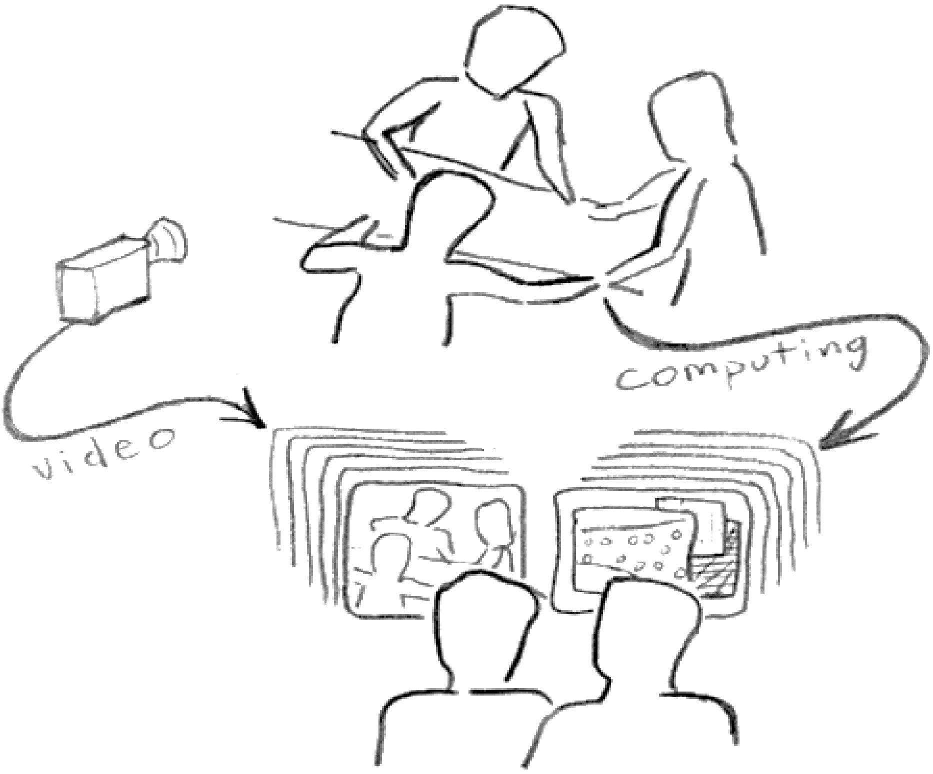


Figure 23: The original concept drawing of a media space by Robert Stults from 1982.

However, nowadays, with the development of media spaces, these data can be shared in a more organized way with spatial interface cloud systems; It is possible to produce and change data simultaneously with media spaces such as Miro, Conceptboard, Microsoft whiteboard, mural, and even with media spaces such as asana and ClickUp, work-tracking and organization-oriented uses can be made in teamwork. Therefore, today, its definition and function have expanded considerably, and it has started to be integrated as an auxiliary component to many other computer-supported collaborative working systems.

Video-conferencing is a telecommunication technology that allows simultaneous video and audio sharing between two or more places and users.(Benford et al., 1996) Contrary to our research, video-conferencing technology in the traditional sense does not support the sharing of spatial information such as gaze direction, relative position, and focus of attention. However, studies show that the gaze directions of the pairs during communication or the focus of a pair during 3D design collaboration are among the essential elements of efficient communication.(Root, 1988) In this direction, spatial video conferencing technologies have been developed that support sharing spatial information to enhance communication as well as simultaneous video and audio sharing. Today, this function is partially provided by pre-defined and dedicated seating layouts to detect the gaze direction of video conferencing applications such as zoom, Microsoft teams, and Webex.

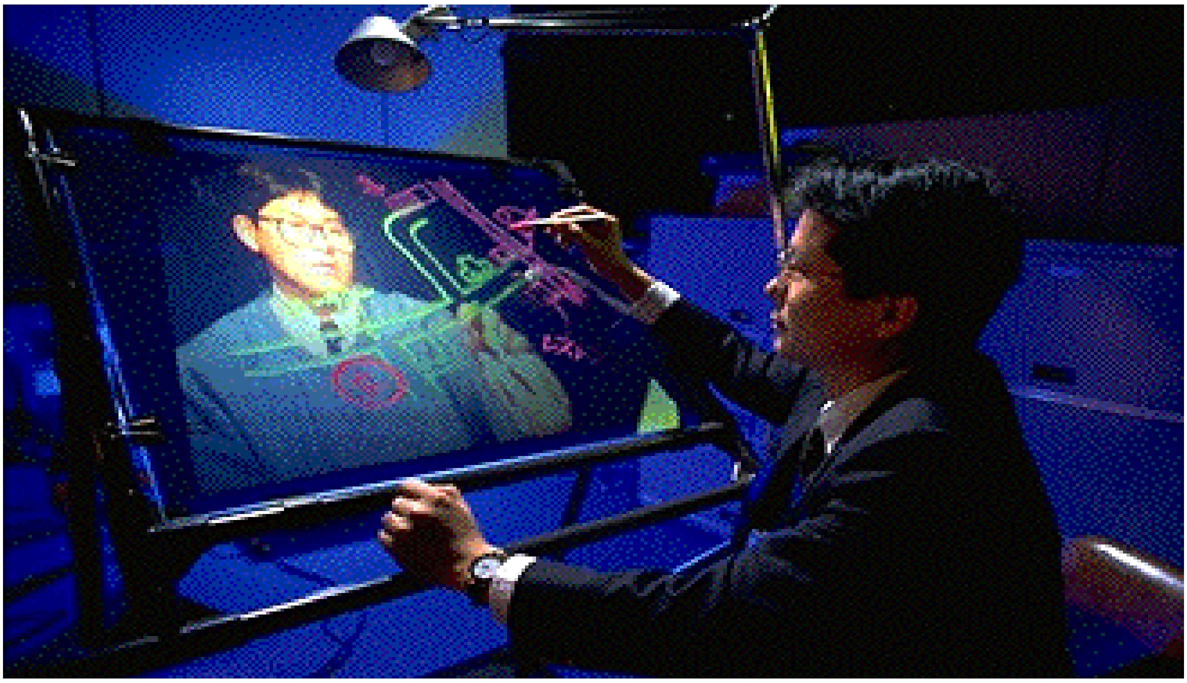


Figure 24: The First prototype of ClearBoard with "gaze awareness" capability by Ishii & Kobayashi 1992

An example of spatial video conferencing technologies can be given as Clearboard, which has media technology integration. Clearboard allows for spatially consistent video conferencing designed for two-person design meetings, with a shared drawing space in addition to video and audio sharing. This concept not only supports users' gaze direction but also shows where they focus in design. (Ishii & Kobayashi, 1992) [Figure 24]

Collaborative virtual environments (CVEs) are computer-supported distributed virtual spaces where users can freely meet and interact with others, agents, and virtual objects(Benford et al., 1994). While the user is present in such places with digital representations called avatars, an experience is built through interaction forms designed for that particular virtual environment. It also increases spatiality considerably, as it provides feedback to other users about digital representations of users, gaze directions, the focus of attention, and even spatial interactions specific to that virtual environment. Since the user's presence is provided through digital representations, it enables forms of interaction and experience that are not possible in the physical world. This advantage makes these environments very attractive for a variety of use scenarios. Today's popular applications are military or industrial simulation training, as dangerous situations can be safely simulated; collaborative design so that users in distributed spaces can produce efficiently in a collaborative environment; and multiplayer games, as the technology can support almost any situation and event, realistic or fictional.

On the other hand, the connection with reality weakens considerably in such virtual environments since the presence is provided through avatars, and the space is produced entirely digitally. Since this situation leads to the loss of organic communication components such as facial expressions, body language, etc., which are vital for communication, this problem is tried to be eliminated with emojis and some animations that provide mood notification. Although some CVE systems users access VR devices try to overcome this problem by transferring mimic and arm movements to avatars via mocap systems, a mainstream solution has not been produced yet, except for simple facial mocap systems in the latest generation VRs. Examples of current CVEs are Spatial, Horizon workrooms, MeetinVR, and even Minecraft education, which is unique with its game origin.

Telepresence is a technology that enables its users to experience a remote physical environment through a physical representation(Benford et al., 1998). It enables the remote participant to see, navigate, and even interact with objects and other participants in the remote environment within the framework of the possibilities of its physical proxy. Therefore, users in Telepresence systems; experience the remote environment with physical proxies rather than virtual representations(avatars) as in CVEs. The quality, limitations, and shape of the interaction depend on the capabilities of the physical proxies that provide telepresence. An example of one of its popular uses is robots (physical proxies) of the Nvidia Omniverse's and BMW group's factory of the future. Even though Nvidia's Omniverse's concept creates an alternative setup over digital twining for CVEs, the robot in the factory being used by remote users to work in the factory is an example of telepresence. Telepresence is an emerging field of computer-supported collaborative workspaces in the control and optimization of automation in production environments such as factories and BMW group's factory of the future.

Collaborative Mixed-Reality Environments are computer-aided spaces in which cooperation is ensured by associating physical and virtual spatial layers. In such environments, digital layers of video and audio data of a remote environment, virtual or physical, are added to the host environment. Today, examples created by adding the digital twin of a physical environment to another physical or virtual space as a digital layer are a growing field used in many sectors. Although most of the popular applications seem to be AR technology as they are provided by augmentation of the physical space with the help of technologies such as smart glasses and devices with cameras, alternative mixed reality uses are also possible in theory by capturing the physical environment and transferring captured data to remote environments. In this direction, as technologies such as Lidar cameras, laser scanners, and photogrammetry become widespread and cheaper, alternative mixed reality environments to AR have begun to be developed since digital reproduction of the physical environment data has been made possible. As an example, The Spatial platform and Nvidia Omniverse's digital twinning are famous examples, BMW's factory project of the future, and industrial applications of Omniverse with Siemens and Eriksson partnerships can be given. Unlike virtual reality, mixed reality technologies do not break their direct relations with the physical environment; therefore, experience and the loss of organic communication factors will not be experienced. Since this situation will allow mixed-reality environments to be preferred in many sectors, collaborative mixed-reality environments became a developing field in computer-assisted collaborative business field studies.

As if the “architecture is the design of the experience of space and patterns of co-presence”, architects should design not only the experience of the space but also how users interact with each other in the space or the environments where the spaces interact. Computer-assisted co-presence technologies and tools provide interaction between distant physical spaces or physical and virtual spaces. This interaction can turn into an architectural tool through mixed-reality technologies. This way, architecture acquires virtual flexibility through mixed-reality and spatial shared space technologies. Moreover, this brings a new layer of experience to architecture.

4.4. Developing Mixed-Reality Architecture

Mixed-reality is an experience brought together by the physical and virtual layers that make up the environment. In the previous sections, we mentioned that Duffy reconceptualized the layers of the building according to the material life, while Brand defined an architectural flexibility by separating it into *shear layers* as we use it today, by changing and renewing each layer in different time periods. Therefore, this discussion is very important for the subject of architectural flexibility and is very valid at virtual spaces and physical spaces as well. For example, if we divide the virtual architecture into its layers, it consists of the graphics and physics engine on which everything is built like a foundation, and 3D models are the elements of the virtual environment, just like the architectural foundation. While editing and changing the graphics and physics engine is quite challenging, changing the 3D models in the environment is relatively easy. Therefore, it can be said that there is a relationship similar to the shearing layer concept between these two layers. These layers may lose their functional life and appeal to the user over time, but optimization can be achieved by changing each layer at different time intervals.

Moreover, if this discussion is to be made through mixed reality technologies, it would be the right approach to see the physical and virtual space as a whole and add the virtuality as a new layer to Brand's *shearing layers*. [Figure 25] Therefore, the layer that interacts with the user the most and therefore needs the most change is a virtual layer. Since it's a virtual layer, it will increase transformation ability of space and define an economically sustainable architecture. From this perspective, mixed reality will not only prolong the functional life of the space but will also ensure the production of a sustainable space and program.

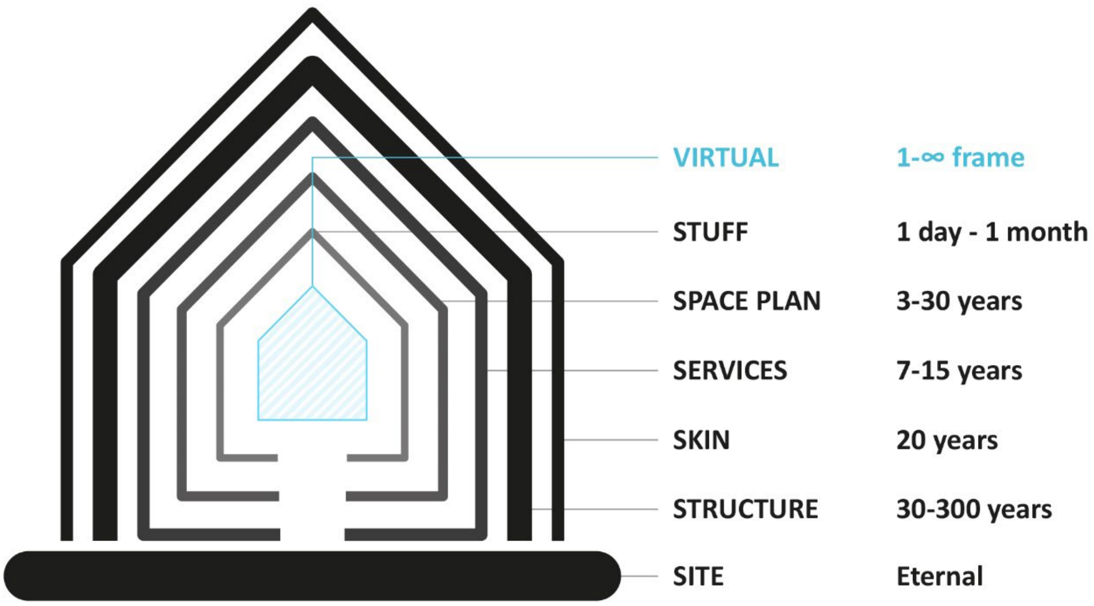


Figure 25: Brands Shearing Layers of Change Adjusted for Mixed Reality Architecture, adjusted by the author.

According to Schnädelbach, "Architecture can be described as structuring patterns of co-presence." In this framework, Schnädelbach bring an architectural perspective to mixed reality technologies as *mixed-reality architecture*, to define co-presences through mixed reality technologies and to shape the architecture around it. This approach inspired and guided this study.

On the other hand, the mixed reality architecture of Schnädelbach is based on the interconnection of physical or virtual environments with mixed reality links, and the mixed reality link is a concept that connects virtual and physical architectural cells. Technically, this definition can encompass almost all interactions between cells but does not describe them. Therefore, a different interpretation should be made at this point. Mixed-reality links are the technological links that use mixed-reality boundaries and augmented reality technologies. Therefore, it intends to structure co-presence patterns through Mixed Reality Technologies. Although this is a working system, it is also open to development. At this point, it is necessary to leave aside the technological principles and focus on the concept. Mixed reality architecture, in its simplest form, enables virtual and physical cell interaction by using mixed reality technologies and interfaces. However, architecture does not play an active role in this interaction. This study brings a new approach by proposing to define the architecture itself as an interface instead of using the auxiliary elements that will transform the space for the production of mixed reality architecture as an interface for virtual and physical environments. Therefore, as an interpretation of Ishii's tangible bits approach, if *architecture* itself is defined as an interface to be used for mixed reality, the forms of interaction will increase and strengthen, as well as a new understanding of architecture will be developed.

The idea of using architecture as an interface to combine virtual and physical environments is based on the interpretation of the tangible bits approach of Ishii and the augmented virtuality approach by using architectural physical/tangible bits as physical proxies of virtual elements in the space. Therefore, the interpretation of tangible bits and augmented virtuality approaches together with mixed reality architecture in a way that supports co-presence interactions forms the theoretical background of this study.

In the previous section, it was mentioned that computer-supported co-presence systems provide solutions to situations where the architecture cannot meet the needs of its users. Although architecture has never aimed at the interaction of people in distant places, this issue has become a subject of architectural debate due to its ability to be an interface between virtual and physical spaces to create interaction between distant spaces through virtual reality and mixed-reality technologies. Through mixed-reality architecture, space can become an interface for computer-supported co-presence systems, and in this way, architecture can become a communication tool, maybe even a media as it was in ancient times.

Last chapter, media spaces, spatial video conference, collaborative virtual environments, telepresence, and collaborative mixed reality environments have been examined. The use of architecture as an interface between the virtual and the physical leads to the redefinition of space as a collaborative mixed reality environment. Physical affordances defined over physical/tangible bits can function as telepresence in specific situations, and the relationship that architecture establishes with virtual environments through the mixed-reality boundary can create a collaborative virtual environment simulacrum using augmented virtuality. Therefore, computer-supported co-presence systems can be used in mixed reality architecture, and it has been used in the production of many concepts that create the design in this thesis or have been inspired.

Furthermore, mixed reality consists of physical and virtual elements. Here, the physical element, the architecture, must have physical flexibility as it will be used as an interface for interacting with the virtual environment. Therefore, the physical/tangible bits of the design must create physical affordances in order to produce an interface for the virtual bits. We will later call these hybrid affordances due to their function in both the virtual and physical environment.

The mixed-reality boundary is a mixed-reality approach created for the interaction of two spaces through a boundary. According to Benford(Benford et al., 1998), the same approach can be used to interact with multiple physical and virtual environments to create a structured mixed reality, Tessellated Mixed-reality that will enable all surfaces of the architectural cell to interact with many physical and virtual spaces in the virtual environment in mixed reality architecture. [Figure 26] While this idea was built for the mixed reality boundary approach, it can also work in much more complex systems that use the mixed reality boundary as an element. Therefore, mixed reality architecture, interpreted by this study with mixed reality boundary, augmented reality, tangible bits, and augmented virtuality approaches, can interact between many spaces by using the tessellated mixed reality concept; it also creates the idea of a mixed-reality metaverse formed by virtual environments and digital twins of physical spaces. Hence, mixed reality not only interacts the virtual and physical layers with each other, but also allows the physical space to become a part of the spatial internet if it occurs. In this context, architecture has turned into a spatial communication tool that can connect present, remote and virtual environments [Figure 27], users, and things, and produce new forms of interaction, thanks to mixed reality technologies. This not only brings a new perspective to architecture through mixed-reality, but also creates the idea of an alternative spatial internet, an alternative metaverse over mixed reality architecture.

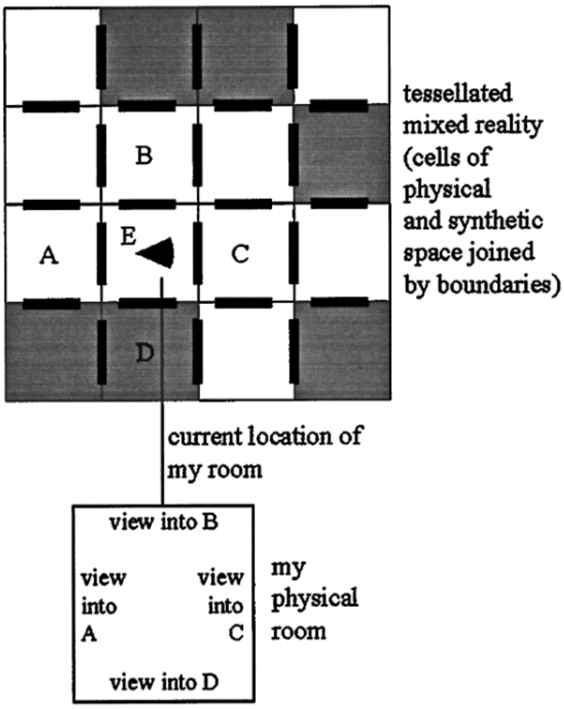


Figure 26: Tessellated mixed reality, physical room as a vehicle to move around structured Mixed-Reality, by Benford from 1998

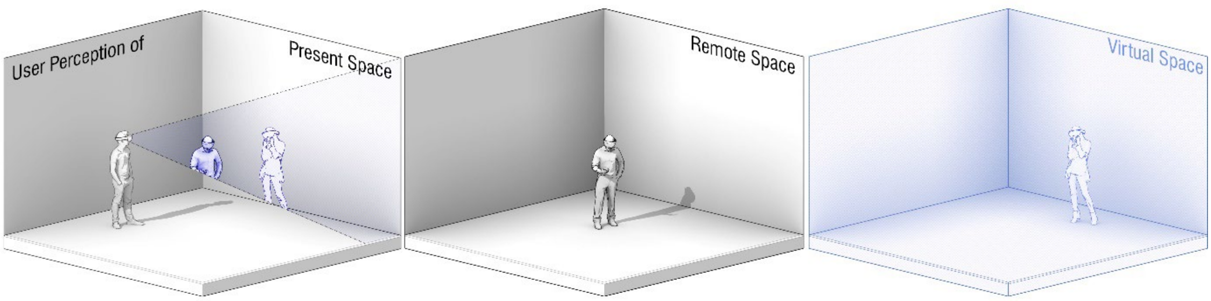


Figure 27: Architecture as spatial communication tool between present, remote, and virtual spaces and their users.

5. THE PROJECT

This chapter explains the reflection of all theoretical and experimental studies in previous chapters in the form of a design statement. In other words, this section is about how expansions in many fields such as virtual environments, metaverse, mixed reality, UX/UI design, and co-presence studies can affect architecture and what inferences can be made as a result. This part will be a multidisciplinary field where the architect works as a polymath and receives assistance from other disciplines.

5.1. Introduction

All the information studied in theory and the results achieved are summarized in a tangible way as a design/guideline. The main objective of this thesis is the Augmentation of Flexibility in Architecture, which develops criticism of the inability of architecture to respond to the instant changes and needs of today's life and proposes a solution with mixed reality technologies and virtual layers of spatial space. In order to better understand the importance of using architecture as an interface between virtual and physical for flexibility in architecture, supporting it with a design project carries a more realistic dimension.

5.2. Conceptual Study

This chapter will discuss notions on which the concept of design is built, their counterparts in the previous chapters, and how they shape the design.

First, the main discussion is shaped around two primary and one side elements. These are the Flexibility of Architecture, Mixed-Reality Architecture, and computer-supported co-presence through virtual architecture as a side element. These elements have allowed us to evaluate the flexibility of architecture and affordances of the space as physical, virtual, and hybrid.

Architecture's ability to respond to transformation has been developed over the ambiguity of the space or its physical affordances' constraints in the past. This attitude compresses the studies around spatial and physical approach and the building configuration approach as a different interpretation of the two. Therefore, this study aims to bring a different perspective to this research field. With this new approach, the building has virtual layers through mixed reality technologies. Using physical and virtual affordances separately or in a hybrid way (hybrid affordances) offers architecture spatial flexibility that traditional architecture has not been able to offer until now. This new approach is called Augmented Flexibility.

The subject of these hybrid affordances was investigated throughout the design process, experienced through trial-error and prototyping, and gave us a clearer perception. To give you an idea, while capturing data for the digital twins of the actors in the space and being able to reproduce them in the virtual environment is a feature offered to us by mixed-reality technology affordances. The potential of this affordance has only been possible with the experimental approach for the architectural programs in which it is used. To illustrate, capturing the actions taking place in the space allows the creation of a spatial data record and thus re-enactments these records if desired. This procedure allows architecture to have a memory and even allows the users to interact with the data about the history of the space and even experience spatial time travel simulacrum. Even the simple affordance of capturing spatial data in such a space, creating the digital twin, and re-enactments it, when necessary, enables the creation of dozens of different architectural programs and forms of interaction unknown to people. That is why the potential of hybrid affordances is beyond our understanding. If we go back to the very essence of architecture at this stage, we can see that a definition of architecture based on the spatial experience of the space is quite similar to the field of user experience design. Therefore, it is not just architecture or user experience design; it is a system design where they all play a role in forming the whole.

On the other hand, before taking the discussion to the next level, it is more convenient to talk about several problems posed by these technologies. First, it has been challenging to use technologies such as virtual and mixed reality for long periods. The biggest reason for this is the motion sickness problem. Although there are many reasons for this, our concern is about the spatial problem. While virtual reality or mixed reality users experience a reality that their physical bodies do not experience through their virtual bodies; because they do not feel the physical effects of variables such as speed, acceleration, and movement, this conflict between physical and virtual reality; our brain seeks a solution to the inconsistency of the signals coming from the balance centers and the visual data coming from the eye. This situation causes the stress levels of users to increase. As this experience gets longer, a phenomenon called motion sickness occurs and develops.(Zuniga Gonzalez et al., 2021)

The design works with the principle of eliminating this contradiction between virtual and physical space to prevent this problem from occurring and ensure the architectural program's consistency. In this framework, physical space kinetically imitates the transformation in virtual space. Therefore, if the transformations in virtual space can be experienced in physical space to a certain extent, motion sickness will not be experienced or reduced. In this way, the affordances provided by the interface for mixed reality will become suitable for creating an architectural program.

