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HOW METAVERSE EVOLVES THE ARCHITECTURAL DESIGN

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Abstract

Architects have long relied on visualization tools to develop their concepts for specific design problems. From the early traditional drawings to the three-dimensional visualizations and virtual environments, all have enabled architects to demonstrate design outputs relatively early in the process. Real-world projects are similar to what architects imagined from the beginning. In other words, the design process has always started by creating the digital representation of a project and then attempting to replicate it in real life. Once the digital representation of design parts is complete, architects prepare their design for construction. However, the final visualization emerges from actual architectural functions, structure constraints, Gravity, materiality, privacy, and physical laws, meaning that architecture evolves the digitally represented visualizations. With the growth of the metaverse, all physical restrictions are being eliminated, and architects can expand the boundaries of how spaces can be represented regardless of being virtual or physical. As a virtual environment on the internet, the metaverse redefines the rules of architecture and offers endless possibilities for architectural innovation. This article aims to explore the role the metaverse plays in designing architecture. It outlines the fundamental concepts of the metaverse to identify significant elements that could influence architecture design.

Keywords

architectural design, digital representation, metaverse, visualization.

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ABSTRACT

Architects have long relied on visualization tools to develop their concepts for specific design problems. From the early traditional drawings to the three-dimensional visualizations and virtual environments, all have enabled architects to demonstrate design outputs relatively early in the process. Real-world projects are similar to what architects imagined from the beginning. In other words, the design process has always started by creating the digital representation of a project and then attempting to replicate it in real life. Once the digital representation of design parts is complete, architects prepare their design for construction. However, the final visualization emerges from actual architectural functions, structure constraints, Gravity, materiality, privacy, and physical laws, meaning that architecture evolves the digitally represented visualizations. With the growth of the metaverse, all physical restrictions are being eliminated, and architects can expand the boundaries of how spaces can be represented regardless of being virtual or physical. As a virtual environment on the internet, the metaverse redefines the rules of architecture and offers endless possibilities for architectural innovation. This article aims to explore the role the metaverse plays in designing architecture. It outlines the fundamental concepts of the metaverse to identify significant elements that could influence architecture design.

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ملخص

لطالما اعتمد المعماريون على أدوات التصور الرقمى لتطوير مفاهيمهم لمشاكل التصميم. بدءا بالرسومات التقليدية المبكرة إلى التصورات ثلاثية الأبعاد والبيئات الافتراضية، فقد مكنت جميعها المعماريين من إظهار مخرجات التصميم في وقت مبكر نسبيًا من العملية التصميمية. وفى الواقع فإن مشاريع العالم الحقيقي تشبه إلى حد كبير ما يتخيله المعماريون منذ البداية. بمعنى آخر، فقد بدأت عملية التصميم دائمًا من خلال إنشاء التمثيل الرقمي للمشروع ثم محاولة تكراره في الحياة الواقعية. بمجرد اكتمال التمثيل الرقمي لأجزاء التصميم، يقوم المعماريون بإعداد تصميمهم للبناء. ومع ذلك، يظهر التصور النهائي من خلال الوظائف المعمارية الفعلية، والمحددات الإنشائية، والجاذبية، والمادية، والخصوصية، والقوانين الفيزيائية، مما يعني أن العمارة تطور التصورات الممثلة رقميًا. مع نمو تقنية الميتافرس، يتم التخلص من جميع القيود المادية، ويمكن للمعماريين توسيع حدود كيفية تمثيل الفراغات بغض النظر عن كونها افتراضية أو مادية. وبذلك فإن الميتافرس يعيد تعريف قواعد العمارة كبيئة افتراضية على الإنترنت ويوفر إمكانات لا حصر لها للابتكار المعماري. تهدف هذه المقالة إلى تحديد المفاهيم الأساسية للميتافيرس واستكشاف الدور الذي يلعبه في التصميم المعمارى.

الكلمات المفتاحية: التصميم المعمارى، التمثيل الرقمى، الميتافرس، أدوات التصور الرقمى.