For instance, the fact that a seating unit created in a virtual space does not have a reality in the physical space does not have any value for someone who experiences only the physical space. In addition, a user who experiences a virtual motion has to face the problem of motion sickness, as he/she cannot experience it with his/her physical body. However, if the seating unit created by the user in the virtual space is imitated in the physical space and the user can physically move in the space and interact with the physical counterpart of the seating unit defined in the virtual space, none of these problems will arise. Therefore, the design solves the mentioned problems by minimizing conflicts between physical and virtual spaces through a kinetic interface. This kinetic interface is called the architectural interface. It refers to the interface the architecture defines between the virtual and physical spaces. In this framework, even if the affordances provided by the architectural interface change shape or be altered, in principle, the function of the architectural interface is to resolve the conflict between the virtual and the physical while increasing architectural flexibility through its hybrid affordances while producing architectural potentials and programs waiting to be explored that conventional architecture cannot give us. In other words, the system design is based on minimizing the conflict between the physical and virtual realities of any architectural interface through its kinetic affordances.

5.3. The Conceptual Background

In the previous section, we stated that architecture should define an interface between virtual and physical spaces through its physical affordances to provide *augmented flexibility*. Furthermore, these affordances should be designed to eliminate the conflict between what is virtual and physical. To do this, the first step of design is to produce a space with hybrid affordances-an affordance can be used both in physical and virtual spaces- to prevent this conflict and meet even real-time transformations.

In this context, we decided to adapt the project, originally developed for Digital Scale-Up Studio, to this purpose. Although the subject and purpose of the project changed many times during the period, it was designed with the aim of an architecture that can be reprogrammed, reconfigured, and transformed according to current needs. Therefore, it can be seen as the beginning of an intellectual continuity.

The design process, which started with the idea of kinetic transformation of the space into almost any shape, created the first simple ideas about the concept by being inspired by the pin table scene in the X-men movie. Although it does not give an idea about the mechanical structure or how the motion is realized, it is an indispensable source of inspiration for the concept as it is a VFX for science fiction movie.

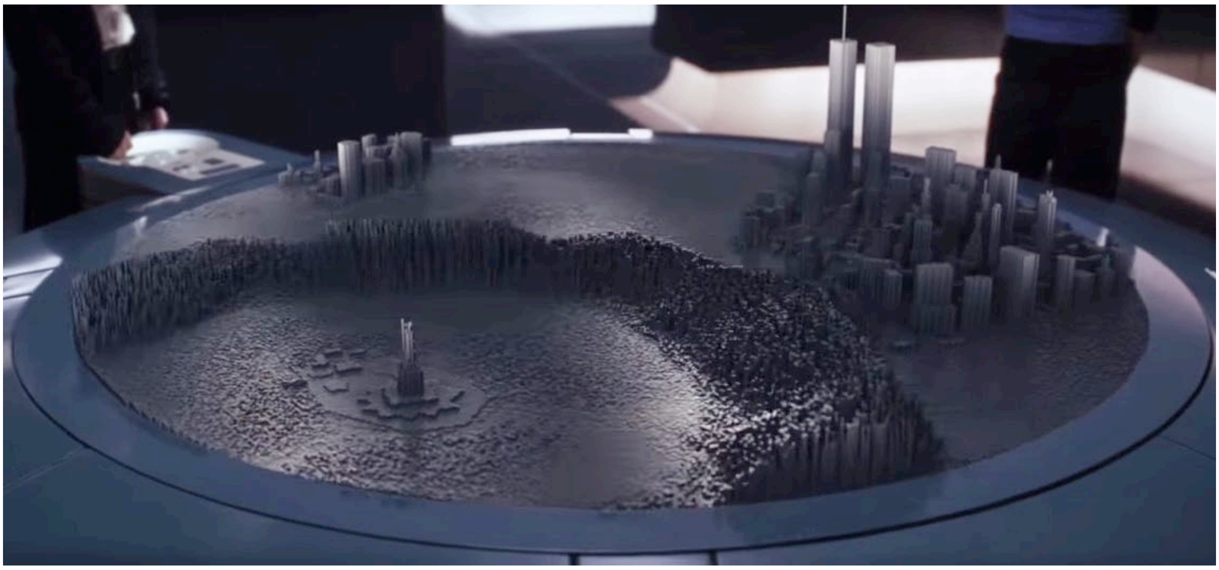


Figure 28: Pin Table scene from X-Men Movie VFX by C.O.R.E. Digital Pictures.

According to this concept, Modules that will provide spatial affordances on a certain grid are placed in a way to define a surface, and this is a flexible surface idea that can transform itself and make a shape-display as a result of the modules moving up and down on the z-axis. While this surface can take almost any form, it cannot display more than one data on the z-axis, so it imposes a restriction on this system. However, despite this constraint, we can talk about the infinite variety of forms that can be produced, while the simplicity of the movement makes it feasible.

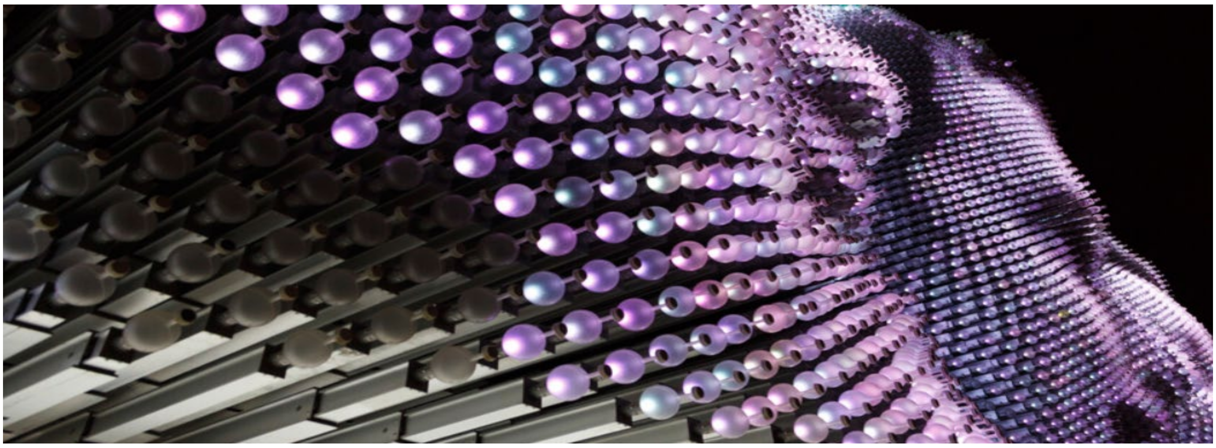


Figure 29: MegaFaces Pavilion, Sochi 2014, Asif Khan

Furthermore, similar examples were examined to elaborate on the concept. For instance, the MegaFaces project(Khan, 2014), which was built for a different function than producing architectural space, creates an excellent mechanical sense with its telescopic modules. However, although it provided a good example in this regard, the dissimilarity in scale and function may raise questions about whether a similar application would work on an architectural scale with users. Therefore, the scale of research later expanded to areas outside of architecture. However, the idea of having LEDs helping to add a graphic layer on the contact surface of this kinetic system and using this surface as a 3D screen was not preferred in this study, but it can be counted as an idea that overlaps with the Augmented Flexibility approach.

In addition, the inForm hardware developed by MIT Tangible Media Lab and the shape display studies carried out with the use of inForm is also essential for the architectural interface idea. Within this interface, not only motion but also the variation of motion over time can be programmed, and to this extent, all the relevant variables that the architectural interface needs to provide flexibility. That is why it is valuable for the concept stage. Furthermore, architectural space will have the potential to constantly transform itself with the help of artificial intelligence or attractors designed to be used as parameters and pre-programmed transformations through this interface. It also shows the potential of designing an experience defined through the programmable shape display, which changes according to sound, light, motion, and many other variables and inputs. This area of study is also an important research topic for the future of architecture that is waiting to be explored.

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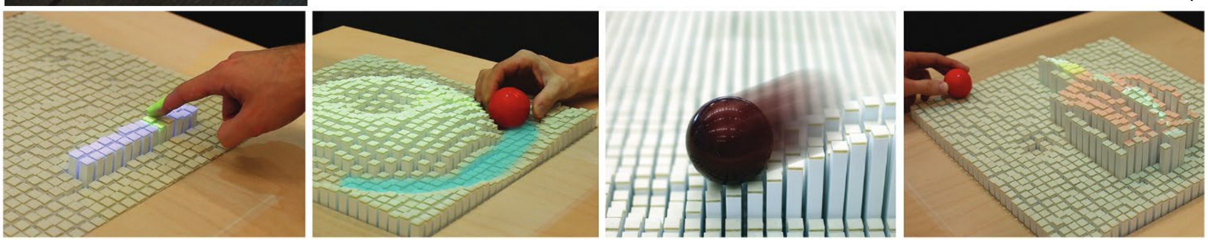


Figure 30: InFORM shape display hardware and interaction techniques for shape displays by Media Lab MIT 2013.

Figure 31: LiftTiles: A modular inflatable actuator as room scale shape-changing interfaces by Suzuki 2020.

In addition to all these studies, when we examine the TilePoP and LiftTiles studies, we see that pneumatic application are predominant, and these are shape displays designed to give haptic feedback for VR environments. (Suzuki et al., 2020; Teng et al., 2019)The fact that it is a room-scale study is precious in terms of the data it offers for functionality and use of possibilities in the concept process. However, even at room scale, they are interfaces designed to avoid conflict between virtual physical rather than architectural elements, as they are designed for haptic feedback for VR environments. This situation has dramatically restricted the functionality of the design and effaces its architectural potential.

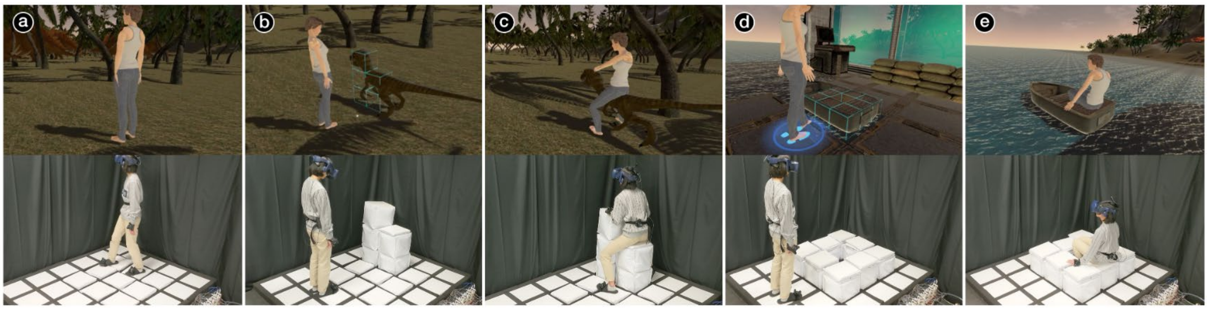


Figure 32: TilePoP inflatable shape display for haptic feedback on VR environments by Teng 2019.

As a result, although these studies were carried out with similar intentions, none of these examples were produced as the mixed-reality-oriented interface unit that we define as the architectural interface, yet they concretely prove the feasibility of the concept. In this context, a concept study will be carried out in the light of these research in the next section.

5.4. The Design Concept

In this section, in order to understand the concept design and conceptual narrative, first the physical components of the concept and then the virtual and mixed-reality components should be explained. Therefore, initially, the physical side of the design, which is also studied in the digital scale-up studio, flexible architectural design, physical affordance design, and the conceptual studies done to control or produce the system design, will be explained. Then, the relationship of this system with mixed reality technologies, hybrid affordances, and overall system design will be demonstrated.

5.4.1 Architectural Concept

In this framework, the idea of the physical part of the design can be simply summarized as that the surfaces that define the spatial space can be divided to organize the space and move in such a way as to provide this organization. [Figure 33]

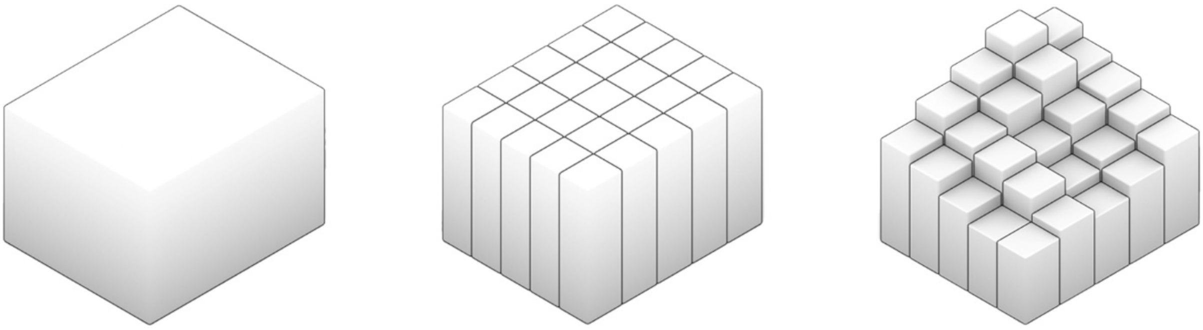


Figure 33: Conceptual diagram of division of bottom surface, illustrated by Author.

Let's start with the depiction of the physical face of the design. What enables the transformation of the space is the physical affordances of the physical bits that make up the design to change the spatial properties, shape, and function of the space. Since the motion of these physical bits to their normal will create new surfaces, it is more accurate to see them as structural modules that can move on a particular axis rather than as a two-dimensional surface. These structural modules are the smallest units that provide the physical affordances of the design. While their individual movements can change a part of the space according to needs, their collective movements define the architectural space and the program. [Figure 34] We call these smallest units as pixels because of their shapes and how they define something bigger when collaborating. Later, each pixel will be called voxels, as virtual layers conceptually

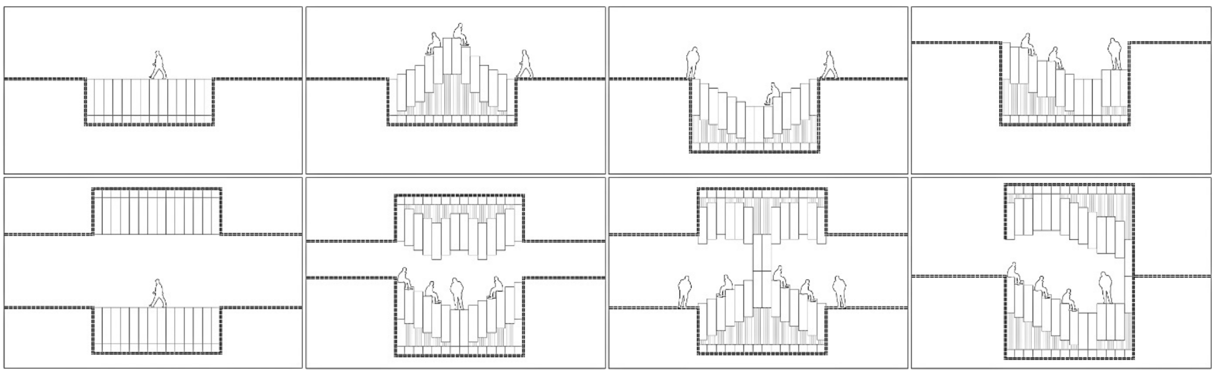


Figure 34: Conceptual sections to illustrate spatial potentials that design offers illustrated by Author.

augment each pixel to a virtual dimension. Still, this definition form remains relevant as we consider design only in its physical form.

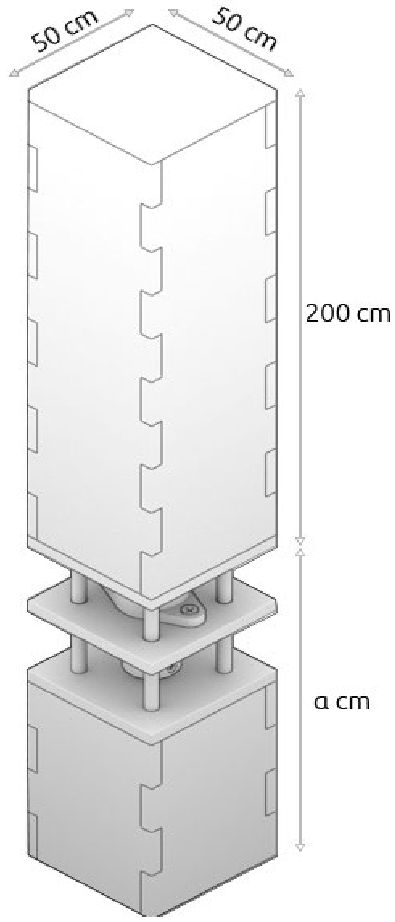


Figure 35: Prototype Blueprint, illustrated by Author

As a result of the movement in the z-axis of these pixels, which make up the design, the space has the ability to transform any form in real-time. For example, pixels moving positively on the z-axis with a certain rule one after another can form a stair, walls formed by the movement of the upper and lower pixels towards each other and sitting and table units can be formed as a result of the partial movement of the bottom pixels. In addition to all these, the potential of this sandbox idea where this transformation will be made by the users and the spatial variations that the user-participated design will produce, and the interaction forms and architectural programs that will be shaped around these variations are limited by the imaginations of the users rather than the predetermined design templates. In this framework, as can be seen in Figure 34, transformations that can completely organize the space can be achieved, as well as movements on a smaller scale that will affect a single user.

The design of these physical affordances should be examined before making expansions about the spatial organizations or architectural programs that may occur in such a design. In addition, this approach allows us to have a clearer idea of the physical and conceptual limitations of the space. The movement principles and physical affordances of these modules, called Pixel, have been prototyped and examined to carry out these examinations. [Figure 35]

During Pixel's design process, the design of the mechanical motion that will move the module on a single axis to realize the module's interface has been developed, and among these ideas, the alternatives have been reduced to the two most suitable. These motion designs include linear actuators and systems using pneumatic/hydraulic fluid mechanics. The physical affordances, working principles, and production methods of the 1/10 scale prototype models made for both will be shared in the continuation of the study.

In this frame, when the DC motor linear actuator example is examined, the design form is completed when the elements that will form the contact surface of the modules are added to the moving part of the actuator design in a way that covers the rest of the actuator. Here, the variables that make up the module are the dimensions of the module user contact surface, the volume, power, and torque of the motor, the length of the linear actuator, and the material preferences for the contact surface. The module's dimensions determine the resolution of the form produced by design, as the module's name is Pixel. The smaller the modules, the smoother and more detailed a contact surface is obtained. However, as these modules get smaller, they cause cost, stability, and durability problems. Therefore, rather than a design idea that goes towards perfection as the module size gets smaller, a design philosophy should be followed in which the optimal size is preferred according to the conditions of the time it is produced. Alternatively, at specific points where more details are expected, module sizes should be preferred to be relatively small at those points. Also, the torque and power of the motor is another design input to consider as it will affect the response time during conversions, the load it can carry, and things like the safety and fluidity of the movement.

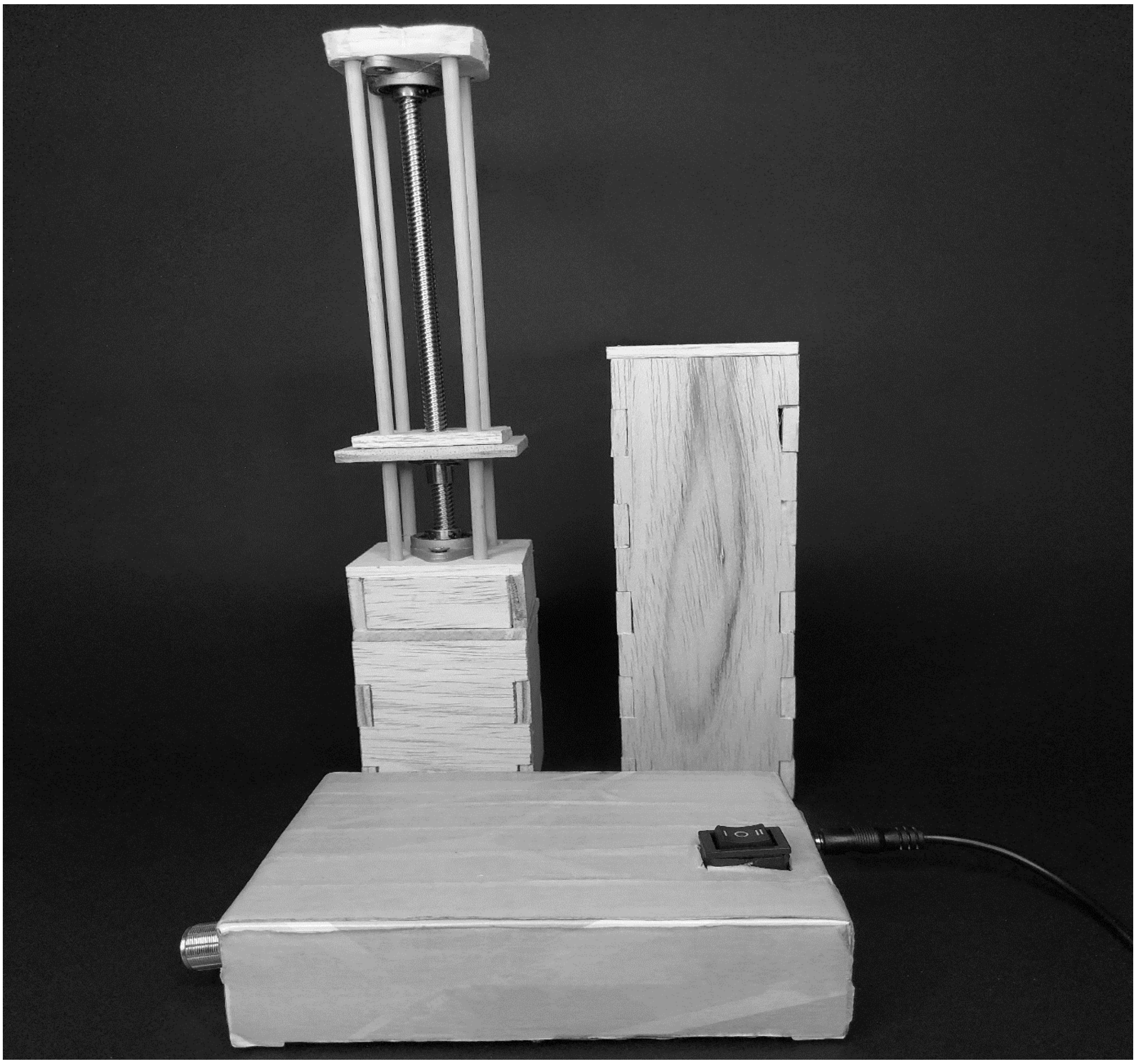


Figure 36: 1/20 Scale DC Actuator Pixel Prototype.

In addition, since the design can be easily connected to an Arduino system even while prototyping, a set of movement patterns can be controlled with the help of a simple program that will generate pre-programmed motions and variables of motion characteristics. The prototype's size is 1/20 prototype of the original, designed to be 5x5x20cm in contact with the user in motion. All remaining sizes depend on the motor used and the size of the actuator's motor connectors. The parts of the prototype consist of a converter from AC to DC, a control board with a slider to help regulate the speed, and the actuator itself. [Figure 36] The prototype worked successfully as designed in the trials. Larger scale trials are required for the continuation of the analysis, but it was not considered necessary for this thesis work as the production of the module seemed feasible.

Moving on to the second prototype, the pneumatic example should be taken into account as more of a principle model. The model consists of 2 elements; the control interface and the shape-display interface. The primary mechanism of the model is to provide this airflow with the help of syringes at both ends that will provide air pressure control and a channel that will provide airflow in the middle of them. Therefore, when the syringe on one side moves, the other side also moves. The intended scenario in the concept can certainly be created in a version with solenoid valves and systems to control pressure instead of syringes on one side. We mentioned two studies that are examples of this concept in the previous section. TilePop and LiftTiles work use pneumatic systems with a similar principle.

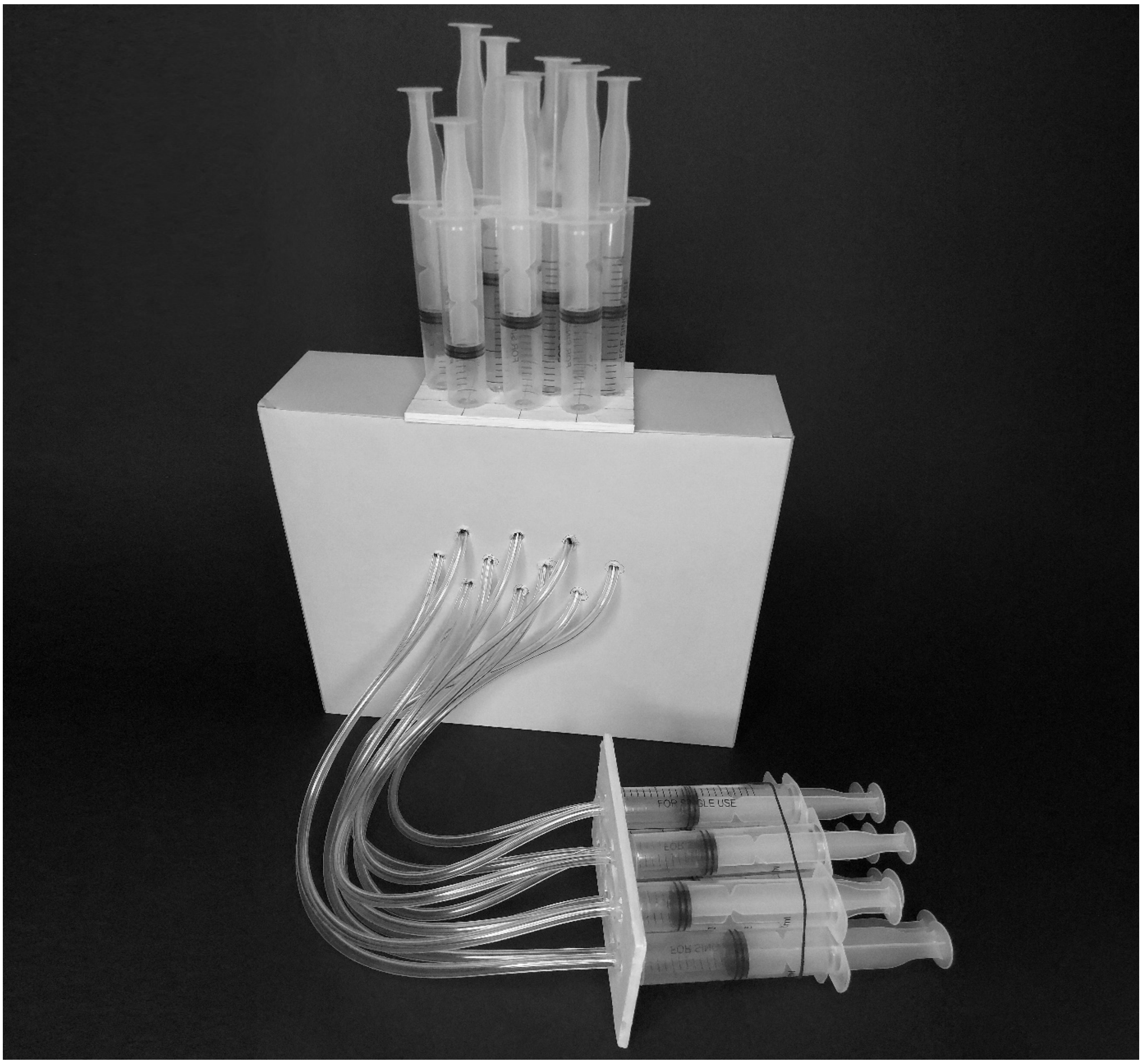
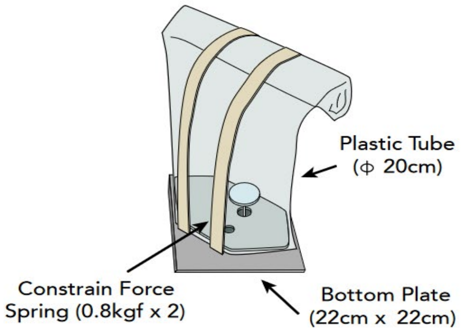


Figure 37: Diagrammatic Model of Pneumatic Pixel Prototype.

For instance, in the LiftTiles Project, the actuator modules consist of constant force springs and plastic tubes in which the airflow will take place, and the length of the module can extend from 15 cm to 150cm when inflated and retract when deflated, with the control of the air pressure. Since LiftTiles modules cost as low as 8 dollars, although the carrying capacity and speed of the modules seem limited, it shows that the principle of the mechanism works successfully. Furthermore, this shows that a system working with fluid mechanics is quite feasible for this concept.



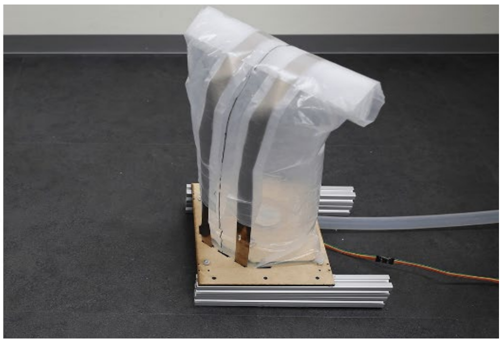


Figure 38: LiftTile actuator module.

In simple trials with the prototype model, it was determined that the model worked as designed, and its mechanism behaved as predicted. However, there was a delay in motion, probably due to the use of air with a high coefficient of compression in the fluid mechanism. It is foreseen that similar behavior will not be detected in a prototype where the same system will operate with liquid with low coefficient of compression instead of air. In this context, the idea that different fluids should be used instead of air was noted when a larger-scale prototype was to be worked on. However, in this thesis study, there was no need for a large-scale model as it was proven that the prototype offered a working mechanism in principle.

When the prototype models were examined, the desired results were obtained at the small scale, and it is expected to work in theory at the large scale. In this framework, two different concepts have been developed, where modules can be applied to provide physical affordances. When the project is implemented, a choice should be made according to the conditions of the place and time of the application.

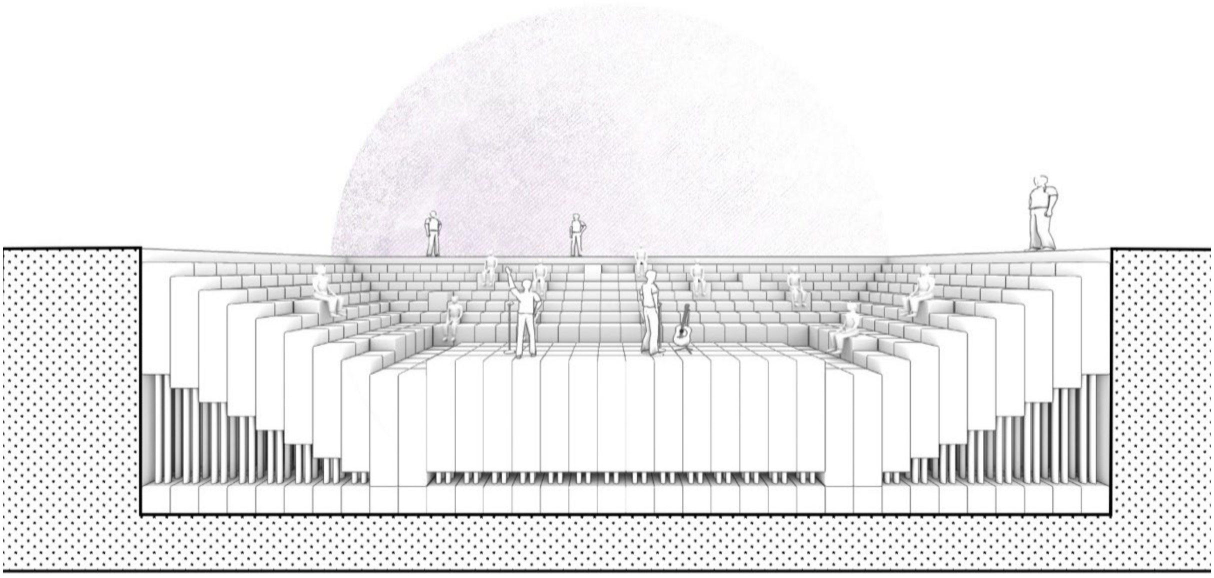


Figure 39: Design scenario, multi-functional urban square, illustrated by the Author

The design defines a user participatory flexible architecture that users can transform the space through pixels that provide physical affordances. This gives the architecture the possibility of having endless form and function. In this way, the design can turn into an amphitheater to host concerts or create dividers between programs that need to run independently; it can even host architectural programs that require sudden and continuous transformation, such as theater sets, exhibition & performance halls, indoor sports. [Figure 39&40]

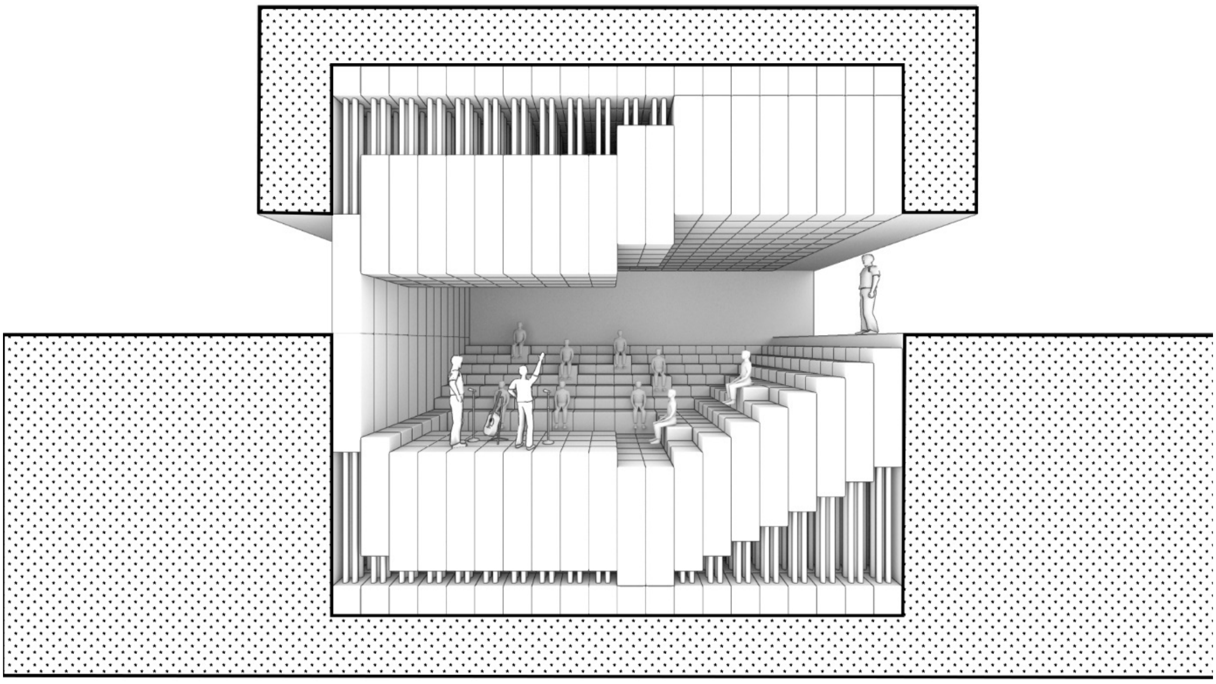


Figure 40: Design scenario, multi-functional room illustrated by the Author

At this point, the design can develop itself in two different directions. One of them is to create design templates designed by architects by regarding the extent of the physical affordances of the design to create an architectural library registered in the design's memory. The most prominent design problem in user-participated designs is where the architect's role ends, and the user's role begins. In this framework, the first aspect is that the architect's role is much more significant, and the user can only make limited choices in a narrowed design universe. Flexible elements in architectural structures often work on this principle. Many flexible elements, such as removable boundaries, demountable elements, and architectural elements that can be reassembled into a certain position, allow the transition between several design options that are essentially narrowed. Therefore, one of the things that this design will achieve can be thought of exactly as this. Since the architectural programs and forms allowed by physical affordances have already been designed by the architects and curators long before the design is ready for use, the touches made by the users to the design can be reduced to minimal or even zero. On the other hand, another direction in which design can be developed is the version in which the architect's role is relatively reduced, but the role of the user increases. To illustrate, the difference between these two approaches is whether the space is in the form of an amphitheater when the user first meets the space or whether it is ready to transform by the user without having a characteristic form. Both experiences have pros and cons, and they are opposite in approach. Returning to the approach where the user role is prominent, the architect faces a second design problem, the architecture-user interaction problem. Furthermore, this problem has not been seen as an architectural problem for many years. Many issues, such as what kind of tools the user will use while transforming the building, how the user interacts with these tools, and the response time of the building to these tools, are the design of the space-user experience. Therefore, this can be seen as an area where user experience design and architecture overlapped. Moreover, in a user-participated architecture idea, the value of the user experience design increases as the user's role in the architecture grows. In a perspective where we define architecture as the design of space experience, the architect designs the experience of the space that the user can constantly transform and interact with, rather than relinquishing his role and encouraging the user to become an architect. This means that the role of the architect is growing and deepening rather than diminishing.

In this framework, the design has focused on the design of architecture-user interaction. First, the user's communication with the design is a design problem, and then the form, speed, and frequency or necessity of the communication is a secondary design problem. For example, in an ideal scenario, a self-transforming design can analyze the user and space needs with the help of artificial intelligence and transform itself into a way to meet these needs without even the user's knowledge. Alternatively, if there is a transformation under the user's control, whether the user verbalizes the instructions, uses some 3D design tools, or pushes and pulls by using their hands are the most critical problems of this user interaction design.

Many concept studies have been carried out on how the user interaction design should be specific to this project. Since these studies play a crucial role in the system design to be designed later, they will be summarized below. The first and most straightforward of these studies is the point attractor method, frequently used in parametric design methodology. In this method, several attractor objects are located in the structure. Their physical movement in the space and the physical affordances provide the spatial transformation of the design, and the user's participation is realized in its most primitive form. Furthermore, the participant can make this change without any design tools or prior knowledge. For example, a point attractor defined as a tiny sphere may describe a spatial state due to its relative position among the physical affordances. In a scenario where this spatial state has a small seating unit, the user can take this sphere wherever he wants to sit and leave it as user wishes, and this can describe the communication with the building.

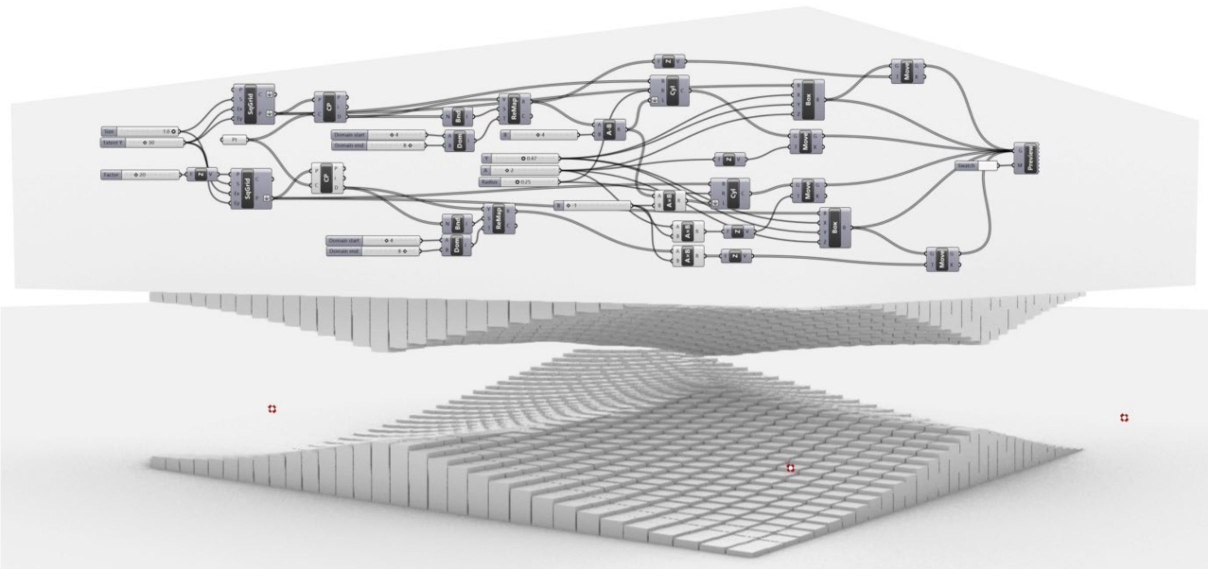


Figure 41: Point Attractor user interaction study in grasshopper, illustrated by the Author.

Or, in much larger samples, this may lead to the identification of an amphitheater or the formation of separating walls. However, the difficulty in obtaining a satisfactory result caused this method to be questioned and shelved due to the trials. But, in a system that works with another principle, additional spatial definitions can be made with the help of these attractors. Children can be given these attractor toys to prevent them from being harmed by the sudden movements of the space or to spontaneously transform the environment of a moving actor in the area. Later, the variations in which these attractors can be defined as physical or virtual and the contributions of this idea to the design will be examined.

Another study is the concept of image sampler attractor. It uses a graphic expression to transform the form of the space. While this can have many alternative uses, the users can control the transformation through a two-dimensional representation of the space in a method where a black and white image is used. In this method, black represents where the position of pixels is lowest, and white represents where the position of pixels is highest in the z dimension. For example, with the help of a sand art lightbox placed at the space's entrance, users can manage the transformations in the space by moving the sand on the lighted table. Or they can play with these images from the applications they download to their phones and tablets. Although this method is suitable for obtaining a form very quickly, it is not preferred for a detailed form because it is a challenging method to learn. However, this method will be used in the future when pre-programmed regional movements are to be designed.

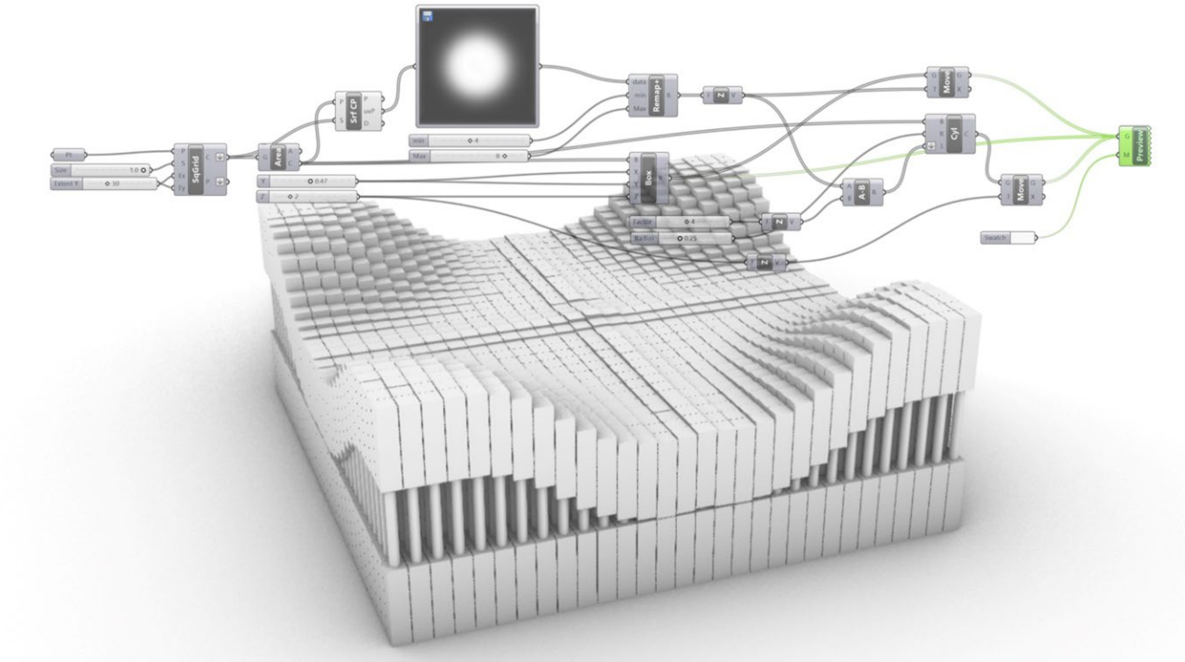


Figure 42: Image Sampler user interaction study in grasshopper, illustrated by the Author.

The last of the studies is the interaction of the user's hand gesture with the design. First of all, in order to establish this interaction, there is a need for hardware that will process hand gestures as data input in the design. For this study, leap motion hardware was preferred due to grasshopper, unreal engine support, extensive tutorial, and gesture library. In an experience where hand gestures provide user-space interaction, a design idea should be developed regarding many things, such as which gesture corresponds to which action or transformation. It can be mentioned here that the interaction design concept has several drivers. The motion of pixels on the z-axis can be considered a telekinesis abstraction. The user can perform this interaction simply by pointing at a pixel and moving it up and down. In addition, to move many pixels, a telekinesis effect can occur from a virtual domain starting from the pointed pixel and decreasing outward from the center of this domain. Variables such as the affected area's size and the effect's severity should be defined here. Furthermore, if the user can control these variables with his other hand, the user can control an entire system with simple hand gestures.

Within the thesis framework, a demo was developed for the interaction established with hand gestures by using grasshopper software. In this demo, simple boxes placed on a grip are controlled by hand gestures captured by leap motion. When using the leap motion hardware, the position of the palm is programmed to select the domain's location, and the hand's distance from the leap motion device is programmed to control the strength of this effect. In addition, the distance between the thumb and index finger can be used to determine the parameter that controls the width of the domain. With another hand gesture, real-time manipulations can permanently be applied to the design. In this way, many users can achieve a cumulative space form by performing their manipulations on each other's effects on the design. After studies on this demo, it was decided that hand gestures are the most controlled and understandable way of interacting between users and space. However, this decision has identified another problem: users will constantly need to carry a hardware or go to the section in the design where the hardware is located.

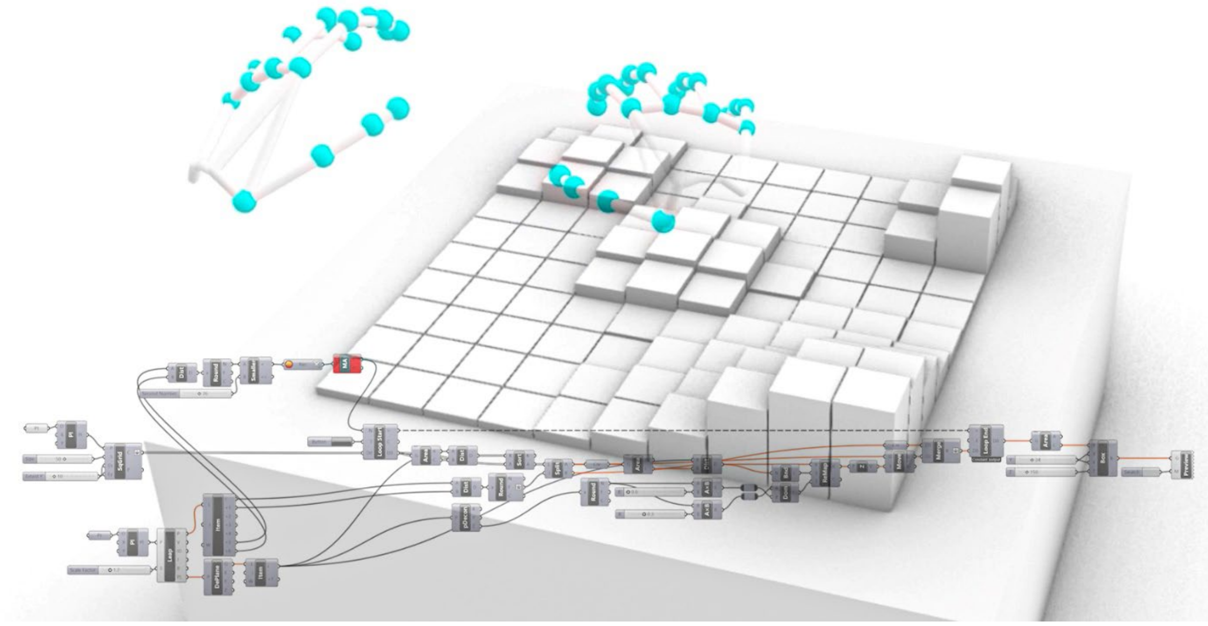


Figure 43: Hand gesture user-interaction study in grasshopper with leap motion device.

During the research on using hand gestures in interaction design, one of the works that inspired the next part of the project was Project NorthStar. Project NorthStar is a concept developed as an augmented reality project by UltraLeap company, which produces the leap motion hardware we use to detect hand gestures. The most significant difference from other augmented reality projects was that it promised interaction through hand and finger movements without using controllers. As of now, almost all augmented reality and mixed reality hardware has started to detect hand movements and design interactions through them, but Project NorthStar is a pioneer in this regard with the knowhow it carries from other haptic products such as leap motion. In Project NorthStar concept demos, it promised interactions that resembled sci-fi technologies, similar to the one Tony Stark performs in his lab with holograms in Marvels Iron Man movies. This form of interaction is conceptually very similar to the desired interaction with pixels, however, NorthStar is a mixed reality technology and the things that hand gestures interact with were essentially virtual elements. However, when we provide similar interaction with physical elements instead of virtual elements, the desired interaction is achieved. Which brings us to the next chapter, the mixed reality part of the concept. Because a mixed reality technology that provides interactions through hand gestures not only provides an interaction between the user and physical possibilities, but also prepares the ground for the idea of architectural interface as it allows the control of computer-aided architectural kinetic elements with mixed reality technologies. Therefore, since the use of mixed reality allows us to interact with physical affordances and virtual elements, it establishes a relationship with the digital layers of the space similar to the one we establish with the physical layers, thus ensuring the integrity of the experience. This holism forms the basis of the architectural interface idea.

5.4.2 System Design Concept

The focus of the thesis is a mixed reality system design that works with architectural interfaces. The physical side of the design is a tool used to better express the design of a mixed reality-oriented system, rather than being the main concept. Therefore, the system design can also be produced by using different physical affordances. On the other hand, since the design of this system has emerged as a result of the intellectual continuity of the flexible architecture project consisting of pixels, the thesis study has continued with this project as physical affordances. However, in future studies, the choice of physical affordances may change shape and method to improve system design.