1. INTRODUCTION

The term "metaverse," which combines the word "meta" (which means beyond) and the word "verse" from the word "universe," refers to the next-generation Internet, in which users can interact with software applications and other users as avatars (Duan et al., 2021). The metaverse is best understood as a frictionless 3D web with three key components: presence, interoperability, and standardization. Metaverse is not a brand-new idea. The term was first used in Neal Stephenson's science fiction book "Snow Crash" in 1992. In this book, Stephenson defined the "metaverse" as a vast virtual environment that exists alongside the real world and in which people communicate via digital avatars (Stephenson, 1992). After rebranding Facebook to Metaverse, the 1992-proposed concept known as "metaverse" has gained widespread popularity (Far and Rad, 2022). The metaverse once thought of as a solitary virtual universe, is currently changing into a multiverse in which virtual worlds overlay the actual one. There will be seamless integration between actual and virtual spaces, people, and activities (Tang and Hou, 2022). The physical and virtual worlds become more entwined because of the opening of new paths made possible by the metaverse (Gaafar, 2021).

On the other hand, there is no denying that architects play a vital role in developing creative projects in the metaverse (Figure 1). Architecture is viewed as a container for places, people, and activities. The emerging duality of the metaverse will change not only architectural requirements but also the very nature of architecture in terms of form and function. It is determined that the core of designing metaverse architecture combines virtual and physical entities, such as architectural features, human presences, and artifact properties, to host hybrid and dynamic activities (Tang and Hou, 2022). Hence, there is excellent potential in the architectural requirements of the metaverse, which can serve conventional architectural practices.

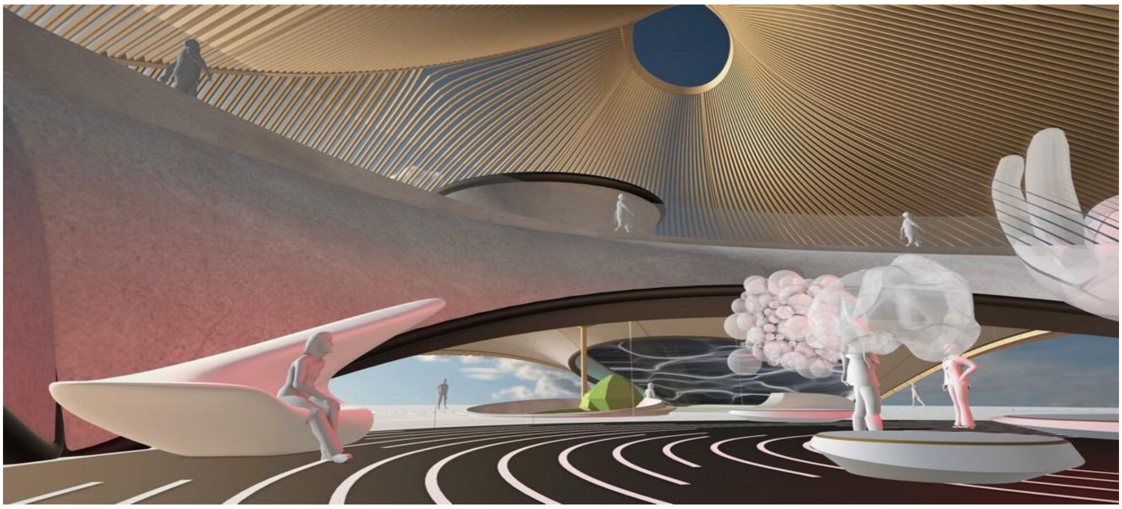

Fig.1: Liberland metaverse (Image credits: Zaha Hadid Architects)

2. METHODOLOGY

To identify the role and effectiveness of the metaverse on architectural design, it is essential to build theory from its main features. The goal is to establish a firm empirical grounding based on metaverse that can be used in architectural design. The metaverse architecture will be examined in three phases and compared to the conventional architectural processes in each step. These phases include tools, design methodologies, and place characteristics. For the first part of the study, we classified the tools into the recent cutting-edge technologies used in the metaverse and some virtual environments including game engines, artificial intelligence (AI), digital twin, and AR (augmented reality)/VR (virtual reality)/XR (extended reality)/MR (mixed reality). Secondly, the design methodologies of virtual environments are analyzed. Finally, the place characteristics of the metaverse and conventional architectural designs are compared. The comparison focused mainly on studying the place-making of both virtual and physical realms. Figure 2 shows the roadmap of the research. This approach helps to detect the current bottlenecks in architectural design, which can be solved by retrieving knowledge from metaverse applications.