The architectural interface concept is based on the idea of avoiding the difference in experiences between the physical and virtual spaces of the same environment and minimizing conflict through virtual twins created from the physical affordances that make up the space.

In this framework, since the pixel modules that establish the physical space will function as a spatial interface for interacting with the virtual layers, they produce the digital twin of their existence in the physical space to the virtual space to avoid conflict. The system works with the generation of digital twins in order to ensure that the elements in the physical space can also be experienced in the virtual space.

Therefore, even if users with purely physical experience do not interact directly with virtual users, but they interact indirectly with virtual users because they interact with physical elements that virtual users interact with their digital twins. Indirect experience also works in reverse, as the effect of a physical user on physical items is experienced by the virtual user through digital twins. In order to provide this indirect interaction, digital twins of physical affordances should be created, and the data created by these digital twins should be kept in server so that virtual users can experience them.

At this point, to understand the concept, it is necessary to examine how the digital twins of pixel modules work. The movement of linear actuators, one of the Pixel concept designs, is provided by electric motors controlled by the server. Since all the operational data of the engines are kept in the system, with a simple calculation, the system will be able to quickly obtain the position data of the pixels on the z-axis, and while the digital twin of the space is produced, the pixels are created in the virtual environment using the location data of the physical twin. In this way, every time the electric motor operates, the pixel's position in the z-axis will be re-rendered in the virtual environment in the cartesian space so that it will be experienced in the same way as the physical twin.

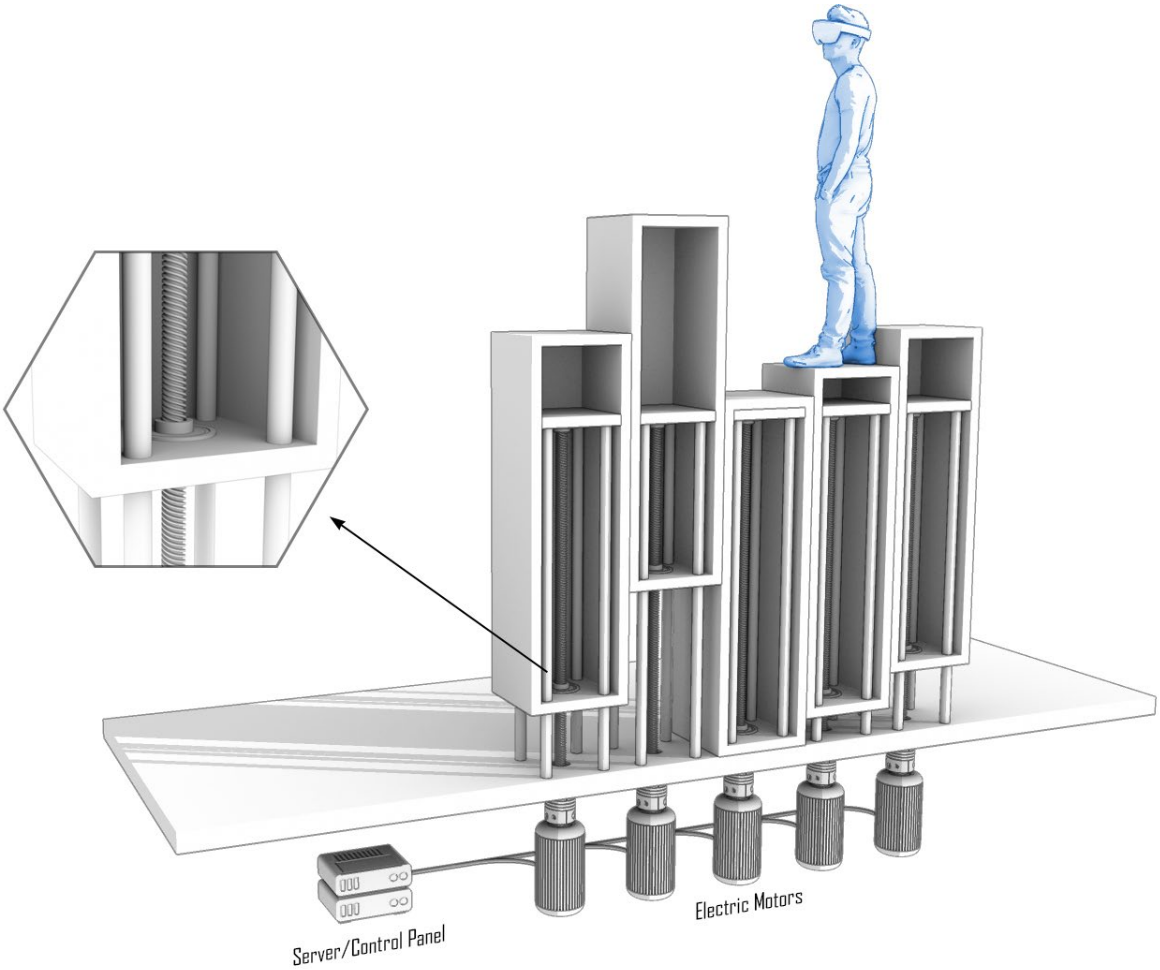


Figure 44: Linear actuator/system interaction concept diagram, illustrated by the Author.

In addition, the second concept, the pneumatic system, consists of a pump/compressor that controls the fluid pressure and solenoid valves located at the connection point with each pixel. While the compressor/pump provides pressure control, the positions of the pixels on the z-axis can be manipulated by controlling the pressure level. With the data from the sensors attached to the pixels, their positions can be easily detected and stored as data in the system to determine the location where the digital twins of the pixels will be created. With the use of solenoid valves, more than one pixel can be controlled with a compressor/pump in collective use. In alternative system designs, the pixels can move in the negative direction on the z-axis without even consuming energy by using the original weights of the pixels and the users on them. As another alternative, in system designs that do not need real-time transformation, the position of the pixels on the z-axis can be manipulated without even consuming energy by using only the solenoid valves and the weights of the users.

Therefore, no matter which system is used, the main focus of this study is to transfer the movement in physical space to the digital twin as close to reality as possible and to produce and keep this transferred data as optimized as possible.

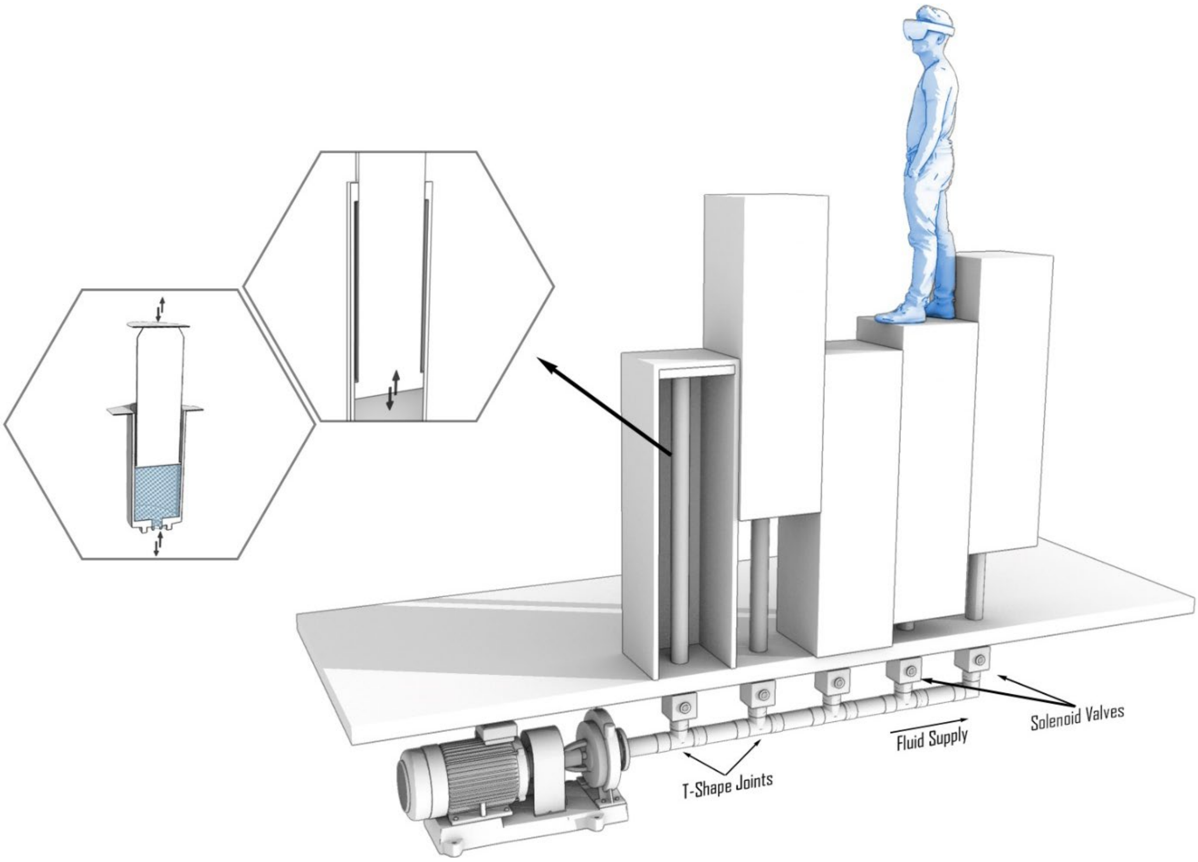


Figure 45: Pneumatic actuator/system interaction concept diagram, illustrated by the Author.

The creation of digital twins of pixels allows the architecture to be experienced virtually. However, when the physical and virtual affordances in the space begin to be experienced by the user through similar interactions, the perception barrier between virtual and reality becomes blurred for the user. In this way, physical affordances gain virtuality, and similarly, virtual affordances also gain physicality, by adding a new dimension to the user-space interaction. The affordance type in which users interact with the elements in the space, which has both physical and virtual affordances through digital twins, is called hybrid affordances. The primary mechanical use of hybrid enablement reduces the difference between virtual and physical from a user experience point of view by defining similar interactions between the actors within the system, whether virtual or physical. In this way, the experience becomes much more holistic, as the user will interact with virtual items in the same way he interacts

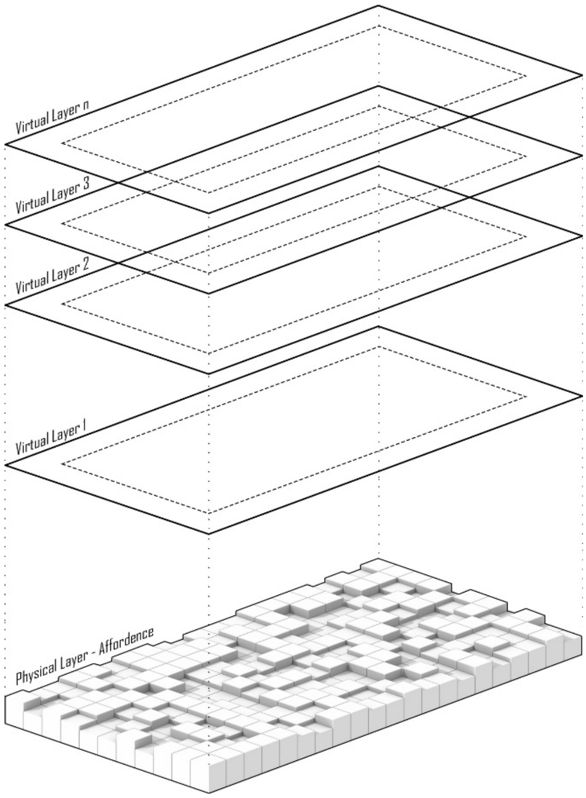


Figure 46: Hybrid Layered Spatial Topologies Concept, illustrated by the author.

with physical items. The concept that distinguishes the project from other mixed reality projects is the Hybrid Layered Spatial Topologies that provide this holistic experience, not only overlapping the physical and virtual layers of the space but also fusing these layers by using hybrid affordances. With this concept, for the first time, the design enables virtual elements to function as if they are architectural elements, and virtual layers have the ability to define an architectural program. The potential of mixed reality to change architecture lies precisely in this concept.

The design consists of two elements. The mixed reality architecture cell consists of pixels as inner cell and the support units surrounding it, which we will call the outer cell in the rest of the work. This union can be thought of as two nested rooms, but they are in a symbiotic relationship with each other. Since the architectural cell consists of only the upper and lower pixels and is not surrounded by delimiters on four sides, users can enter this cell from all four sides and mixed reality technologies are experienced when they enter it. Therefore, it would be best to consider the outer cell as a threshold. The outer cell can be equipped with service units or auxiliary functions to the program planned in the cell, depending on the purpose of use.

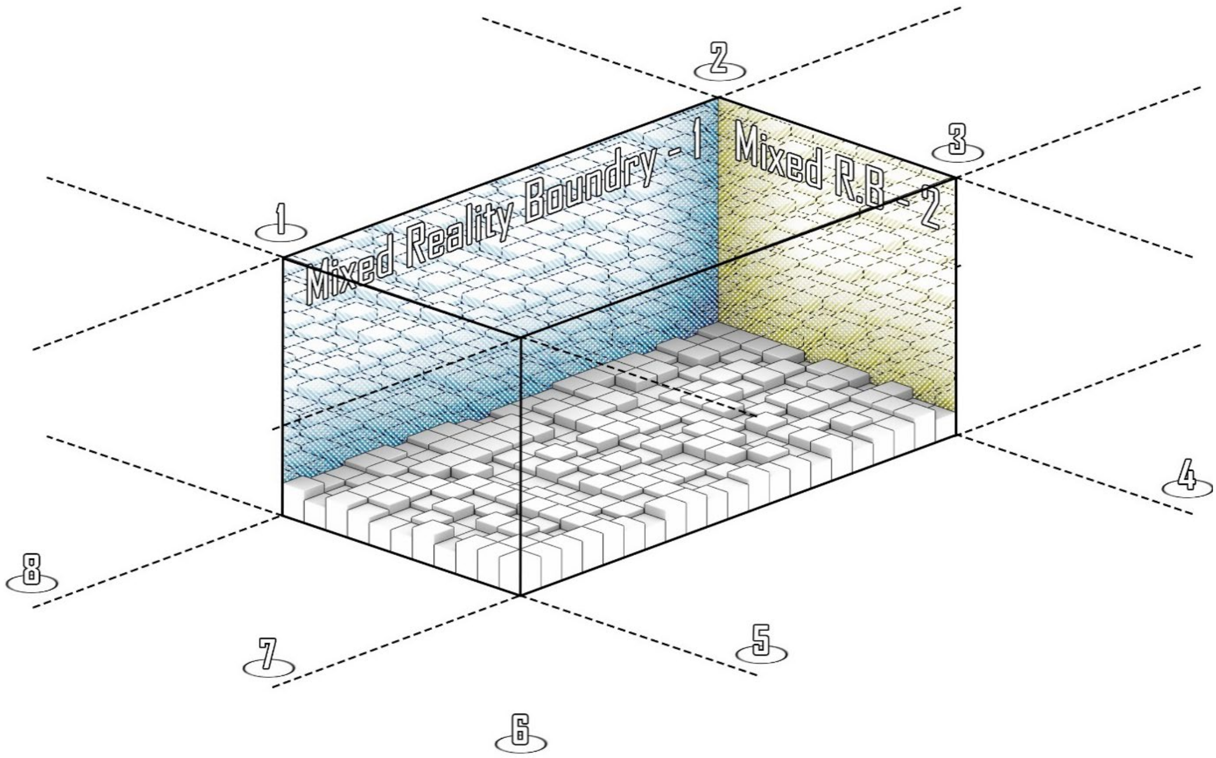


Figure 47: Expandable Space Concept through mixed reality boundary, illustrated by author.

For example, if a virtual design workshop is planned in the cell, it may be surrounded by a digital fabrication laboratory. Thus, things that are designed as virtual can be produced physically and can be prototyped. Therefore, the relationship between the inner and outer cells should always be symbiotic.

Returning to the Concept, let us extend the idea of Design to the interaction of identical mixed reality cells distributed over different cities and continents. If all these mixed reality architecture cells are connected to a single digital twin on the server since all the cells will

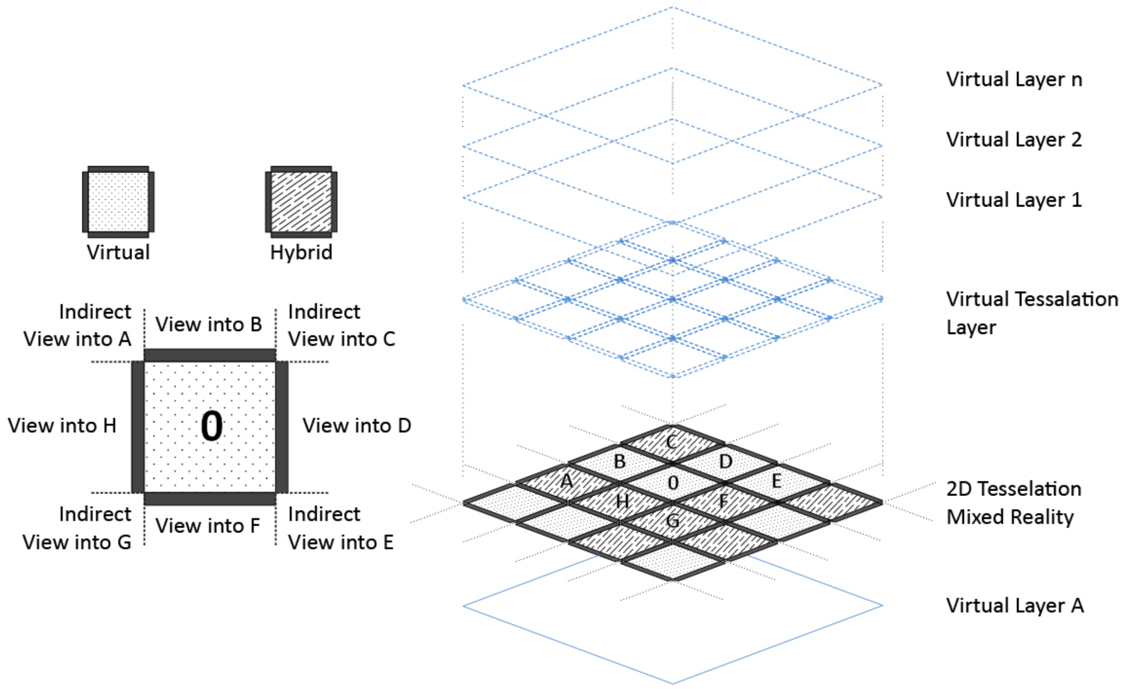
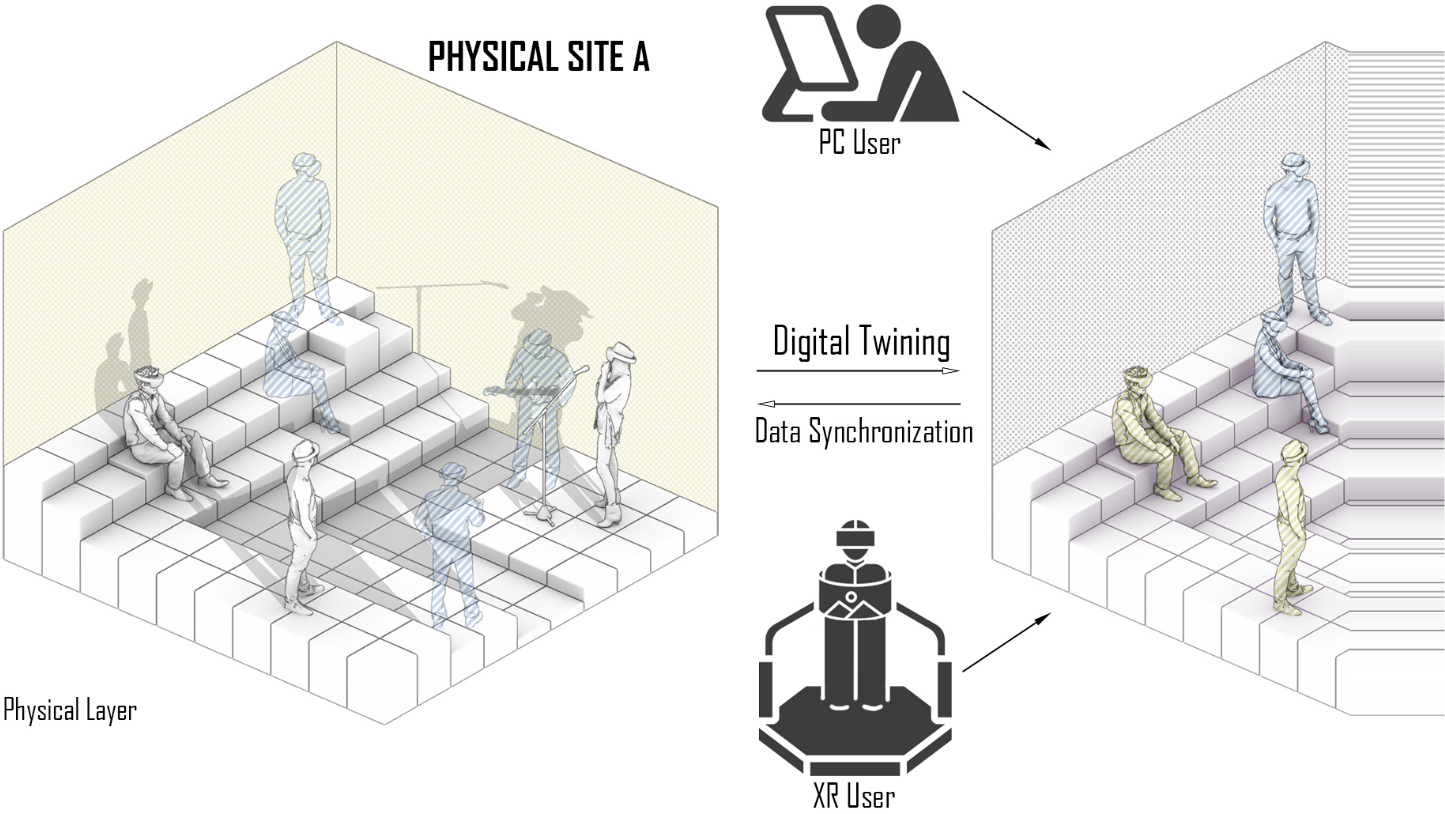


Figure 48: 3D Tessellated Mixed Reality Concept, illustrated by the author.

transform themselves to be the same as the digital twin, they will continue to be the same, even if they transform, since no matter what transformation happens in any city, and it will also happen in cells in other cities. This situation allows the same space to be experienced in different parts of the world, no matter how much the spaces transform. Therefore, it can be thought of as a spatial communication tool. Another alternative is that if the mixed reality architecture cells are connected to different digital twins, and these digital twins develop vicinity with each other in the virtual environment, a user in the cell can see other cells using the mixed reality boundary over the exposed surfaces of the cell. Therefore, it provides the possibility to bring the spaces that are far apart from each other side by side. This provides something that architecture has not been able to achieve until now. Due to this concept, architecture begins to connect spaces as if it is a communication tool. Virtual spaces, the digital twins of physical spaces, and thousands of virtual layers that can overlap them come together and create a virtual universe by producing thousands of spatial combinations. The interrelationship of these cells and layers is called 3D Tessellated Mixed Reality, referring to Benford's tessellated mixed reality. In Benford's concept, mixed reality cells interacted with each other via cameras and projections over mixed reality boundaries. However, the design defines a spatial interaction by using the vicinity of virtual twins instead of experiencing mixed reality boundaries through fixed cameras. This extended mixed reality boundary design is called the Expandable Space Concept.

In addition, Layered Spatial Topologies created through hybrid affordances transformed space into augmented spaces where multiple realities overlap. The virtual universe of mixed reality architectural cells interacting through layered spatial topologies and the Expandable space concept is called 3D tessellated mixed reality. This concept can simply be called a metaverse of mixed reality architecture cells.



5.5. The Design

The main research topic of this thesis is augmented flexibility in architecture. Moreover, in order to provide augmentation on flexibility, the hybrid affordances created by the architectural elements that make up the space physically should reduce the conflict that may occur between the physical and virtual layers of the space and prevent the user's experience with the virtual and physical elements from being differentiated relative to each other. This situation not only minimizes the problems such as motion sickness caused by technologies such as mixed reality, but also integrates the different layers of experience of the space. With the integration of experience, all virtual or physical layers that make up the space gain the ability to transform the architectural program and experience.

In the previous chapter, we described concepts such as hybrid affordances, layered spatial topologies, expandable space, and 3D tessellated mixed reality that provide this holistic experience and augmented flexibility. With these concepts, the architecture incorporates virtual layers within the place into the experience of space and has enabled distributed spaces to be experienced together by establishing interactions in a way they have never done before. Now, space can offer the same experience in more than one place, and places far from each other can be experienced as if they were side by side.

This section will examine the architectural qualities of technology and the possibilities provided by these concepts. In this framework, the spatial qualities that the space cannot have with conventional architecture but offered by augmented flexibility should be examined.

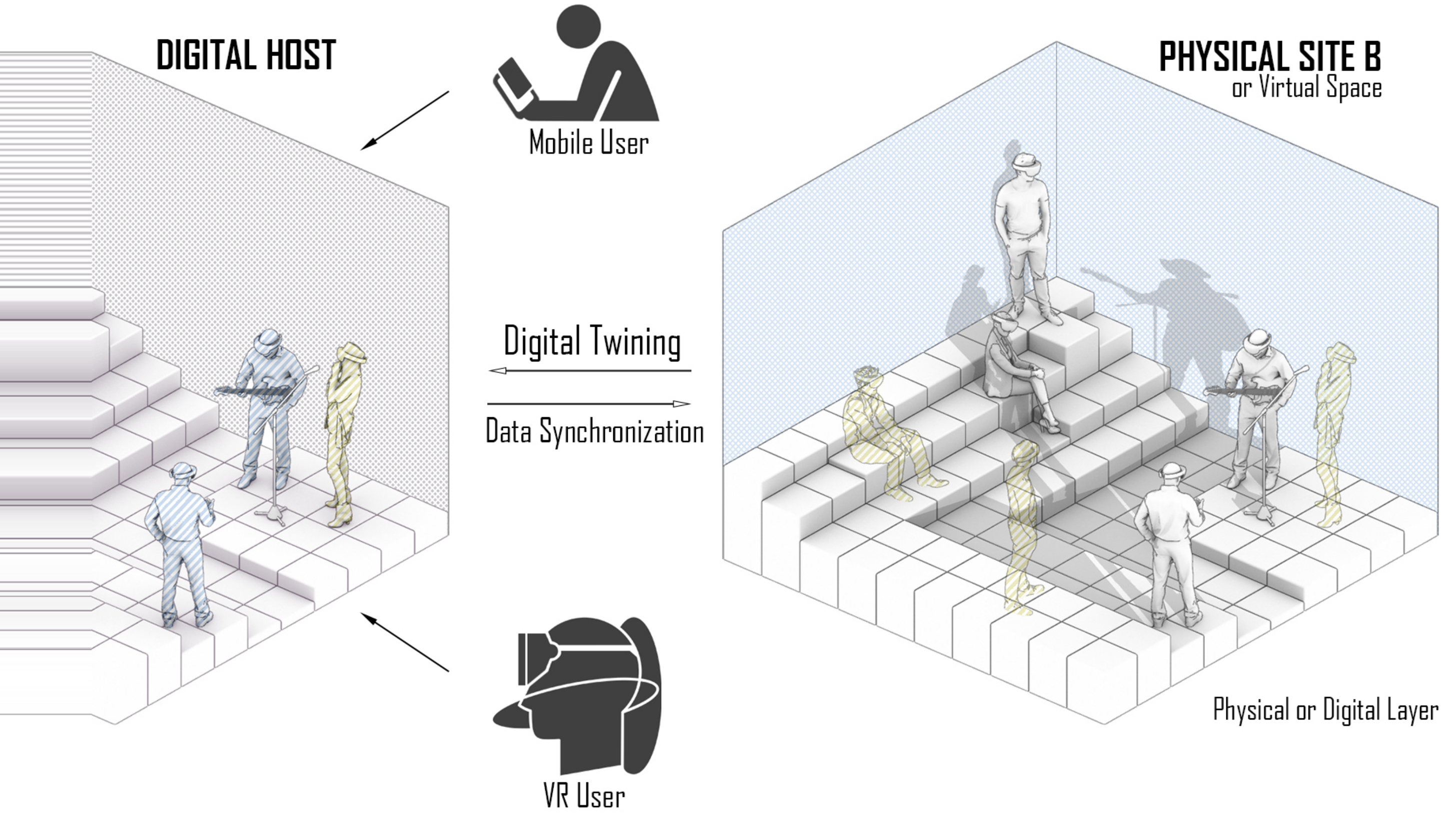


Figure 49: Architectural Diagram of Augmented Flexibility in Architecture

Let us examine the spatial analysis of distributed spaces. [Figure 49] Seeing this concept as a spatial communication tool can help us understand the concept. If communication is simply defined as the exchange of information between people, the architectural interface is the architectural communication element that enables the exchange of information between spaces. In this way, the spatial form created with the possibilities of flexible architecture in space A can also be experienced in space B. In the previous section, we briefly discussed the compatibility of how the pixels' data is created. Therefore, all that was required to shape-display the same spatial data in multiple locations was the creation of a digital twin of the architectural interface. However, here, the concept is a little more complicated than that. Although the concept of a digital twin refers to the digital existence of a physical entity, which is an exact digital copy, even if there are some transformations in the entity, they define two spatial things that are synchronized with each other in this project.

To illustrate, let us consider the scenario where musicians from two different places give a concert together. Let the band's soloist at point A be the guitarist at point B, and the audience is coming to watch this concert at both spaces. In theory, the digital twin of space A can be experienced as a virtual layer within space B. Assuming that these two spaces are exactly the same mixed reality architecture cell, the spatial form of the space in the digital twin of space A can also be produced in space B, with the use of hybrid possibilities. At this point, even though place A seems to be hosting space B, it can be manipulated with hybrid affordances in space B thus they have mutual relationship of spaces. [Figure 49]

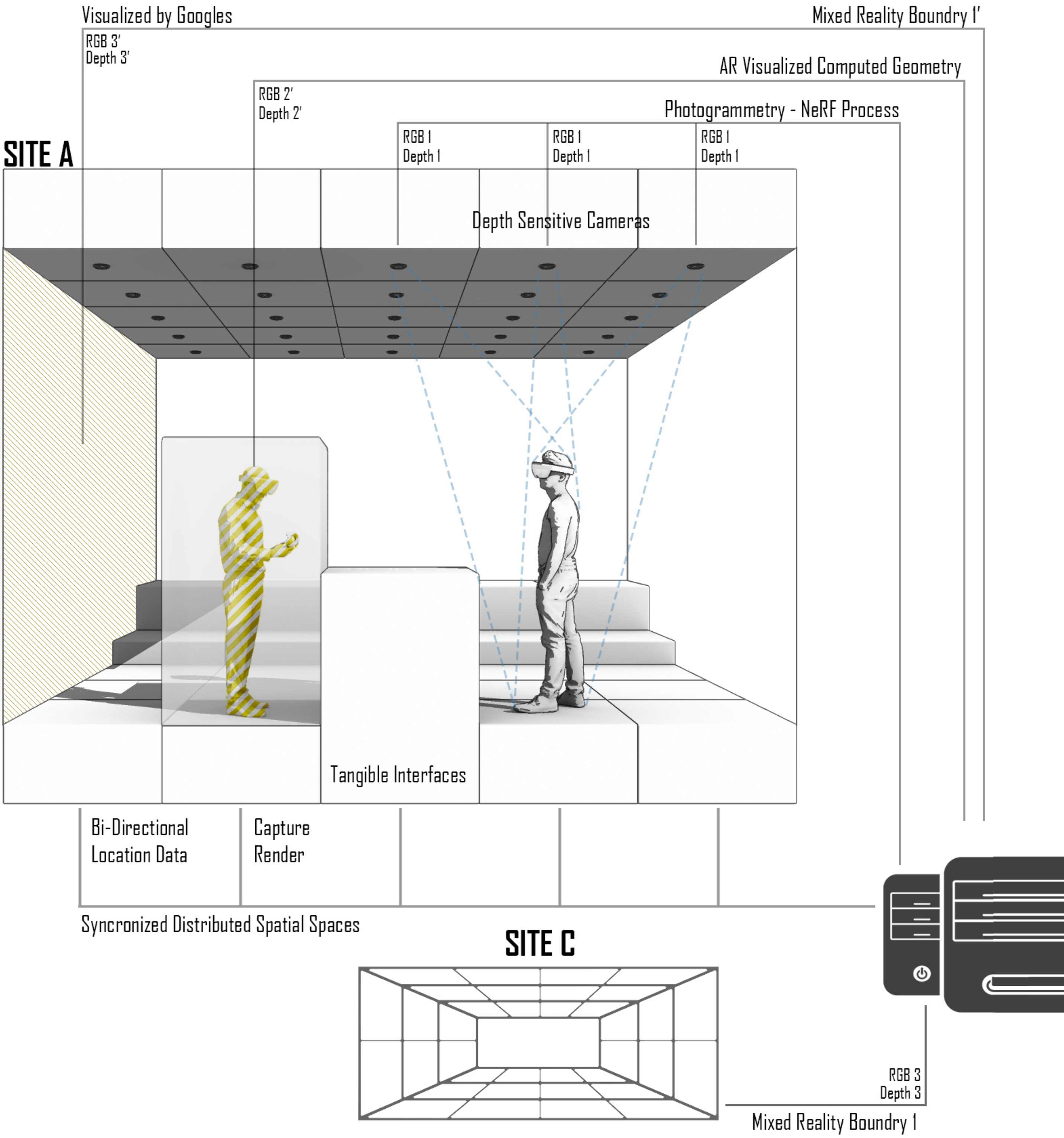
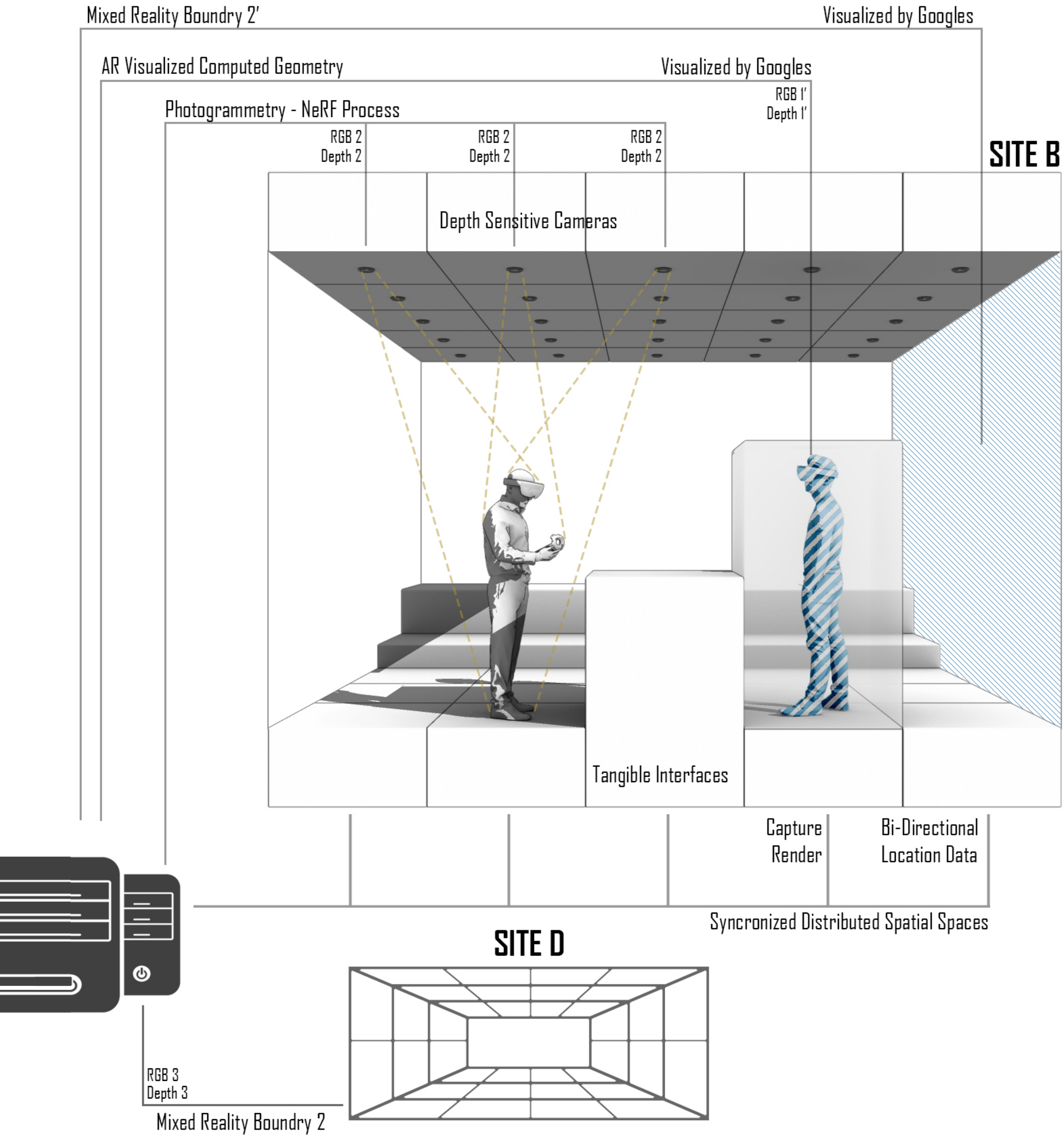


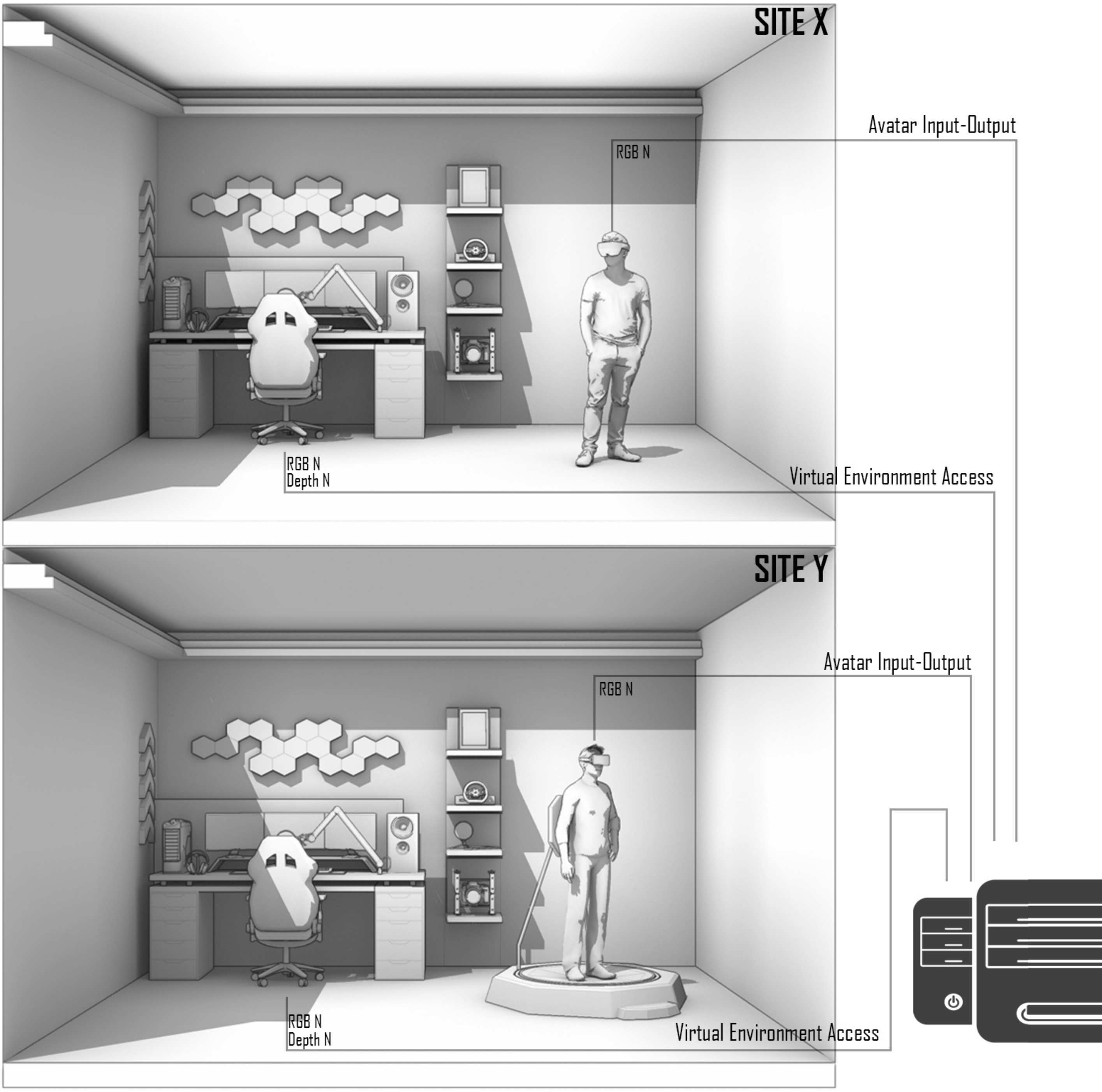
Figure 50: Tessellated Synchronized Distributed Spatial Spaces 1

In this example, it would be more accurate to define the digital twin as the *digital host* since it holds data of two separate physical spaces, which are then uploaded to the digital twin. Hence, places A and B become interfaces that provide data entry to the Digital host. The concept of architectural interface points to precisely this function of the space. Due to this data flow, audio and video data captured in two separate places are reproduced first in the digital host and then in the other place so that a similar space and concert experience is



experienced in two separate places. However, capturing data to create digital twins of mobile objects and users in space is a design challenge of the system.

In this context, the data of the users in the space are taken with Depth sensitive LiDAR cameras on the pixels above them; the visual twins of the mobile elements in the space can be produced by artificial intelligence-supported image modeling systems. Today, with the use of the *Instant NeRF* technologies developed by Nvidia, models that need dozens of photos to



produce with photogrammetry are now produced in under a second with 2-3 photos. In its current state, even if the resolution is too low to be ignored when rendering in real time nowadays, by looking at the development speed of this technology in the last few years, with this system, objects in a specific space can be captured in 3D with the help of a few depths-sensitive cameras and artificial intelligence with Instant NeRF in the near future. (Müller et al., n.d.; Munkberg et al., 2022)[Figure 52]

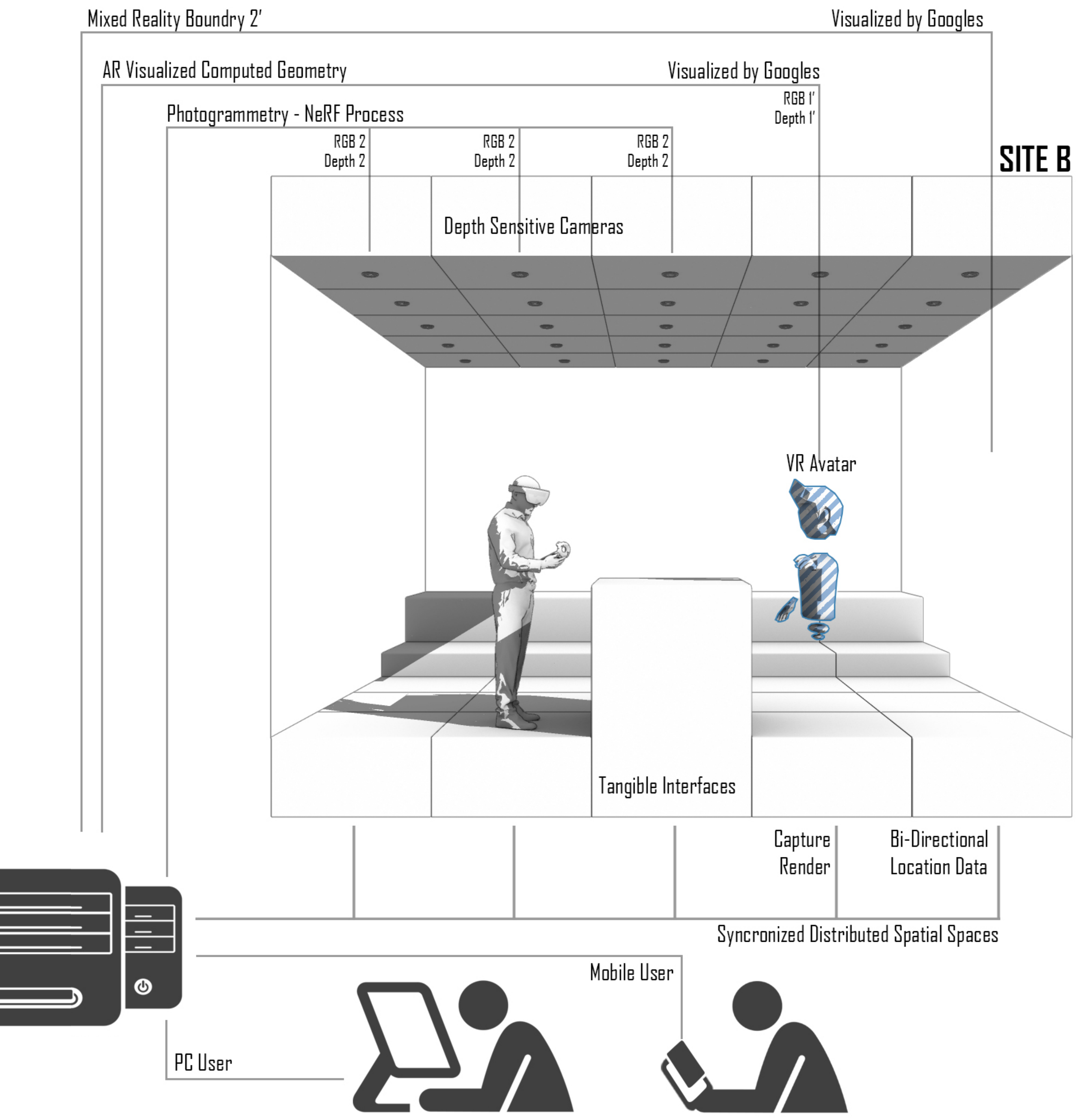


Figure 51: Tessellated Synchronized Distributed Spatial Spaces II

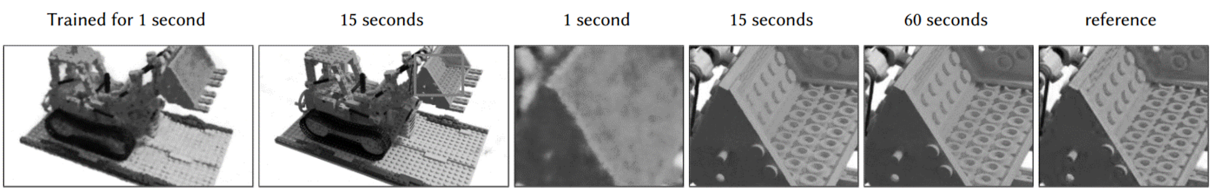


Figure 52: Nvidia Instant NeRF Project time dependent performance results by Müller from 2022.

Since the captured 3D images will be stored in the digital host, they can be recreated on all physical twins of the digital host when desired. When the architectural interface is deemed necessary, it can act as a physical proxy and a placeholder for users when the haptic interface function is required for this captured data to create some sort of augmented virtuality. [Figure 50] In addition, since all data is shared over the digital host, this is a system for virtual users to connect from anywhere they want and to match the virtual environments they access with VR, mobile devices, and computers for their own use. [Figure 51]

This system turns into a metaverse that can interact with physical spaces with each other, virtual spaces with physical spaces or other virtual spaces, and all of them with each other.

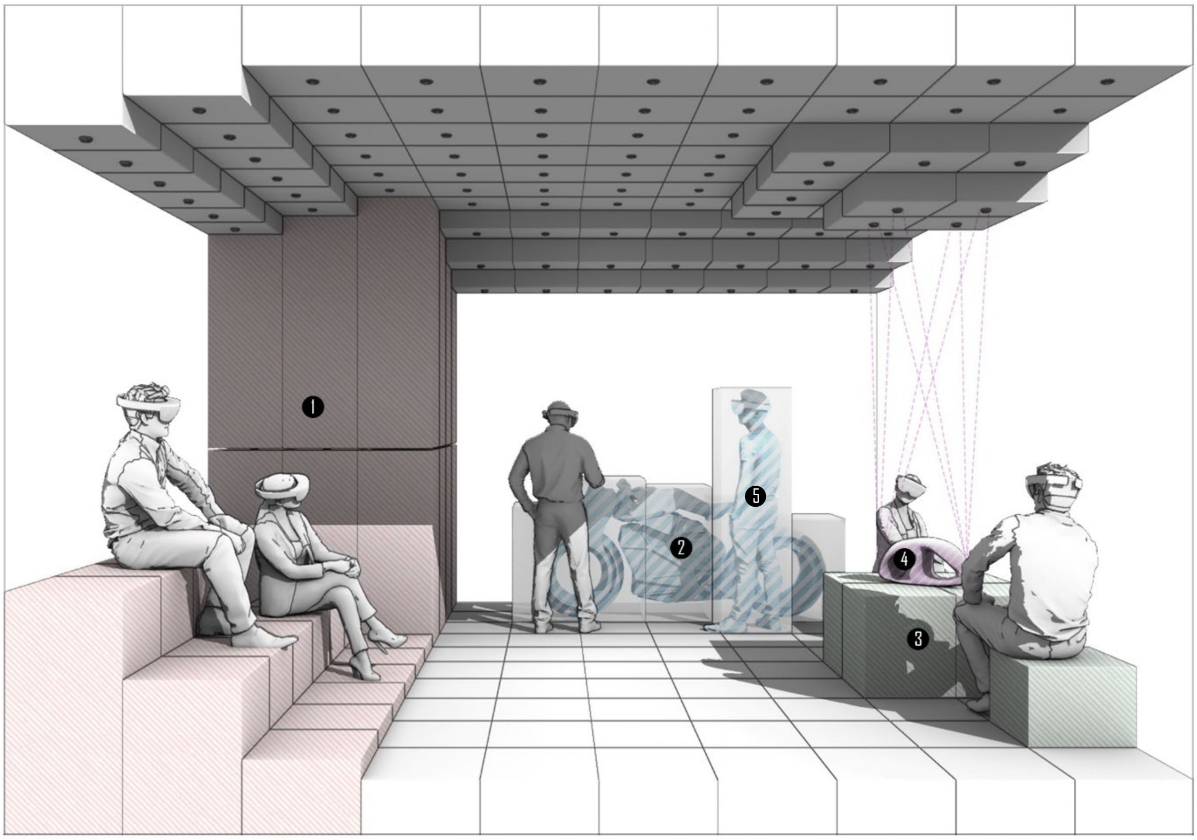


Figure 53: General Function Diagram, illustrated by the author.