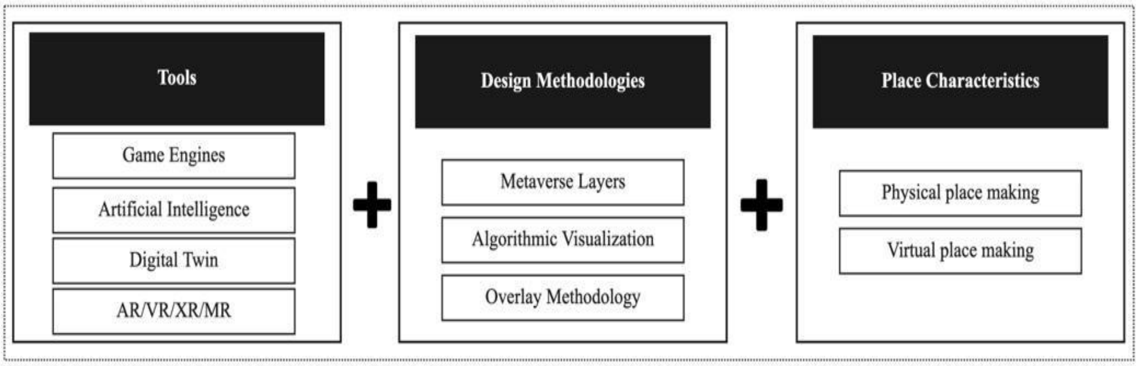

Fig.2: Research roadmap (by authors)

2.1 TOOLS

"The buildings and communities of the near future will be planned with the aid of some development of these theories (new technologies). Whether or not they are planned by architects may pretty well depend on the way architects today prepare to use such tools". (Eames, 1954)

2.1.1. Game Engines

Gaming is anticipated to be a key use case for the metaverse due to its immersive nature. Tech companies have already included metaverse components into well-known games like Animal Crossing, Fortnite, and Roblox, the latter of which reported having over 49 million daily active players in November 2021. Specifically, Second Life, a platform for online social interaction free of plotlines and obstacles, was the first effort on the internet to replicate a metaverse world (Robinson, 2022). Second Life was created as an empty place to be filled with content created by users, in contrast to games with predefined surroundings. This characteristic naturally drew the attention of architects and urban planners. Because it is more than simply a game and serves as a hub for creative expression in online and offline cultures.

On the other hand, it is common for conventional architectural design to illustrate architectural works using various visualization techniques like renderings or videos. While 2D representations have traditionally been utilized to convey designers' intentions, 3D representation technologies are now employed more often (Hamzeh et al., 2019). Architects use 3D modeling software like 3ds Max, Blender, Cinema 4D, or Maya to create 3D models. The models created for real architectural projects often concentrate on construction details and leave out minor details that are less important to the topic (Branco and Leitão, 2018).

Contrarily, 3D modeling for the metaverse may need new talents and a change in perspective to integrate expert knowledge from various domains, such as user interface, content, character, and game design. To do so, game engines are used to create the spaces within the metaverse. Although numerous game engines on the market are easily accessible, the research of Smith and Trenholme (2008) demonstrates that first-person shooter (FPS) game engines often contain more extensive capabilities for modifications. Unity and Unreal are the most remarkable ones. However, in terms of cost and quality, Unity is one of the most well-balanced engines and is readily available to every user (Schoreder, 2011).

Fortunately, some university architecture studios have used game engines as central design instruments in conventional architectural designs. Students got a much-enhanced understanding of the spaces and took advantage of time-based design opportunities not available when working in other media. They highlighted four main advantages of real-time modeling with game engines over physical scale modeling, including comprehension of scale, engagement of other senses with sound, understanding of space and time, and the ability to interact with others in a virtual space

(Johns and Lowe, 2006). However, real-world projects lack the extensive use of game engines, and very few practical methods can enable a professional designer to effectively interact and collaborate with end-users/clients on a functional level (Edwards, Li and Wang, 2015).

2.1.2. Artificial Intelligence

As a pervasive field, artificial intelligence (AI) is even influencing the field of architecture. Pattern recognition in architectural drawing, early-stage design, space planning, automatic generation of the new design, dynamic optimization of architectural design, crowdsourced design, digital fabrication, and form-finding optimization are among the architectural issues dealt with artificial intelligence (As and Basu, 2021).

Besides, AI in the metaverse advances automation for designers, and it surpasses conventional approaches. However, there has not been much progress in using AI to simplify user interaction and enhance the immersive experience. Existing artificial intelligence models are often quite complex and demand high levels of computing. Consequently, it is essential to create artificial intelligence models that are light and efficient (Lee et al., 2021). Since the virtual environment within the metaverse is vast, it might not be possible to make these improvements and maintain the user experience while employing artificial intelligence at its peak efficiency. Additionally, these technologies will always need to function at a high level of performance and stay up to date as the number of users grows (Nalbant and Uyanik, 2021).

2.1.3. Digital Twin

The idea of a digital twin (DT) was first introduced in 2002 by Dr. Michael Grieves of the University of Michigan. The idea claims that every system comprises two sub-systems: a virtual system that holds all the data relevant to the physical system and the physical system itself. As a result of the connection between these two systems, information can flow between the physical and virtual systems (Grieves and Vickers, 2016). It is believed that incorporating DT design principles into the metaverse can provide consumers with natural/actual qualities, increasing the appeal and usability of the metaverse (Far and Rad, 2022). We can use 3D reconstruction methods to create digital twins in the metaverse for structures, items, and settings that already exist in the real world (Zhiliang and Shilong, 2018).

Contrastingly, in conventional architecture, DTs are produced by computers, 3D scanners, and developers based on actual physical things (Far and Rad, 2022). They are mainly used for construction approaches. However, the adoption of DT in the construction industry was relatively low until 2018 compared to the other industries. Most of the projects applying digital twin technology to the construction phase focus on the structural systems integrity of the object (Opoku et al., 2021). Moreover, construction researchers emphasized the contrasts between BIM and Digital Twin, despite the similarities in their definitions. The aim, technology, end users, and a facility's life stage are some of the ways that BIM and Digital Twin differ from each other, according to Khajavi et al. (2019). In the body of construction knowledge, the applications of BIM have been thoroughly studied. While contractors utilize BIM to manage production, conduct constructability analysis, site, and safety management and perform conflict detections and material take-off throughout the design phase of a project, it does not work with architects and engineers (Volk et al., 2014).

2.1.4. VR/AR/MR/XR

Virtual reality (VR) refers to a computer-generated environment that closely resembles reality to the person experiencing it. Although virtual reality is not a new technology, current applications of the tool include a variety of markets such as gaming, education, design, architecture, and the metaverse. According to (Drew Hill et al., 2019), virtual reality is increasingly being adopted as a tool for architectural visualization and presentation in the late stages of the design process. However, numerous advantages that make VR useful in the final phases of the design process indicate that it may also be useful in earlier stages like analysis and concept development. In architecture, VR technologies can create settings for improved stakeholder collaboration, enable a better understanding of complex designs (A.G, 2019), identify design issues (Romano, S. et al, 2020), and represent building geometry to help users understand a project and make a better design decision (Bille et al, 2014), and support collaborative decision-making (Zou et al, 2018). Besides, the metaverse utilizes VR as a platform where multiple users receive identical information and interact in real-time (Lee et al., 2021). Beyond the boundaries of pure virtual spaces, augmented reality (AR) offers users different experiences in their actual surroundings with an emphasis on improving the real world. The user interaction with digital entities in augmented reality has been significantly improved from the very first development (Lee et al., 2021). Augmented reality (AR) technology allows users' visual areas to be expanded with relevant information (Branco and Leitão, 2018). On the other hand, in real-world architecture, AR is used in many fields such as construction maintenance and productivity and architectural and environmental planning (Alizadehsalehi, Hadavi and Huang, 2020).