In this framework, if the functions of the design, in general, are to be summarized:

1- With hybrid affordances, an architectural layout can be made at room scale, and spatial forms of virtual or remote physical spaces can be shape displayed.
2- The digital twins of the persons or objects in the remote physical space or virtual space created on the digital host function as haptic interfaces or placeholders to the physical twins created by the use of hybrid affordances in the design.
3- It is possible to create small-scale manipulations and programmed movements that constantly transform themselves; these can also be produced in a virtual environment or a remote physical environment, and shape displays also can be made.
4- Capturing the people and objects in the room with the depth-sensitive LiDAR cameras of the upper pixels and the image processing technology of the system and creating their digital twins on the digital host and recreating them in remote mixed reality architectural cells.

5- Using the surfaces of the voxels as mixed reality boundaries, 2D images can be displayed.

Thus, these five features increase the flexibility of the concept's architecture to the extent that has not been experienced before and produce hitherto unexperienced forms of interaction and architectural programs. [Figure 53]

5.6. Usage Scenarios

This chapter focuses on the use cases developed to examine the new forms of interaction and architectural programs that the augmented flexibility of architecture will produce. These scenarios will then be used to produce the prototype produced to understand, test, and present these new interactions and architectural programs.

Before explaining the usage scenarios, the methodology followed in producing these scenarios should be mentioned. This study is the production of scenarios that can be given examples of the main mechanics of the system, rather than producing the spaces that can be made using this system and design. Therefore, each architectural scenario is designed to describe and explore the mechanics of the system or form of interaction between users.

In this context, if the architectural scenarios are summarized scenarios will be as follow:

- First of all, an empty room waiting to be transformed by the users, where the basic setup is explained
- An amphitheater scenario where presenters and users in different places can experience a single symposium
- A conventional classroom to demonstrate that user and content can be captured and reproduced to define new interactions
- A collaborative education scenario where architectural design studios in different places can experience a joint studio
- A scenario in which the memory of the space can be reproduced in the past captured states of the user and the content
- An F1 design scenario to demonstrate the collaboration mechanics of remote design-engineering workplaces and the contribution of spatial mixed reality tools to design
- A theater set scenario to demonstrate the spontaneous transformation of space and the use of mixed reality layers
- The scenario of a scrum meeting of an architecture and urban design office’s multiple branches in different places to demonstrate the design and collaboration skills of distant spaces
- A fashion show scenario to show multiple pre-programmed motions and to demonstrate the space shaped by a user's motion by using the point attractor.

Many alternative scenarios have been thought about, and even prototypes have been produced. In the next section, the conclusions in the light of these scenarios and the studies made on the prototype will be shared and what kind of inputs for future studies will be examined.

In the continuation of this section, architectural programs and scenario studies that were born in the light of these new forms of interaction will be examined.

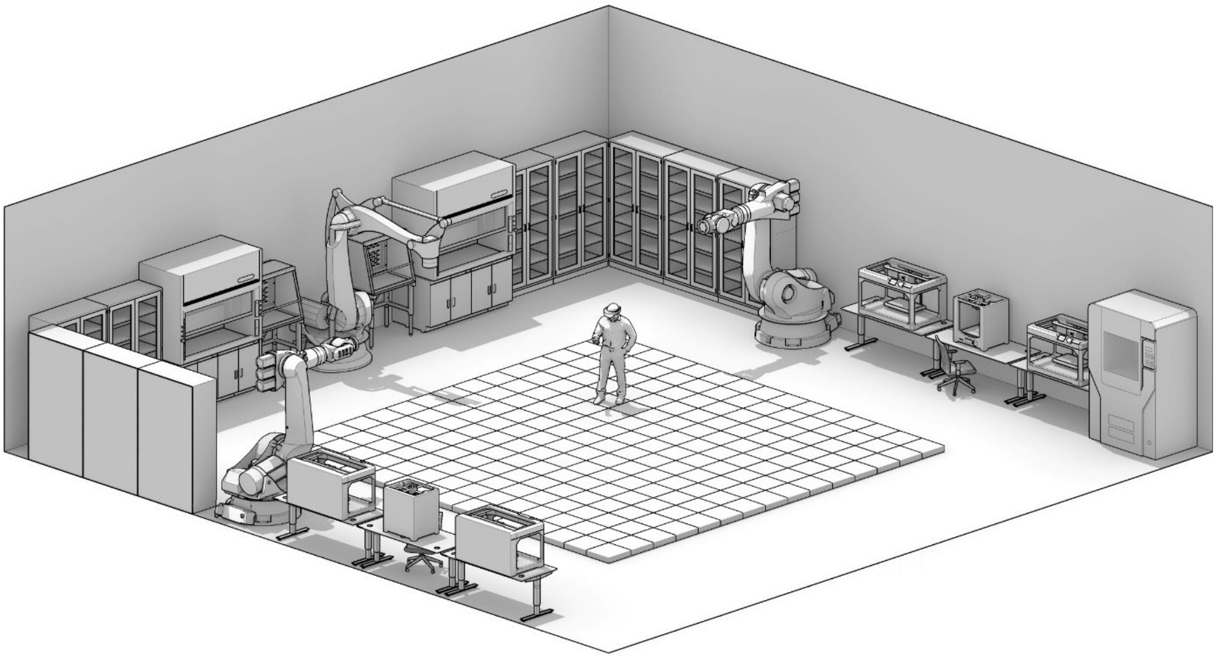


Figure 54: Augmented Flexibility Base Room Set-up/Only Physical, illustrated by the author.

First of all, these new forms of interaction and the system in which architectural programs and scenarios should be examined. As mentioned in the previous section, the main mechanic used by design to create augmented flexibility is eliminating conflict and incongruity between physical and virtual experiences. This already forms the basis of the architectural interface idea. In addition, the place where the scenario experiments were carried out was developed within the framework of this approach. The space is divided into inner and outer cells. The inner cell is a mixed reality architectural cell, while the outer cell is created as a digital fabrication laboratory to eliminate the conflict between these physical and virtual experiences. In this way, concept designs produced by virtual production tools in the space can be produced in the laboratory when needed, and the production process itself will become a hybrid rather than just a virtual process. In this framework, there are robotic arms, 3d printers, and similar equipment for material development, which will be used in the continuation of the study, which has the function of an external cell digital fabrication laboratory, in which the physical production of virtual entities can be provided.

The in-out cell concept radically changes the idea of mixed reality architecture that Schnädelbach defined. In Schnädelbach's design, the mixed reality architecture consisted of physical and virtual cells connected by a mixed reality boundaries which he called MRLinks. Since the mixed reality boundary concept is created with cameras and projections, some limits can be overcome by the virtual mixed reality boundary concept proposed by design.[Figure 54-55-56] The virtual mixed reality boundary is the rendering of the digital twin of the other cell that interacted with in a 3D environment and experiencing it from a frame that opens to that environment, rather than projecting the data captured by a camera on the other cell that interacted with onto a two-dimensional surface of the physical room. [Figure 54-55] Therefore, it is a different and enhanced concept. It is a modern interpretation of the existing. Data captured for the virtual mixed reality boundary concept does not need a surface to be

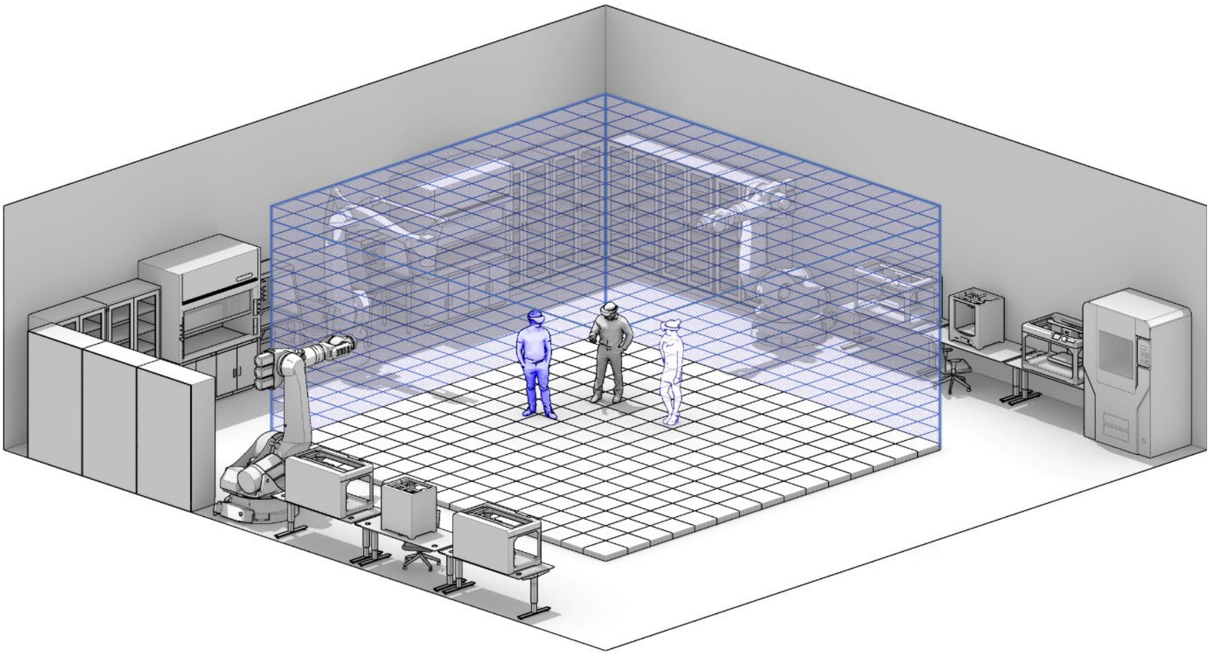


Figure 55: Augmented Flexibility Base Room Set-up/Mixed Reality, illustrated by the author.

viewed because the mixed-reality glasses can view it. Therefore, it eliminates the need for a surface to project the image on the design's periphery; in this way, the space can be divided into interior and exterior cells. There are two reasons for this distinction. The first is the need of privacy due to the publicization of the space, being online and its ability to interact with remote spaces with mixed reality technologies. The second is that since the space is defined as an architectural interface, there will be no fixed elements that cannot function as an interface in the space. Therefore, the need for a place where all the elements that would not define hybrid affordances, which are 3d printers, robotic arm, sink, pc, library, and storage areas, will be found. In this framework, the space is divided into inner and outer cells; the inner cell focuses on increasing mixed reality performance and interaction with remote or virtual cells. On the other hand, the outer cell defines the threshold between physical and virtual for users, with the need for privacy arising from this interaction and the things that will negatively affect mixed reality performance in this area. The necessity of this threshold will be explained along with the reasons while examining the architectural scenarios.

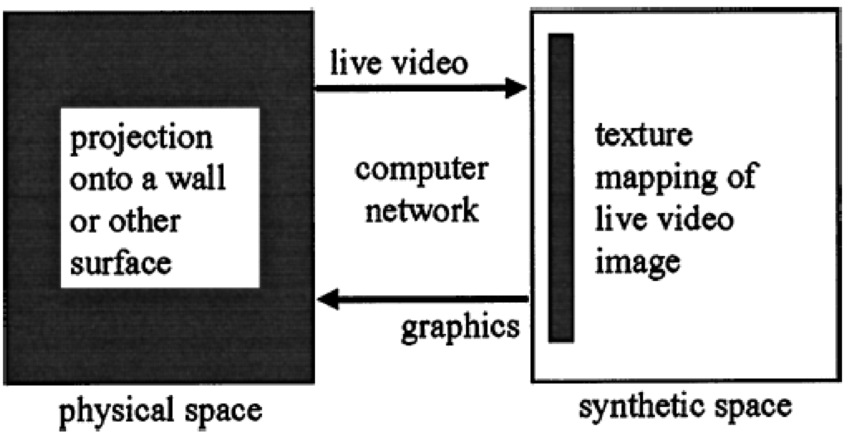


Figure 56: Creating a simple mixed-reality boundary by Benford from 1998.

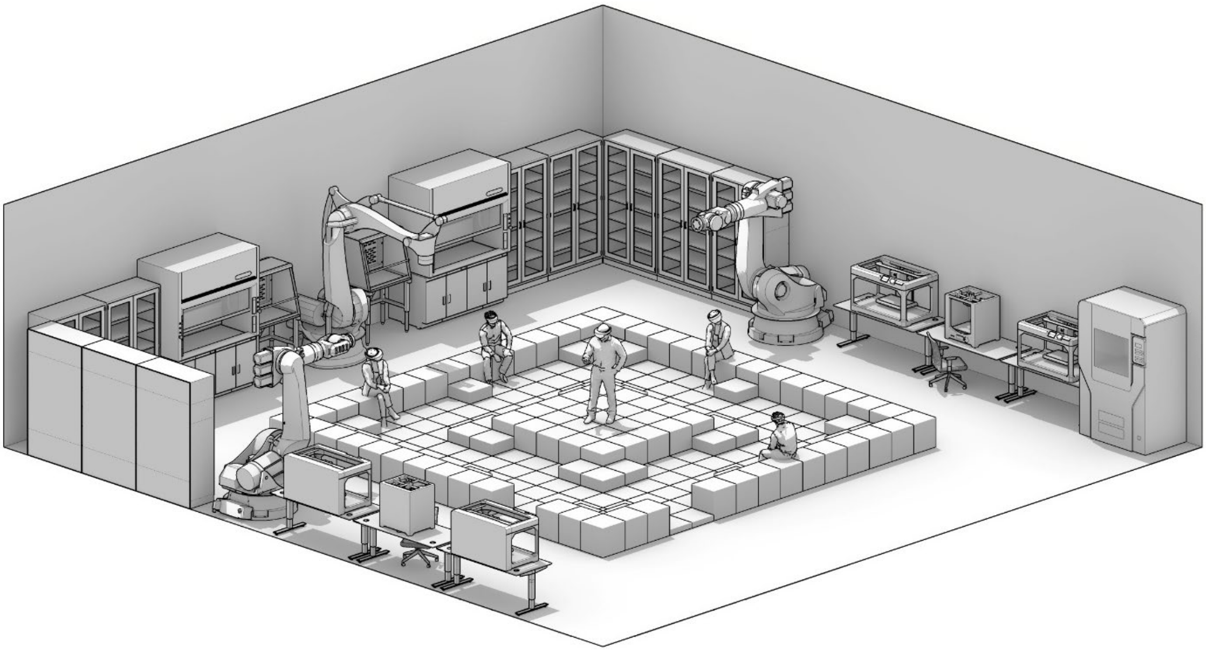


Figure 57: Augmented Flexibility: Symposium scenario/Only Physical, illustrated by the author.

Therefore, from a user experience perspective, the user will experience the physical room in the outer cell and can only interact with the physical elements. However, as soon as the user enters the inner cell, the mixed reality experience begins, and the visual communication of the user with the outer cell is interrupted due to the activation of the virtual mixed reality boundaries. While inside the inner cell, the user can manipulate the position of the pixels, which are hybrid affordances, and starts to build experience with the virtual layers brought by Hybrid layered spatial topologies and expandable space concepts. With the concept of hybrid layered spatial topologies, digital layers are formed in the space, and the user can activate the experiences that overlap with distant places if the user deems necessary. With the expandable space concept, it is possible to develop vicinity with remote spaces by using the virtual mixed reality boundaries in the inner cell periphery, and the space acquires a virtual expansion potential. While designing the user experience in the inner cell, attention was paid to ensure that all elements visually interacted in the space are virtual, physical, or remote physical, and this distinction is made by making the physical elements appear as they are, color coding the virtual elements and being transparent to a certain extent. In this way, the user can understand whether the elements he/she interacts with are virtual, remote physical, or physical. This is a very important issue in terms of user experience. Similarly, the virtual mixed reality boundary adds a colored filter to the image of the environment behind it, showing the inner cell boundaries and where the neighbor cells begin. In this way, users will be able to develop an awareness of all the elements they see and where they are, thanks to mixed reality, and they will be able to interact within this framework.

The first scenario proposal to examine the system is a mixed reality symposium of speakers and audiences in different places. This scenario was chosen as the first scenario because it is the most suitable scenario for expansions on the main mechanics of the system due to its easy architectural structure and clarity. [Figure 57&58]

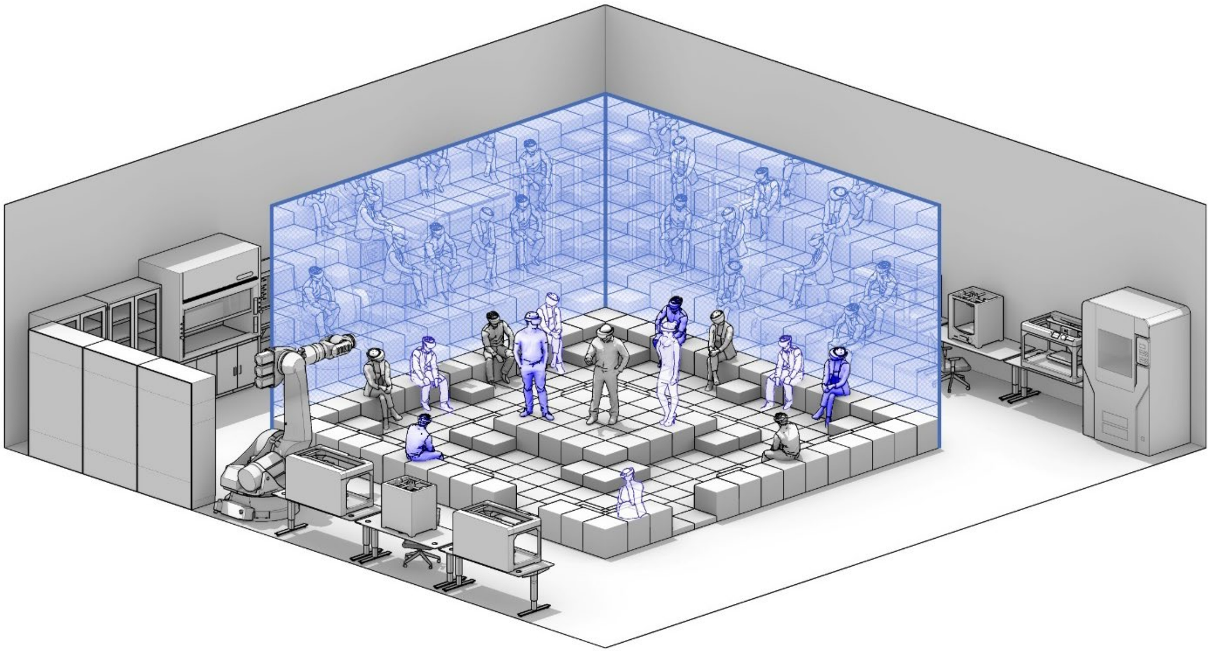


Figure 58: Augmented Flexibility: Symposium scenario / Mixed Reality, illustrated by the author.

First of all, this scenario is based on the idea that two architectural cells with the same features are in separate locations and that these two spaces together give a symposium. For example, a professor at the University of Colombia, a professor at the University of Politecnico di Milano, and a professional in an ancient city archeology field are planning a symposium. These users, who hold a symposium but will not be able to come together due to logistical impossibilities and a tight schedule, can meet with this design established in different universities; and with VR glasses that the professional in the field of archeology will use to attend this symposium. Mixed reality architecture cells in two separate locations are physical twins of a single digital host. In this way, the same space experience will be experienced in both universities, and since the participant with VR glasses will be directly connected to the digital host, digital twins can be created in the architectural cells of the universities. In this way, the experience in one of the places offers a symposium experience conducted by three speakers, one physical, one remote physical, and one virtual user. Moreover, since the audience in the architectural cell will also have digital twins at the other university, all audiences can experience each other's existence. Therefore, two different spaces experience the same experience, including virtual participants. Where desired, other audiences can participate in this symposium with the expandable space concept and virtual mixed reality boundaries across the space. With the 3D tessellated mixed-reality concept, the spatial space of this symposium can grow virtually infinitely or, if desired, users can give up their virtual twins in the virtual space and experience the speakers as if they are in front of them. Therefore, the space can put thousands of people in the same place, gain a conceptual depth, and expand it infinitely with the concept of 3d tessellated mixed reality. It is a critical scenario. Although the idea of the symposium does not seem like the right idea to describe a concept that allows real-time transformations because it does not need a real-time transformation in the space, it is pretty helpful in this part of the study since spaces that are far from each other can have a shared experience and are suitable for understanding many concepts related to the design.

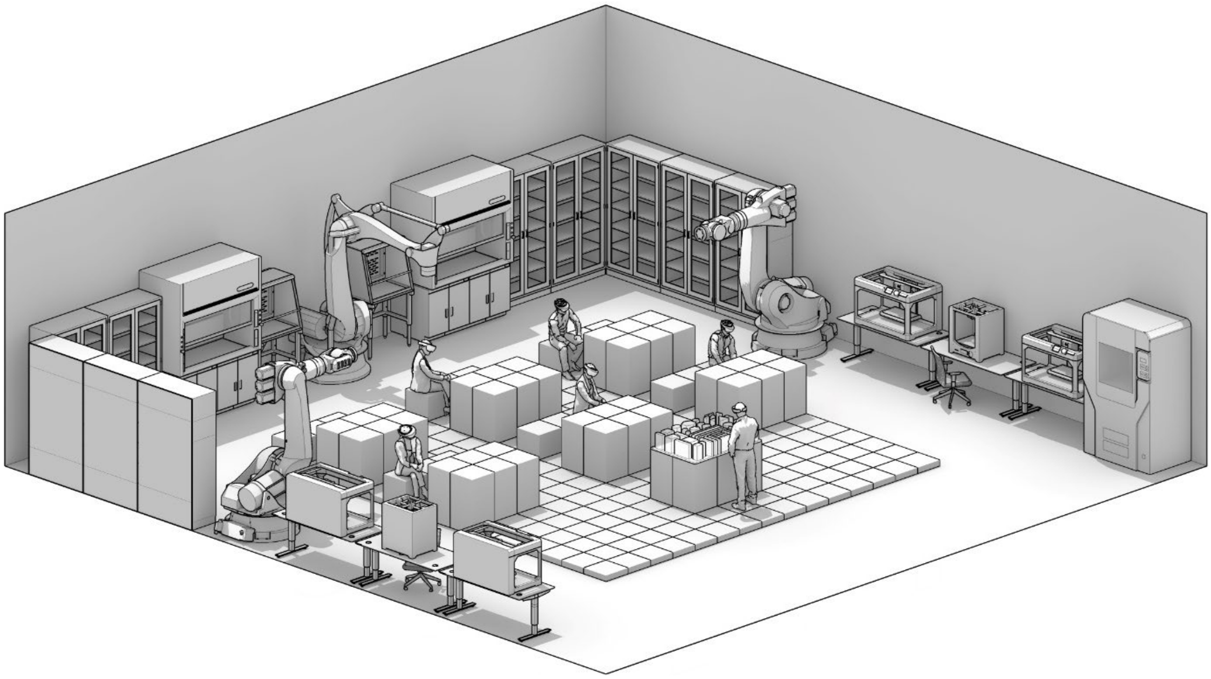


Figure 59: Augmented Flexibility: Classroom scenario/Only Physical, illustrated by the author.

The second scenario is a classroom, which includes some new mixed-reality mechanics. [Figure 59-60] Design studios and Art classes are very flexible spaces in terms of their functions. Architectural flexibility here is usually provided with loose-fit, open plan approaches, and the equipment in the space is constantly changed according to the usage. Therefore, the contribution of design to the flexibility of this program is on new forms of interaction rather than transformations within the space. Through hybrid affordances, students can create 1/1 scale prototypes of the space they create, or the entire inner cell can be used as if it were a low-resolution terrain model. However, the contribution of the design to the program is the interaction forms brought by the system design rather than the operational contribution of the hybrid affordances. For example, in this classroom scenario, as in the previous example, classrooms in different locations can conduct a shared lesson. This is a form of interaction used and expected in almost all scenarios.