Although there is no widely accepted definition for MR, it is essential to have a phrase that characterizes the alternated reality between the two extremes of augmented reality and virtual reality (Lee et al., 2021). MR is another version of AR. To create new habitats where digital and physical items may interact in real-time, mixed reality (MR) mixes the virtual and physical worlds (Apollonio et al., 2011). Users can experience the metaverse through many other realities in physical and virtual realms because of the MR continuum's diverse categories (Pakanen et al, 2022). Besides, in real-world projects, MR is used in many fields, including the AEC industry, prefabrication, site survey, and remote design problem-solving (Alizadehsalehi, Hadavi, and Huang, 2020).

Extended Reality (XR) is the term for the real and virtual worlds that wearable technology creates (Gaafar, 2021). The XR, as used in computer technology and wearables, refers to real-and-virtual mixed settings and human-machine interactions. VR, AR, and MR are all parts of XR. In other words, XR may be characterized as a phrase that unifies AR, VR, and MR under one heading, reducing ambiguity for the general audience (Alizadehsalehi, Hadavi and Huang, 2020). In the metaverse, users in the physical world can control their avatars through XR and user interaction techniques for various collective activities such as content creation (Lee et al., 2021). XR technologies, which simulate building projects in multidimensional digital models and exhibit many features, can significantly aid all phases of a project in the Architecture, Engineering, and Construction (AEC) sector (Alizadehsalehi, Hadavi, and Huang, 2020).

2.2. Design Methodology

Design for a real-space is constrained by physical laws (Kim, Lee, and Lee, 2017). However, virtual design approaches differ from real-space design procedures. Furthermore, as the metaverse is still in its early phases of development, neither academia nor industry has a consensus on how it should be structured (Duan et al., 2021). Nevertheless, some attempts have been carried out to deal with this problem. For instance, layered metaverse methodologies were established by some researchers. Additionally, design methodologies of digital games, as the most similar environment to the metaverse, and the algorithmic approaches of 3D modeling, as a methodology for the effortless generation of adaptable visualizations, can be adopted.

2.2.1. Metaverse Layers

To meet the requirements of the metaverse, this virtual world needs structures. For this means, a seven-layer metaverse design was developed by Jon Radoff. The levels include infrastructure, human interface, decentralization, spatial computing, creator economics, discovery, and experience. Additionally, a generic three-layer Metaverse design (Figure 3) was proposed by Duan et al. (2021). The seven levels of Radoff's metaverse are broken down into the three phases below based on Duan's suggested architecture: A) Infrastructure: This layer establishes the fundamental and physical necessities, such as the blockchain, network, and processing power. B) Interaction: This layer links the Infrastructure and Ecosystem levels, where the metaverse's contents are formed. C) Ecosystem: This is the Metaverse, a parallel digital universe. This layer combines AI, economics, and user-generated content. The Interaction layer connects the Infrastructure and Ecosystem in this suggested broad architecture of the metaverse. This approach looks at the architecture of the metaverse from a more macro viewpoint.

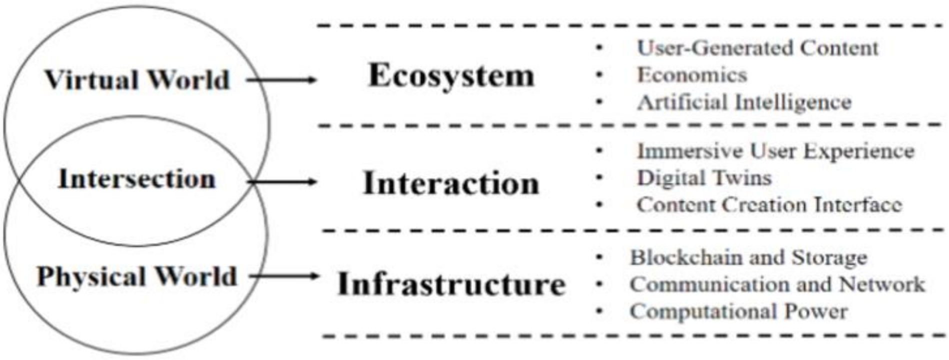

Fig.3: Three-layer architecture of the metaverse (Duan et al., 2021)

2.2.2. Overlay Methodology

To train designers and architects to design and build virtual environments with higher efficiency, Kim et al. (2018) have suggested the Overlay methodology to design the virtual space within digital games. As both real and virtual environments have interactive space characteristics, it is persuasive to apply the design approach or procedure from real space to a virtual environment (Kim, Lee, and Lee, 2017). Therefore, the Overlay design methodology was inspired by Ian McHarg's design approach for landscape architects (Mcharg and Mumford, 1969). The steps in the Overlay methodology are as follows. After developing the game's concept, the type of its place is first defined as described in the place-making in virtual environments of classification method research (Kim, Lee, and Lee, 2017). Secondly, the recommended information is extracted from the classification methodology, and players' activity is developed as bubble diagrams, Player Activity Map (PAM). Finally, developers design each layer in a defined order: story, natural environment, artificial environment, and media with information, file them all together and build a master diagram (Kim et al., 2018) (Figure 4).

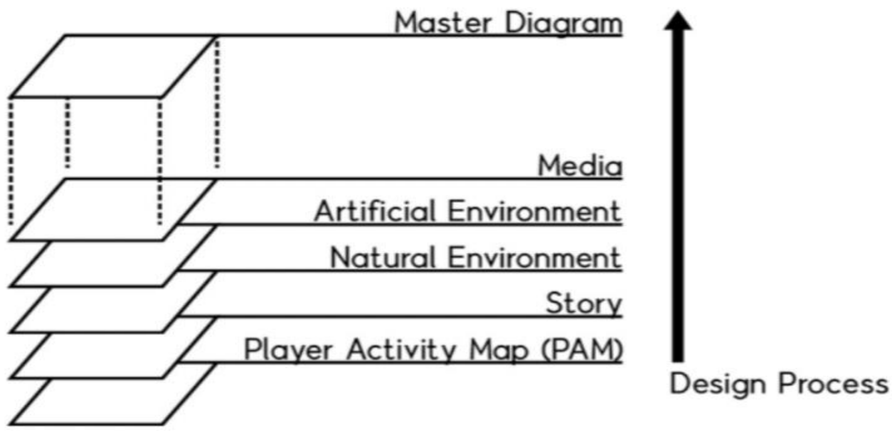

Fig.4: Overlay design methodology (Kim et al, 2018)

2.2.3. Algorithmic Architectural Visualization

According to Gerber and Ibaez (2014), algorithmic design (AD) refers to creating architectural designs using algorithmic descriptions. In contrast to conventional design methods, algorithmic design entails the architect creating software that creates the digital model rather than the model itself. Since the resulting algorithmic descriptions are parametric, they can;

- model more complicated geometries that would generally need much time to construct;
- automate time-consuming, repetitive operations; and
- quickly generate a variety of design alternatives.

When using algorithmic design, the architect creates the program that creates the digital model, using a combination of geometric, symbolic, and mathematical representations of the objects. While the spread of this design approach creates a challenge for visualization, the algorithmic architectural visualization (AAV) process, which makes it simple to create adaptable visuals, looks like the solution. AAV depends on the parametric descriptions of the rendering tasks that follow the parametric description of the architecture is included, along with the model's description. As a result, camera placements and alignments follow the project's logic, and modifications to the design also result in modifications to the visualizations.