In the previous section, we mentioned that the elements, users, and objects in the architectural cell could be captured in 3D, with the use of LiDAR cameras on the upper pixels and data processing technologies, and with these 3D data, digital twins of everything in the room can be produced. This affordance was normally intended so that a digital copy of the space could be experienced by VR users and remote mixed reality architectural cells. However, this affordance can also be used in the same cell if desired. For example, the professors in the classroom and the materials they use to teach the lesson can be captured with the same affordance and recreated in front of each student. This way, all students can participate in the lesson as if they were in front of the teachers. When a student wants to take the floor or make a statement on the material, even if the student is in a distant place, he can attend the lesson as if he is right in front of the teachers. In this way, teachers and students can interact as if they are side by side despite the distances, with the interaction they establish through each other's digital twins, and course materials can be reproduced for everyone through digital twins. This system can be seen as a mixed reality architecture interpretation of the distance education model implemented by the education system during the covid-19 period in terms

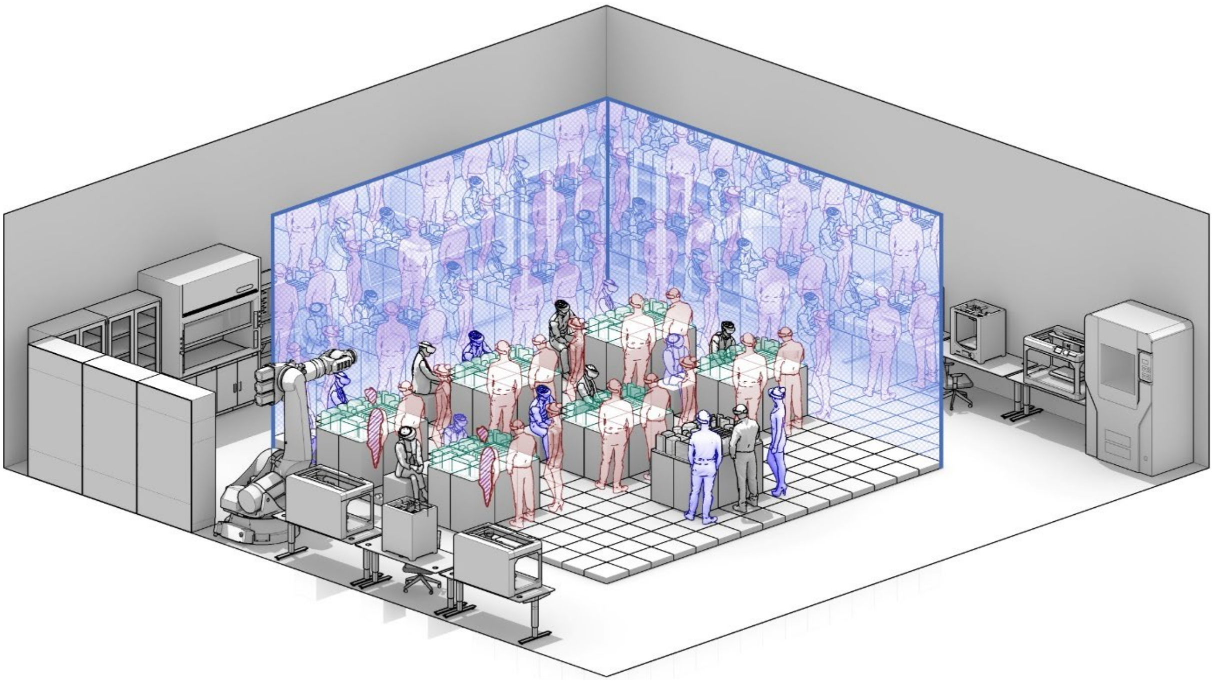


Figure 60: Augmented Flexibility: Classroom scenario/ Mixed Reality, illustrated by the author

of its similarity to the video conferencing method. It is adaptation of the distance education model to mixed-reality since the interaction will take place in a spatial way, not through videos.

Moreover, this mechanic can be used for many different interactions, as it allows to capture and reproduce everything inside the inner cell. For example, since it captures what happens in the place to create its digital twin, it can also record it when desired. Therefore, the architecture begins to form a memory. A user who wants to repeat a lesson experienced in the past can revive a past moment in the place memory with this mechanic. The idea of being able to travel in the memory of the space, which includes what can happen inside all similar cells, enables the design not only to interact with spaces that are far from each other but also at different times. This is an area with great architectural potential waiting to be explored.

Figure 61: Augmented Flexibility Prototype: Education Scene 1 – Conventional Classroom

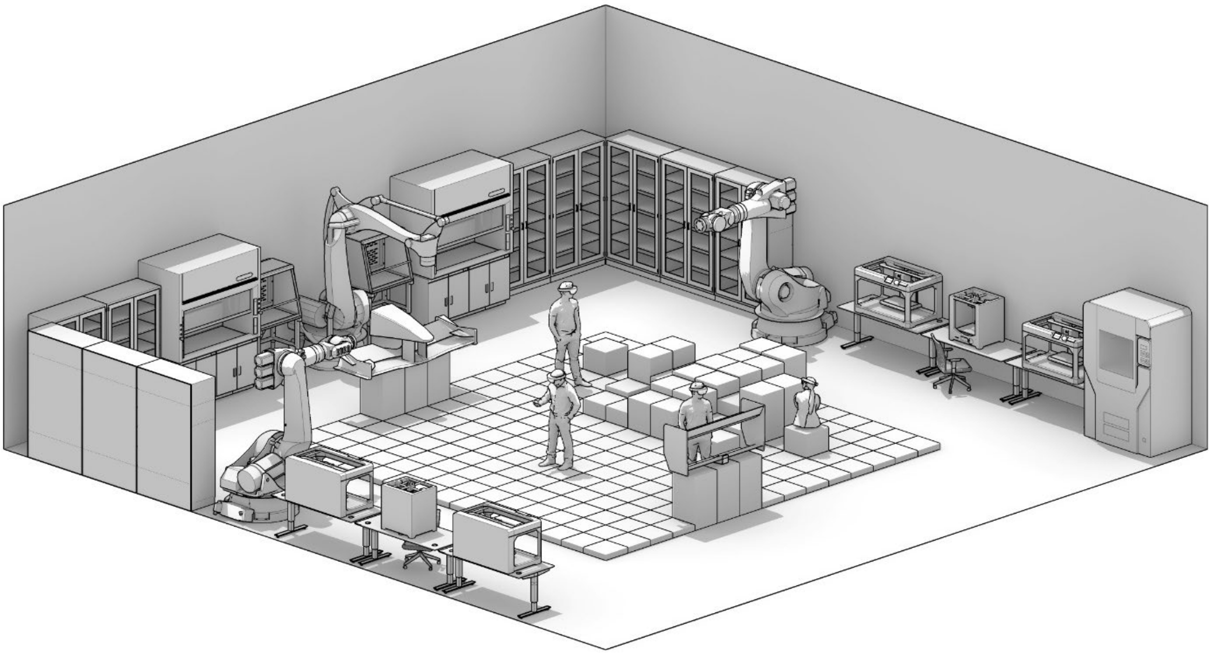


Figure 62: Augmented Flexibility: F1 Design scenario/ Only Physical, illustrated by the author.

Another scenario in which we examine one of the new forms of interaction is the system of a collaborative study of remote locations. In this example, an F1 design team has been studied, which must travel due to the race schedule, and the vehicle development teams are scattered in different cities.

The space in the Figures 62,63 illustrates the mixed reality architecture cell, where the team responsible for the aerodynamics of the vehicle is located. The team uses the mixed reality design tools and tests the vehicle's aerodynamic performance with the physics engine they modified to work with this system. The focus was on a meeting moment that the project teams held about the development of the vehicle. In this sequence, three people, one physically in space, another in a remote physical space, and the other completely virtual, are talking about the improvements to the vehicle's engine, while one team is working on the front wings of the vehicle, the other team is working on the rear wing and another team is working on the vehicle wheels and shock absorbers. Within the possibilities of the digital fabrication laboratory, the front and rear wings of the vehicle are produced, and work is carried out on the form.

While the system's contribution to users' ability in distant places to work in joint projects can be observed in previous scenarios, there is a positive use of inner and outer cell connections here. In addition, there is an application that this system, which is not in other examples, is a low-resolution haptic interface for virtual elements, which is a different type of interaction. Since the mixed reality architectural cell of the distant place is larger than the physical cell, a part of the vehicle extends beyond the inner cell and is experienced over the virtual mixed reality boundary. [Figure 64] In addition, since the vehicle is not in the physical cell, only the front wing is present, and the other parts are represented by haptic interface through voxels of the architectural interface. Although this mechanic does not have a critical place in the F1 design, it can gain a critical function for programs such as military training tracks and mixed reality sports complexes. [Figure 65] When the real-time transformation in architecture gains the function of a shape-display and a haptic interface for the virtual to initiate augmented virtuality, the interaction potentials of the space expand to the extent of the use of mixed reality.

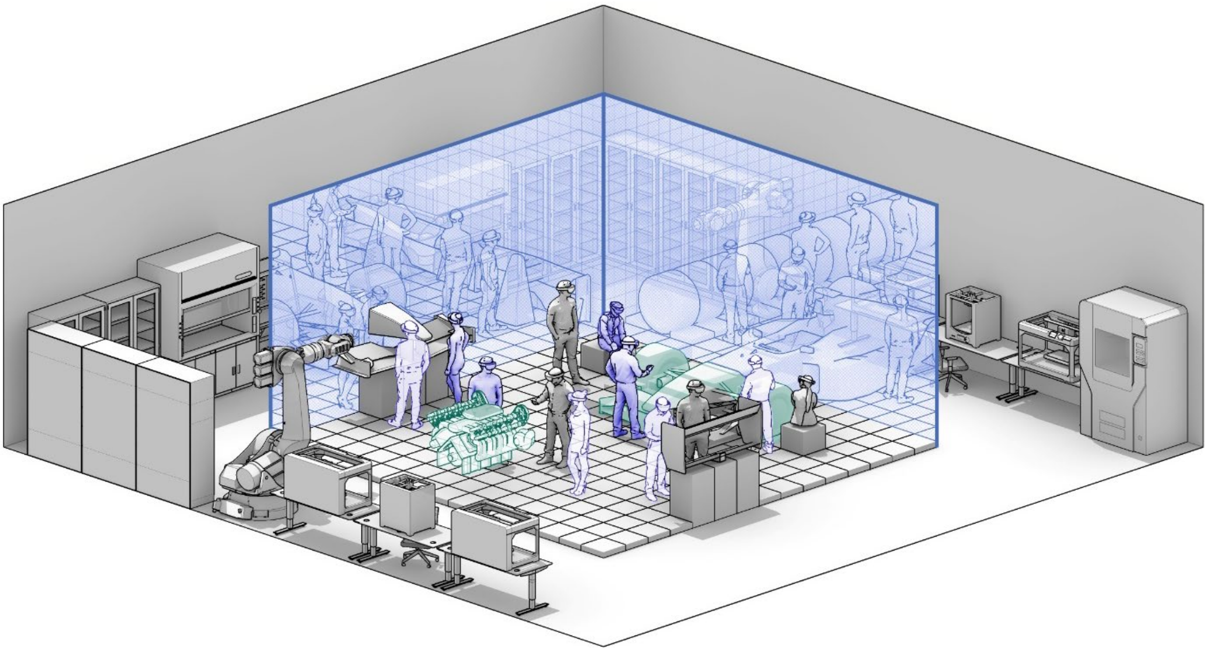


Figure 63: Augmented Flexibility: F1 Design scenario /Mixed-Reality, illustrated by the author.

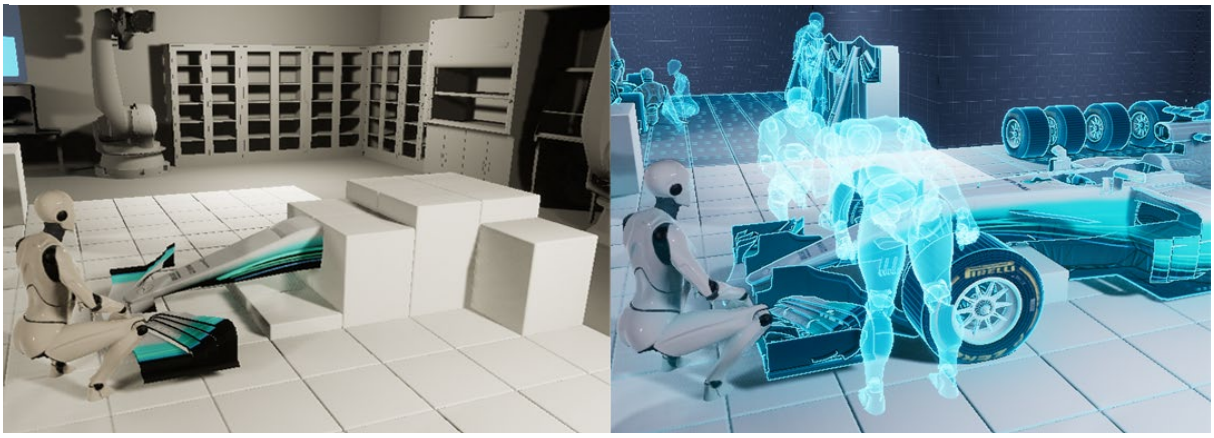


Figure 64: Augmented Flexibility Prototype Collaborative Workspaces F1 Design Studio Scene

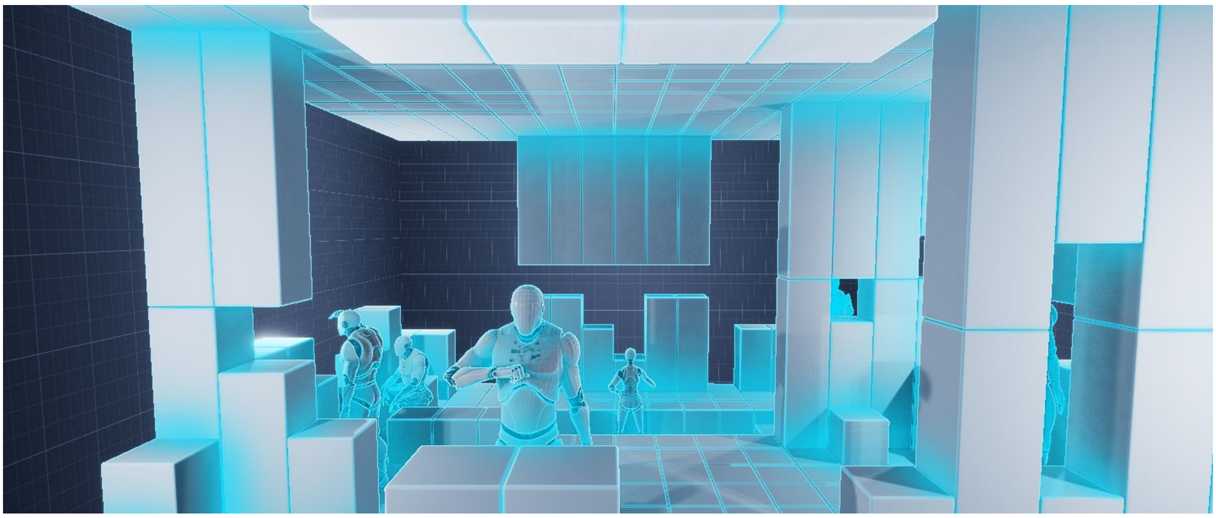


Figure 65: Augmented Flexibility Prototype Entertainment 2 Mixed Reality Shooter Game Scene

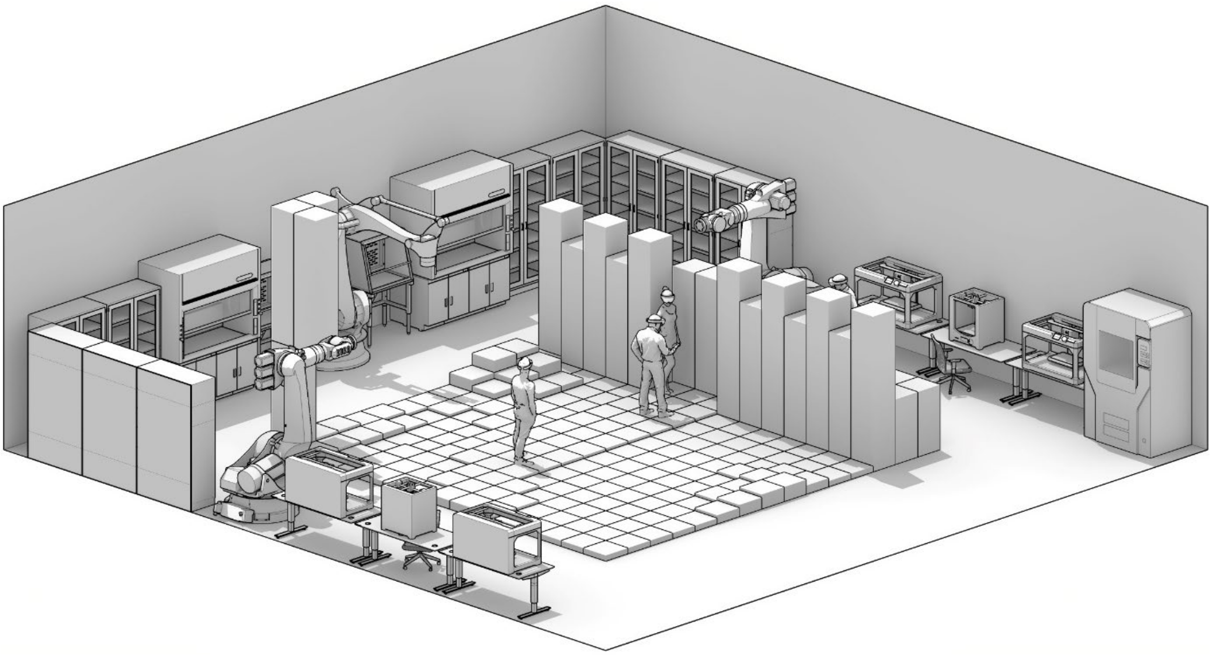


Figure 66: Augmented Flexibility: Networked Performance Spaces/Only Physical, illustrated by the author.

Another scenario is the Networked Performance Spacesthat needs real-time spatial transformations. [Figure 66-67] The design brings a whole new perspective to theater architecture. With mixed reality technologies, everything on the stage can be developed and changed according to the needs of the theater play through virtual layers. In addition, the inner cell outer cell dynamics can work here as stage and backstage, and if desired, some objects and clothes can be produced in the digital fabrication lab. It transforms this design into a unique stage for the theater program. It would be more accurate to call this architectural program a stage for performing arts rather than theater since the audience is not in the place. However, this definition can be considered sufficient for now, as the intellectual continuity of the idea derives from the idea of theater and probably defines an architectural program that did not exist before.

With this new program, the idea of a theater where artists from distant places can participate in a play can be mentioned in this framework. In this play, the artists in distant places can participate in the same play by interacting with another mixed reality architectural cell through the digital host. An artist who could not come to the mixed reality architectural cell for logistical reasons but whose performance in previous rehearsals were recorded can join these artists by reviving his performance. In addition, with mixed reality technologies, fictional characters can be added through virtual layers, or figurants can be included in the play with VR glasses. With hybrid affordances, the space can be transformed in real-time according to the wishes of the actors and the director. What is seen as a castle wall for the audience can be a non-woven voxel surface for the actors. Therefore, in this scenario, different user groups who experience the place can be provided with different experiences with the affordances of mixed reality technology. Movements within the space can be recorded and then used to produce movies or broadcast in real-time as a hybrid mixed reality theatre. With the 3D tessellated mixed reality concept, the neighbor architectural cells, where the audience will be, can be reproduced as much as desired, and the space of the play can grow and deepen in the same way. In this framework, the space can transform due to the needs of the actor and the director and can be experienced differently by different user groups.

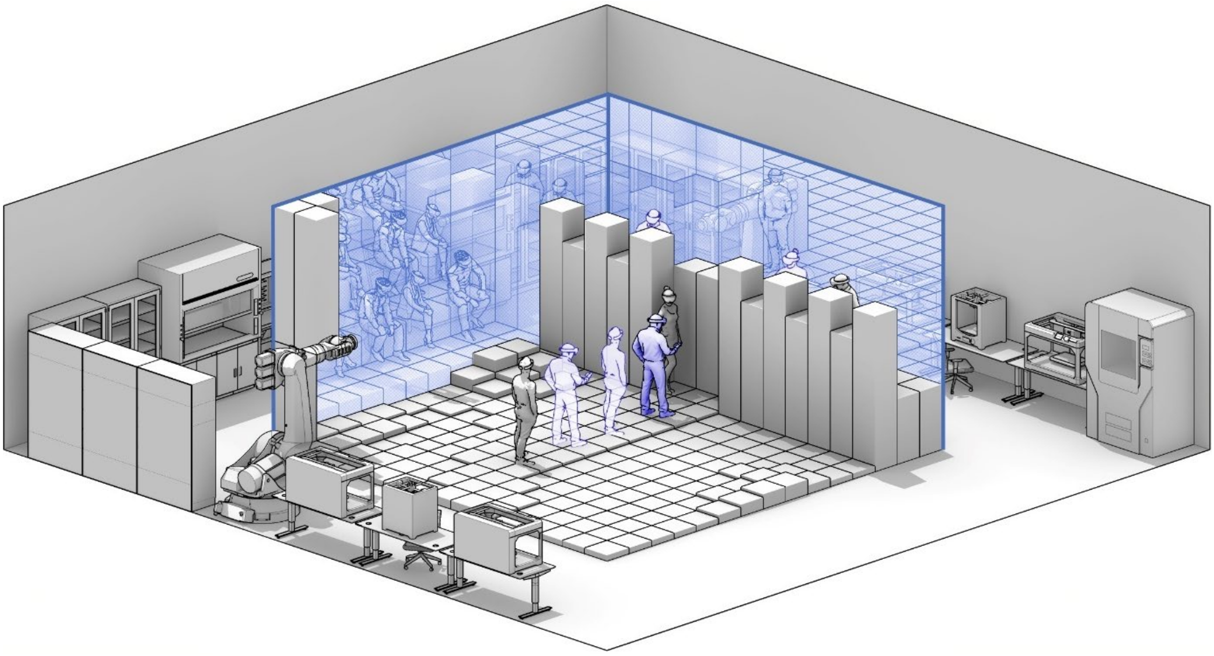


Figure 67: Augmented Flexibility: Networked Performance Spaces/Mixed-Reality, illustrated by the author.

Figure 68: Augmented Flexibility Prototype: Entertainment 2: Theater Castle Entrance Scene

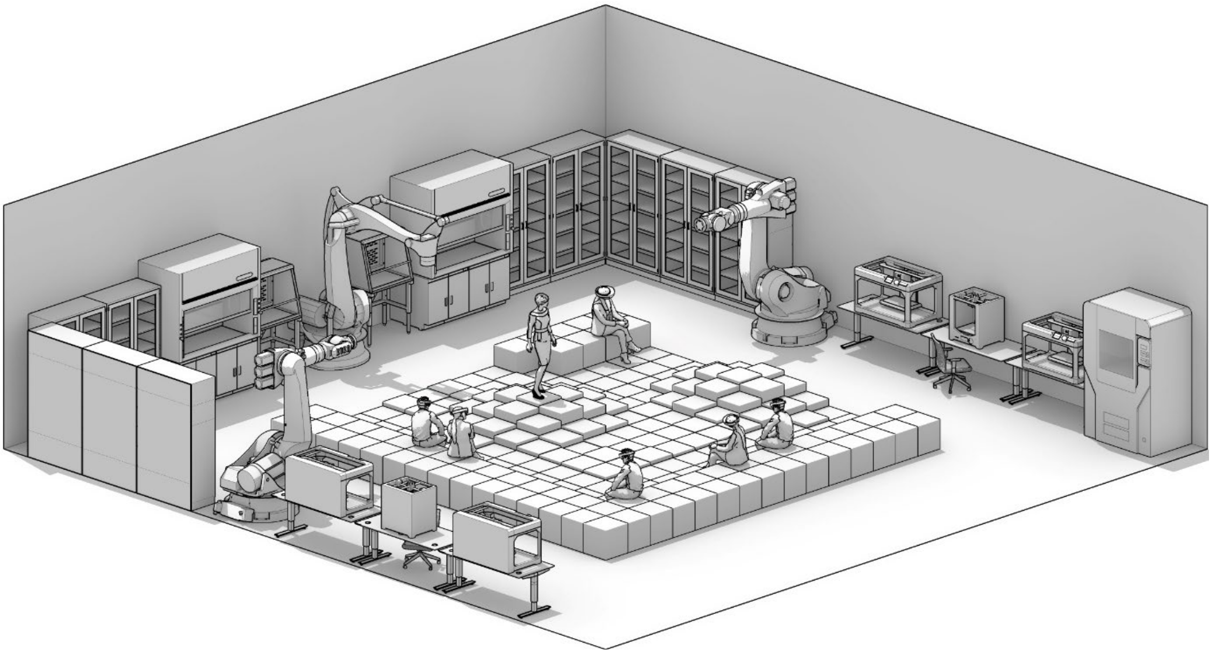


Figure 69: Augmented Flexibility: Fashion show Scene/Only Physical, illustrated by the author.