This methodology consists of two tasks that can only be programmed and automated as far as the rendering software in use allows. The level of detail depends on both the project's development stage and the purpose of the render itself. These phases include establishing scenario features, such as sunshine, sky, and other environment settings, and detailing the model to generate ambiances, which may require specifying furniture components, coatings, lighting, etc. (Branco and Leitão, 2018).

2.3. Place Characteristics

In determining the elements that affect place characteristics and the sense of place, scholars have conducted research in both physical and virtual realms. Placemaking's core concept can be traced back to the 1960s, when urbanists and activists like Jane Jacobs (Jacobs, 1961) and William H. Whyte (Whyte, 1980) utilized their theories to reshape the structure of cities, focusing on people rather than cars and shopping. The process by which humans turn the tangible environment into a living place that hosts their activities is described as place-making (Schneekloth, and Shibley, 1995). Place-making refers to various actions to increase the chances of good places forming or flourishing. New developments, improvements to existing places, or interventions that create an activity in a space can be considered place-making.

2.3.1. Place-making in Physical Environments

There are several dimensions of place-making in physical environments. Researchers have found interdependent aspects to it. For instance, Punter (1991) believes that place aspects include form, activities, and meanings. Likewise, Canter (1977) suggests form, activities, and conceptions. Subsequently, physical features, individual features, activities, and meanings were proposed as the main factors of a place. (Falahat, 2006) Besides, a more recent work covers the physical, psychological, and social domains.

Architecture, even in its conventional form, intends to enhance the quality of human experiences while turning spaces into places of living. Fortunately, certain research focus on the place-making problem. The identified features of place in physical environments are listed in Table 1.

Table 1: Physical Place Features

source	realm	place features
(Punter, 1991)	Physical	form- activities- meanings
(Canter, 1977)	Physical	form- activities- conceptions
(Falahat, 2006)	Physical	Physical features- individual features- activities - meanings
(Al-Kodmany, 2012)	Physical	physical- psychological- social

2.3.2. Place-making in Virtual Environments

The place is a concept that may be applied in various settings, not only physical ones. Many virtual environments can be thought of as having their distinct place-ness. The aspects of place are quite significant in this realm because place-based, embodied explorations of virtual environments make it easier to study a place than in natural settings (Quiring, 2015). Virtual place making is identical to physical place making because it has been built on communication networks between humans, their environments, social traditions, and other personal experiences. A virtual place's layers, functionality, interaction, communication, and perception contribute to its sense of place (Piercy, 2019) These factors are the elements that give meaning to each place and provide reasons for users to have emotions and attachment to a virtual environment.

Accordingly, some researchers examine the place-making of digital games to help reflect on the sense of place within virtual spaces. While (Purzycki, 2019) devised a framework based on setting, community, events, perception, and meaning, (Piercy, 2019) believes the three pivots of social, audio-visual, and developer-based communications comprise the virtual places within games. On the other hand, (Kim, Lee and Lee, 2017) classify virtual places based on five principles of story, space shape, space and action dimension, user complexity, and interaction level. He further explains and classifies the terms. First, the story is about providing an engaging narrative, divided into two categories representing and generating. Space Shape refers to the structures of implemented virtual places. Based on the edge of the space and the flexibility of the player's direction, it is divided into spot, linear, chain, and face. Space and action dimension refers to the corresponding movement and implemented dimensions needed for the user to direct the character inside the space. There are four different varieties of it: 2D-2D, 2D-3D, 3D-2D, and 3D-3D. Finally, while user complexity is known as simultaneous utilization of the place by several users that can be separated into single, group, and massive, the interaction level is described as the

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amount of engagement between the user and the virtual place, classified as none, partial, and all.

The identified features of place in virtual environments are listed in Table 2, and (Kim, Lee and Lee, 2017) classification conditions of virtual places are represented in Table 3.

Table 2: Virtual Place Features

source	realm	place features
(Purzycki, 2019)	Virtual	setting- community- events-perception- meaning
(Piercy, 2019)	Virtual	social communication- audio-visual communication- developer based communication
(Kim,Lee and Lee 2017)	Virtual	story- space shape- space dimension- user complexity-interaction level

Table 3: Virtual Place Classification Principles, adapted from (Kim, Lee and Lee, 2017)

Principle	Variable	Description
Story	Representing	Player follows the given story line (close ending).
	Generating	Player generates a new story (open ending).
Space Shape	Spot	Player freely moves around in a limited space that has boundaries.
	Linear	Player is guided to a move toward certain direction in a limited space.
	Chain	Combination of Spot and Linear. The player is allowed to move freely in a spotted space, and moves to the next spotted space to play further.
	face	Unlimited space with player's free movement
Space and Action Dimension	2D-2D	Require two axises (XY) to build the world, requires two axises (XY) to the players to play the game
	2D-3D	Requires 2 axes (XY) to build the world and requires more than 2 layers of two axes (XY) to the players to play the game
	3D-2D	Requires 3 axes (XYZ) to build the world and require 2 axes (XY) to the players to play the game
	3D-3D	Requires 3 axes (XYZ) to build the world and requires 3 axes (XYZ) to the players to play the game
User Complexity	Single	Player is the only one in the game (a single player at a time)
	Group	More than two players play the game together, sharing same goals
	Massive	More than two groups of numerous players play the game simultaneously, with various goals.
Interaction Level	None	No interaction between the player and the environment except as the boundary of a void space
	Partial	Player can interact with designed limited environment resources in the space
	All	Player can interact with every environment resources in the space

3. RESULTS

The results of the article are drawn by assessing and comparing the main characteristics of the metaverse architecture and conventional real-world architecture. This comparison helped us detect the similarities and differences between these two fields and the potential opportunities they can obtain due to the bottlenecks. As shown in Table 4, although game engines have succeeded in taking the attention of both architects and metaverse designers, real-world projects lack the extensive use of this powerful tool. Additionally, metaverse and architectural design contain structures and layers to construct their design projects. However, these structures differ from each other. Furthermore, metaverse and actual architecture mainly differ in terms of the features of the place. While both virtual and real architectural places rotate on the pivot of meaning and story, interaction is the element that architecture has not paid enough attention though being one of the prominent factors of virtual places. A place exists in a natural environment whether or not you interact with it. In a virtual environment, though, the place loses its meaning with no interaction. A more extensive overview of the two realms of conventional and metaverse architecture is provided in table 4.

Table 4: Results

Results' Highlights
While every single detail can be highlighted in the metaverse design, architectural projects concentrate on construction details and leave out minor details that are less important to the topic.
Real-world projects lack the extensive use of game engines as a virtual platform to interact with others.
AI has been used to its maximum potential in architecture, whereas there has not been much progress in using AI to simplify user interaction and enhance the immersive experience in the metaverse.
While the digital twin in the metaverse mainly focuses on the design phase, architecture mainly utilizes this tool for construction, focusing on the structural systems.
VR/AR/MR/XR tools focus mainly on construction, prefabrication, and the AEC industry instead of architectural design, while metaverse benefits from these tools.
Although containing different design methodologies, virtual places drew inspiration from architectural design methodologies in some cases.
Both architectural and metaverse designs contain structures and layers, although they do not have the same functions.
Meaning and story remain the core concept in both virtual and physical spaces.
For virtual places, interaction has a great degree of importance.

4. CONCLUSION

This study aimed to investigate how the metaverse influences architectural design. It defined the fundamental ideas of the metaverse to pinpoint important components that could affect architectural design. Along our journey, we also provided insight into recent developments and tools that link the physical and virtual spaces. Based on our comparative review of the three phases of tools, design methodologies, and place characteristics, we concluded that each design has its challenges and opportunities with similar and different features, which can help both fields to boost their place qualities. Yet, further research is needed to explore the design development process and how architecture professionals use 3D modelling software for different design briefs in the metaverse and real-world design problems.

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