Another architectural scenario where we study many new mechanics is the fashion show scenario. In this scenario, similar to the previous scene, since the outer cell can be used as backstage and the inner cell can be used as a stage, it is an application that uses the inner-outer cell concept very efficiently. However, the main research topic of this scenario is the re-enactment of some pre-programmed animations and movements with hybrid affordances. For example, in the previous section, we briefly mentioned how the point attractor method could be used in this design. We have deduced that while it is a very problematic space organization method when used to transform the entire place, it can be used for more local transformations. This scenario was deemed suitable for review as it contains an excellent example of using point attractors.

Fashion products produced by digital fabrication methods in the outer cell are exhibited by professionals in the podium area designated in the middle of the inner cell to be exhibited. However, as part of the performance, the podium perceives the models walking on the podium as attractor points and builds their environment as they walk. In this way, each time the model takes a step, the ground rises, and forms as he/she completes the step. This is the way this place participates in this show. Thousands of interactions could be designed for stage performances and shows like this one, and architecture can be the message itself by gaining a role that we did not know before. Alternatively, as Victor Hugo said, it can restore this ability to architecture, which has lost its feature of being a media.

In addition, programmed transformations in place can also be programmed, as we examined in the image sampler attractor method. In a room-scale installation design for the art gallery scenario, the motion of the hybrid affordances that make up the inner cell is determined by using the graphical data of a simple noise map to create a sea wave effect. Moreover, since this noise map is constantly being moved, the voxels in inner cell are going to act like a low-resolution abstraction of a water wave motion. Many interaction and space organization techniques save the architecture from the problem of being stuck in time and turn it into a transformation itself.

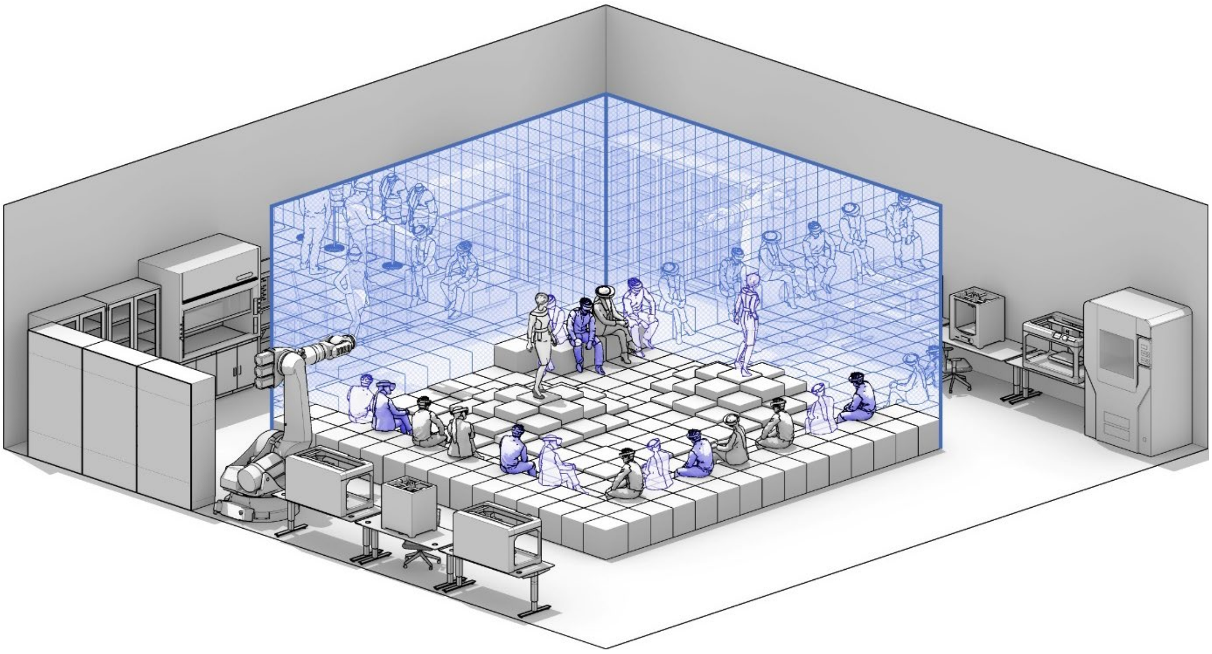


Figure 70: Augmented Flexibility: Fashion show Scene/Mixed-Reality, illustrated by the author.

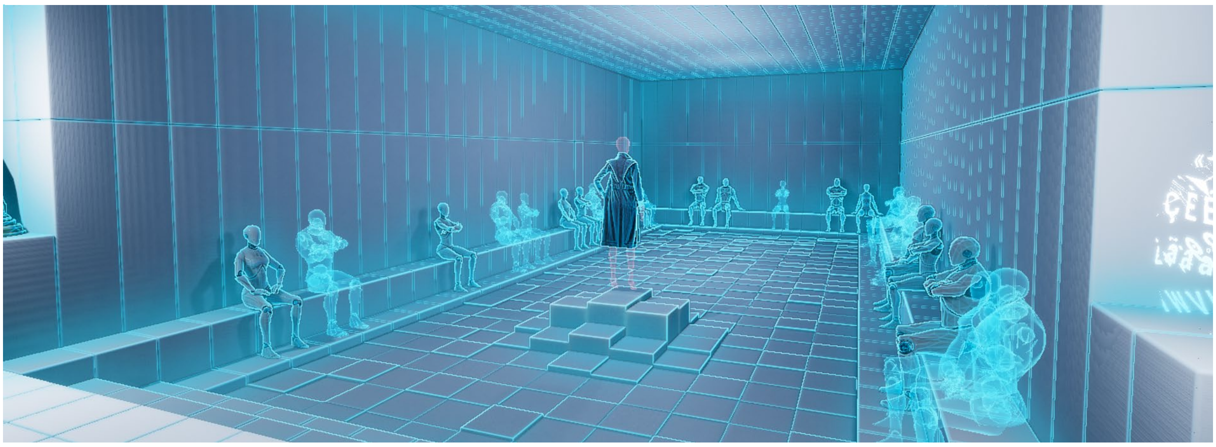


Figure 71: Augmented Flexibility Prototype: Entertainment 1: Fashion Show Scene

Figure 72: Augmented Flexibility Prototype: Entertainment 1: Room-Scale Installation Scene

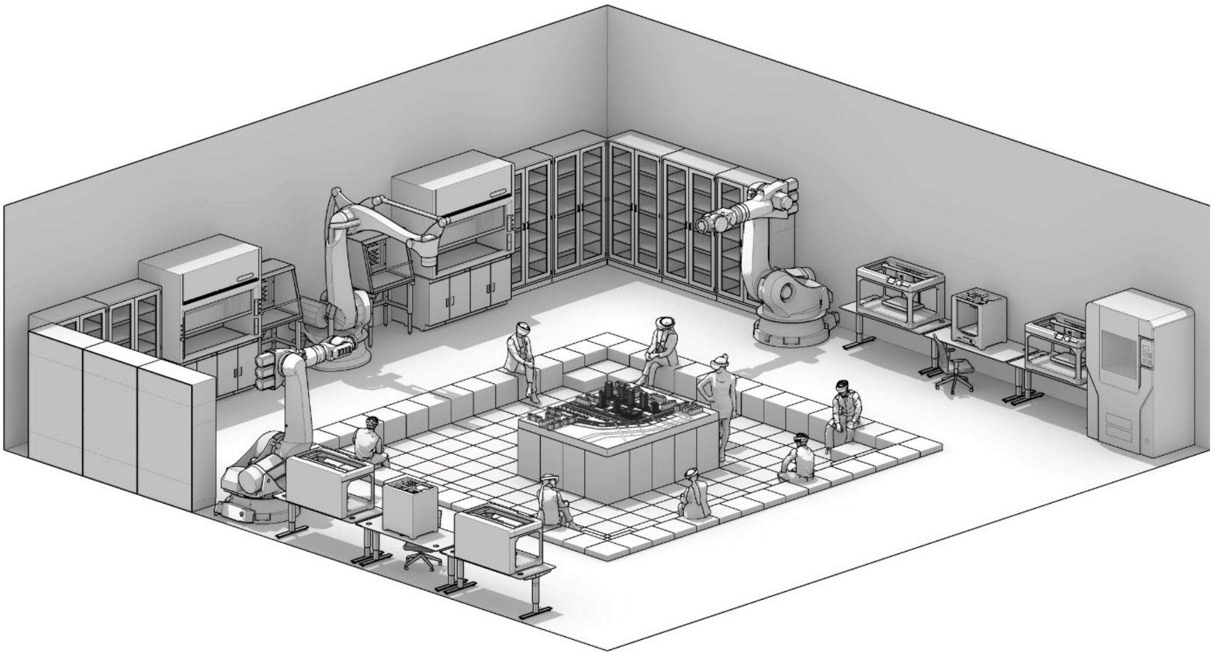


Figure 73: Augmented Flexibility Scrum Meeting Scene/Only Physical, illustrated by the author.

The last scenario example is a scrum meeting, conducted by an urban planning and architecture company with several branches. This example is critical to discussing the mechanics of collaborative working in distant spaces. The flexibility of architecture and the ability of the space to change form and function according to needs is one of the main focuses of this study. However, design is an interface and user experience design as well as an architectural design. In this framework, design has also turned into a collaborative design platform, as mixed reality technologies and 3D design tools serve as an interface for the virtual layers in the space and are a reference and calibration point for the smooth operation of these technologies. The instruments produced to realize this space function are 3D design tools that have been tried in the prototype and can be considered a research subject for future studies. Everything produced in the system is transferred to a digital host, as in the design work carried out on a shared server, and this data is reproduced in all other physical or digital twins. When a change is made to the digital or physical twins, this change is committed to the digital host, and the system continues to operate in this way. Therefore, since the main synchronization principle of the system is the same principle developed by 3d design tools for collaboration, the space itself can be seen as a modeling design tool.

While conducting a meeting, the design company in the scenario produced part of the design and model that was discussed. For both teams, the real-time change they make in a part of the whole will be processed into the primary model simultaneously. While a branch in city A is working on the housing designs in the master plan, the draft proposals they quickly produce upon feedback at the meeting can be processed into the masterplan model in real-time, thus ensuring cooperation. The multi-user design of the system not only brings users together to communicate and interact but also provides simultaneous access to all tools. When we consider architecture with its virtual layers, this situation has transformed it from being just a place into actions and a tool because it is an interface. The process of architecture as a media and a tool is the beginning of a process that moves away from the current definition of architectural programs and structures and will radically change architecture.

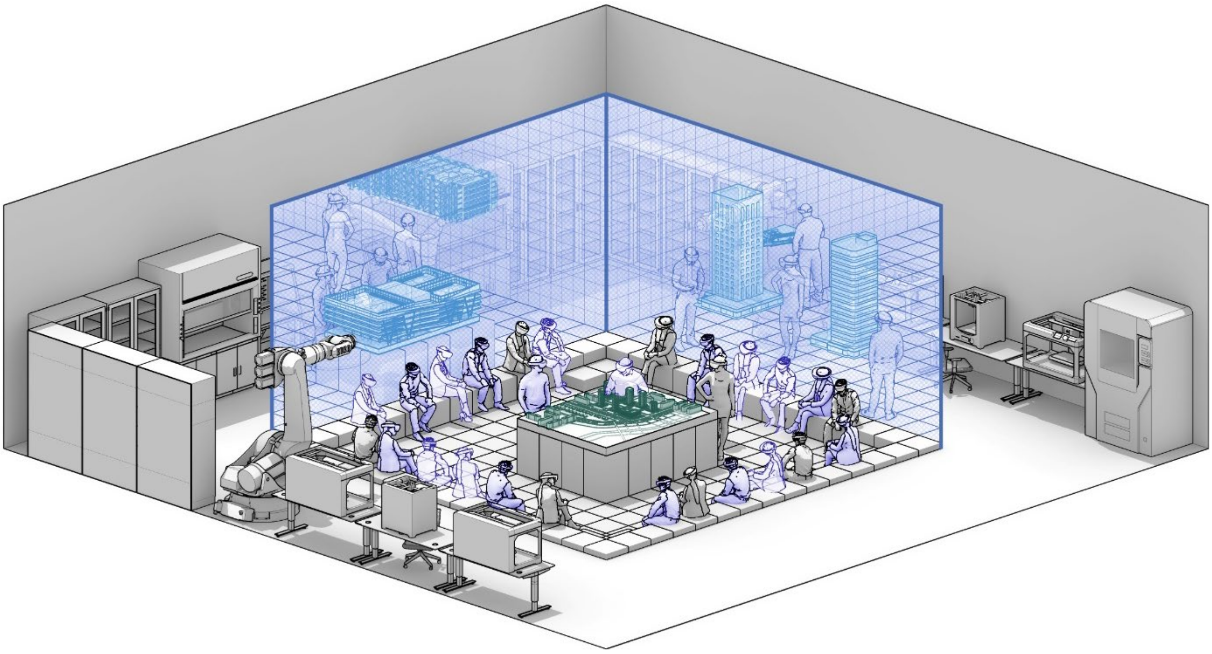


Figure 74: Augmented Flexibility Scrum Meeting Scene/Mixed-Reality, illustrated by the author.

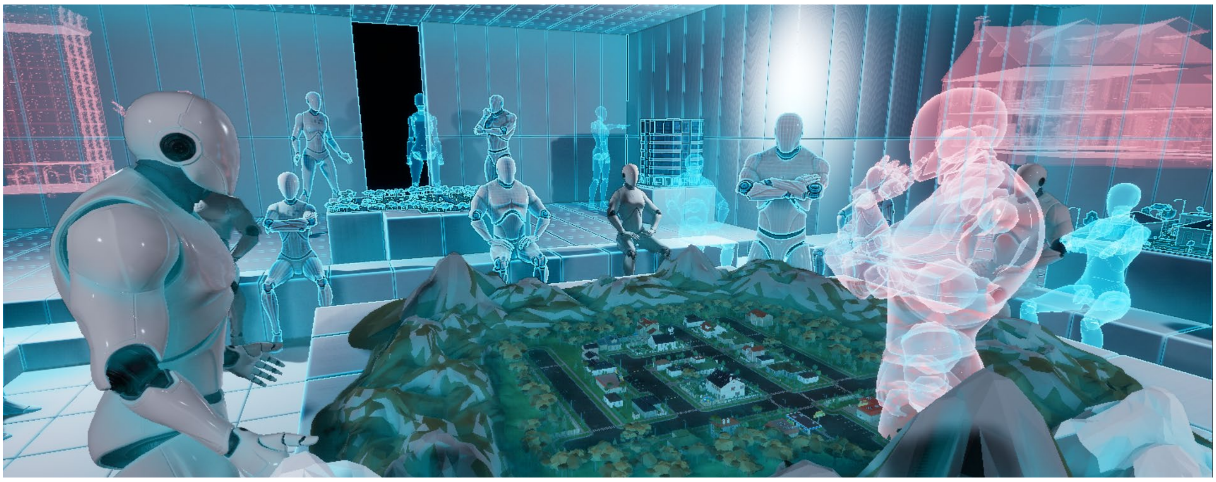


Figure 75: Augmented Flexibility Prototype: Collaborative Workspaces 2: Masterplan Scene

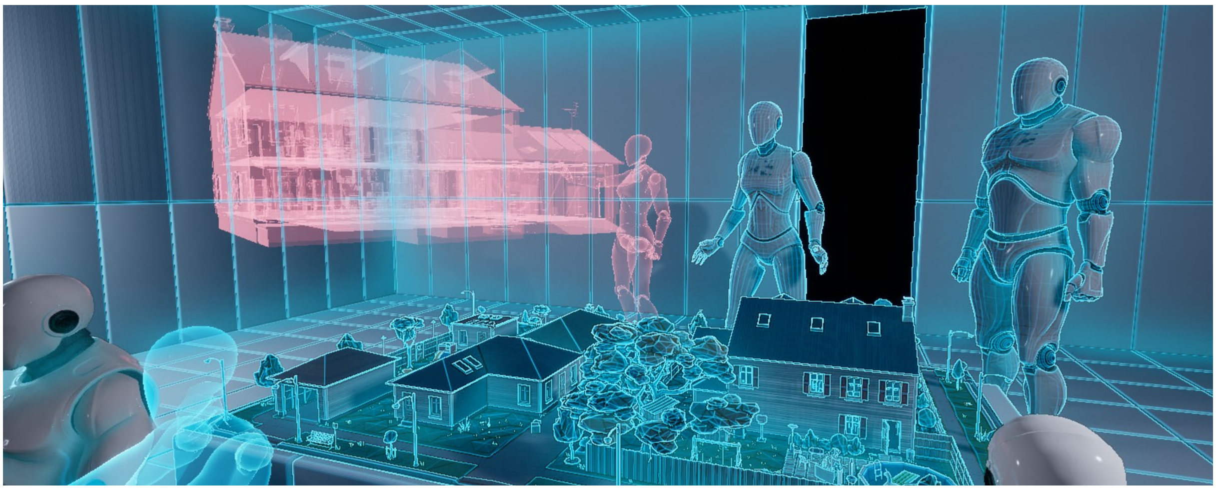


Figure 76: Augmented Flexibility Prototype: Collaborative Workspaces 2: Detail-work Scene

5.7 Prototype Study

In this section, studies on the Augmented Flexibility prototype will be shared. In brief, why this prototype was created, what was taken into consideration while creating, and expected and obtained results will be examined.

First, technologies such as mixed reality and virtual reality are seemingly easy but relatively challenging to present and understand technologies. For this reason, during the thesis studies, it was decided that the study should have an experience-oriented presentation due to the combination of physical and virtual environments using an architectural interface. Therefore, the prototype is critical for the design presentation to be understood, experienced, and comprehended by the users.

In the production, the priority was to convey the experience first, and then to explain the system with all its details and mechanics. It is not feasible to produce a prototype in which the whole system can be experienced since the physical prototype is not produced in more than one location. Therefore, a simulacrum, in which the prototype experience can be fully simulated, is built in a virtual reality environment. In this way, not only the technological layers of the design will be experienced, but also the physical layers will be experienced through a simulacrum and a presentation where the system can be fully understood. Therefore, a mixed reality simulacrum was created in the virtual environment by using virtual reality technologies to produce the prototype.

During the development process, it was preferred to use the Unreal Engine 5 game engine, which is one of the most preferred software due to its visual coding support and one of the most powerful engines in the industry to develop virtual and mixed reality experiences. In addition, Advanced Framework - VR, Mobile & Desktop developed by the Human Codeable team was used to accelerate and facilitate VR interface integration and prototype production. The Augmented Flexibility prototype created mixed reality architecture with the inner and outer cells. The outer cell is designed as a digital fabrication laboratory, and the inner cell is designed as a mixed-reality architectural cell consisting of pixels. Based on this prototype room, nine different levels were designed, which were mentioned while the scenarios were explained in the previous section. These levels represent different scenarios involving different mechanics of the system. These scenarios are:

- Collaborative Workspaces 1: F1 Design Studios
- Collaborative Workspaces 2: Multi-Branch Architecture & Urban Design Studio
- Entertainment Scene 1: Fashion Show & Art Gallery
- Entertainment Scene 2: Mixed-Reality Shooter Game
- Entertainment Scene 3: Networked Performance Spaces
- Education Scene 1: Symposium of Distributed Spaces
- Education Scene 2: Conventional Classroom with Mixed-Reality Tools
- Education Scene 3: Joint Architecture Urban Design Studio Class of Distributed Spaces

Each scenario is designed to describe another feature of the design to the user. In this framework, through these scenarios, the same space can be experienced in different places, different user groups can experience the same space differently, the space has a memory and users can access it, the use of mixed reality technologies in the space and many similar features are explained and the interface defined by the architecture for these experiences is examined.

Since it took half an hour to experience each scenario and examine the general features of the prototype, a video consisting of sections from the prototype experiments was produced for this thesis and presentation. The QR code, which will provide the necessary link to watch the video, can be found in the appendix at the end of the thesis.

In conclusion, architecture is “the design of the experience of space and patterns of co-presence”. Therefore, the presentation of such an architecture should be experience-oriented. In this framework, a mixed reality experience that will explain the architectural concept and the system's mechanics, a simulacrum in a virtual reality environment, has been designed and presented.

5.8. Summary

This section includes a summary of the project and the design equivalents of the conceptual and theoretical expansions made in the previous sections. *Architecture* is the design of human interactions and experiences through patterns of spatial experience and coexistence. Therefore, the distinction between architecture, sociology, psychology, experience design, interaction, and interface design are becoming increasingly blurred. Furthermore, architecture is experiencing challenges in the face of changes in daily life, and this thesis developed an architectural flexibility approach supported by a mixed reality by looking at architecture from a polymath perspective to adapt itself against transformation. This approach is based on redefining architecture as an interface and organizing the interaction between virtual and physical environments. This organization is established by structuring interpersonal and human-space relations based on eliminating the conflict between virtual and physical experiences.

In this framework, the design rests on two main pillars. The first of these is an adaptive architecture, which is the physical element of the interface that will eliminate the conflict between virtual and real; The second is mixed reality architecture, which redefines the space-user experience and the relations of users with each other by using mixed reality technologies.

The physical element, adaptive architecture, is a combined interpretation of adaptive architecture's physical bits approach and Ishii's tangible bits approach to mixed reality, so the physical/tangible bits that make up the structure define an interface to interact with the virtual elements. Through this interface, users can interact with virtual and mixed realities. When necessary, they can enhance their experience with virtual elements, similar to the augmented virtuality approach, by using the physical/tangible bits that define the interface as physical proxies of virtual elements. This will eliminate the problems caused by the conflict between physical and virtual in the interaction of users with virtual elements.

The concept is dependent on the design and actualization of the virtual layers of space. However, the term virtual is used here as a double entendre, the procedural design of spatial possibilities that can be actualized like Deleuze's virtual definition and the design of a computer-aided environment like Ettlinger's virtual definition. Therefore, there is a conceptual relationship between the innermost layer of *shearing layers* (adjusted from Brand’s) of architecture that is most in contact with the user is a virtual layer and spatial possibilities that space can transform and can be actualized. Many architectural scenarios have been studied in order to evaluate these actualizable possibilities of the space from an architectural point of view.

Based on this, architectural scenarios describing the concept of inner-outer cells and the reflections of the concepts of augmented reality, augmented virtuality, tangible bits, and mixed reality boundary, which are the approaches that make up mixed reality, were created. Furthermore, each scenario was created in order to examine another mechanic and feature of the system and was prototyped on the unreal engine to evaluate it. Through this prototype, a media was created for the presentation of the experience, as well as the research of the design experience.

In summary, a new approach has been introduced to mixed reality architecture by defining architecture as an interface. With this new approach, architecture, like Deleuze's virtual, designs the possibilities of what can be actualized and makes Ettlinger's "virtual" from virtual-physical duality one of the shearing layers of architecture. As a result, architectural flexibility is maximized by the inclusion of virtual layers in space and the architecture, reaching the possibility of producing infinite spatial possibilities through mixed reality technologies and architectural interface. This is called augmented architectural flexibility and it will redefine the human-space relationship and bring a new approach to the experience of space. This will put architecture in an irreversible process of change and development.

6. CONCLUSION

The merge of the physical and virtual experiences of space will bring many new and unknown possibilities to the user-space interaction and will irreversibly change the notion of space. The space has been waiting for this change for a very long time since architecture has difficulty responding to its users' current needs and desires. The life span of architecture is decreasing day by day because it cannot keep up with the transformation in human life, wishes, and expectations. Although the adaptability and flexibility of the architecture is an odyssey for a solution to this problem, a breakthrough similar to the one that architecture needs have not been experienced since the birth of vertical architecture with the invention of the elevator.

By defining architecture as an interface between virtual and physical spaces, this study offers a holistic mixed reality experience by eliminating conflict and experience incompatibility between physical and virtual environments. Architecture is at the center of this holistic experience. Defining the architecture as an interface could define the breakthrough that architecture is searching for in its flexible architecture odyssey to adapt to human life's transformations.

With the help of the Covid 19 process, virtual spaces have started to take the place of physical spaces, and this process has led to the adoption of new interaction forms, habits, and actions by users and the start of an irreversible process. While this transformation provided by technology affects every part of life, architecture continues to resist being a part of this transformation. Like Victor Hugo's dictum that the book killed architecture, the internet either destroys or engulfs everything else today. Architecture is long dead, but the merging of virtual and physical spaces can resurrect architecture from being a place where things are experienced to being the thing that is experienced again.

In summary, this thesis redefines architecture to encompass virtual and mixed realities and the design and transformation of their spaces. Architecture is the design of spatial experience, whether physical, virtual, or mixed; it is about the events and interactions that happen inside. The beginning of architecture to produce virtual, physical, and mixed reality spaces is the construction process of the spatial internet and the architecture of the future. Transformation always comes with a process; however, the concepts of program, function, space, time, and reality will also change once transformation occurs.

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LIST OF APPENDIXES

[1] Augmented Flexibility Prototype Video made by the author.

QR Code for Augmented Flexibility Prototype Video: