The Metaverse and The Real Estate Industry

Sanzida Mojib Luna, Jiangnan Xu, Garreth W. Tigwell, and Konstantinos Papangelis

1 Introduction

The metaverse is a multifaceted concept that has been defined in various ways by researchers, reflecting its complex nature. According to Dionisio et al. [14], the metaverse is defined as:

> The Metaverse refers to a fully immersive three-dimensional digital environment in contrast to the more inclusive concept of cyberspace that reflects the totality of shared online space across all dimensions of representation.

Similarly, Kye et al. [30] described the metaverse as:

> Not a simple combination of the world and virtual reality (VR), but an interaction; furthermore, the metaverse can denote a world in which daily life and economic activities are conducted in a unified way.

Both Dionisio et al. [14] and Kye et al. [30] emphasize the immersive and integrative nature of the metaverse, but they approach its definition from slightly different perspectives. Dionisio et al.'s description highlights the metaverse as a fully immersive three-dimensional digital environment, emphasizing its distinction from the broader concept of cyberspace, which encompasses all forms of shared online

S. M. Luna (✉) · G. W. Tigwell · K. Papangelis
Rochester Institute of Technology, Rochester, USA
e-mail: sl8472@rit.edu

G. W. Tigwell
e-mail: gwtics@rit.edu

K. Papangelis
e-mail: kxpigm@rit.edu

J. Xu
Tampere University, Tampere, Finland
e-mail: jiangnan.xu@tuni.fi

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spaces. In contrast, Kye et al. focus on the interaction between the physical and virtual worlds, suggesting that the metaverse represents not just a digital environment but a space where everyday life and economic activities are seamlessly integrated. While Dionisio's definition is more technical, focusing on the metaverse's spatial and visual elements, Kye et al.'s definition stresses the social and economic dimensions, portraying the metaverse as a world where virtual and real-life activities converge. Despite these differences, both definitions underscore the transformative potential of the metaverse in reshaping human interaction within digital spaces.

The metaverse has recently seen a significant surge in popularity and has been referred to by Cheng et al. [11] as "*the successor to the mobile Internet.*" Since its initial conception in 1992 [14], the metaverse has undergone substantial development. However, there remains considerable potential for further growth before it reaches a mature state. In its fully realized form, the metaverse will enable the seamless integration of virtual and physical worlds, creating a space for socializing, interaction, and creativity that can be accessed anytime and from any location. The ultimate immersive experience with both virtual and physical objects will be provided to users in the metaverse's final stage.

With the metaverse still being developed, researchers have differing views on its precise architecture. The term "precise architecture" refers to the underlying framework and technological components that define the structure and functioning of the metaverse, including layers such as infrastructure, content creation, user interaction, and the economy within the virtual world. Various architectural models have been proposed based on different perspectives, such as layered model [35, 62], modular architecture [35], and decentralized framework [73]. While these models emphasize different aspects, such as user interaction, flow of data, content generation, and governance, they all converge on the core technologies that the metaverse is based on.

The metaverse holds significant potential as a transformative tool for various major industries. Sectors such as healthcare, gaming, retail, and fashion are actively exploring ways to integrate the metaverse into their operations. This shift is driven by the need to stay aligned with rapid technological advancements, ensuring that these industries remain competitive in a digital-first world. Real estate, on the other hand, is one of the biggest global industries that is lagging behind in the race to adopt new technologies. However, real estate is slowly trying to catch up with its peers by integrating new technologies in order to modernize itself. Furthermore, researchers have come up with several disruptive technologies, such as drones, internet of things (IoT), clouds, software as a service (SaaS), big data, 3D scanning, wearable technologies, virtual reality (VR) and augmented reality (AR), and artificial intelligence (AI) and robotics, that enhance the core functions of this field [40, 46, 59, 67, 68, 70]. Surprisingly, these disruptive technologies have a lot of similarities with the technologies that the metaverse is based on, which will not only elevate the real estate industry technologically but also help the industry access the metaverse. Furthermore, as the real estate industry has been following traditional approaches for a long time, adopting several massive technological changes to enter the metaverse will impact the real estate industry, both positively and negatively, which needs to be discussed.

In this chapter, we briefly go over the origin history of the metaverse and its current definition. Then we discuss several architectural models of the metaverse proposed by different researchers, find out the fundamental technologies from these models, and see how they will bring the metaverse to maturity. Later, we discuss the types of metaverse from a business perspective and try to fit one of the massive global industries, real estate, into the types. Then we walk through the current technologies available in real estate, followed by a discussion of the disruptive technologies in this field, how they fit with the fundamental technologies of the metaverse, and how they can benefit the industry itself and access the metaverse. Finally, we discuss the mutual impact between the metaverse and real estate from multiple perspectives.

2 What Is the Metaverse

To understand the concept of the metaverse, it is important to trace not only its formal origin—popularized by the term in the 1990s—but also the earlier technological and conceptual foundations that contributed to its evolution. For instance, in 1935, American science fiction author Stanley Weinbaum introduced the concept of an immersive virtual world in "Pygmalion's Spectacles" [74]. In this work, the protagonist experiences a fictional environment through a pair of goggles that simulate sight, sound, taste, smell, and touch. Building upon such imaginative ideas, Morton Heilig developed the Sensorama Machine in 1956 [2], widely regarded as the first VR device. This machine combined 3D visuals, audio, scents, and tactile feedback through a vibrating chair, creating a multisensory simulation of a motorcycle ride through Brooklyn. In the 1970s, the Aspen Movie Map, developed by MIT, marked another significant milestone [4]. This system allowed users to take a computer-generated tour of Aspen, Colorado, and was among the earliest applications of VR to transport users to a digital representation of a real-world location. The term "metaverse" combines the prefix "meta," which denotes virtuality and abstraction, and "verse," which represents the universe [14]. Neal Stephenson's 1992 novel "Snow Crash" served as the basis for the three-dimensional virtual world known as the Metaverse [26, 42]. According to the book, the metaverse is a computer-generated 3D environment where users can interact with one another, play games, socialize, and even engage in combat using avatars. Additionally, there are instances of what is now known as "user-generated content" (UGC) that only exists in the metaverse. Even three-dimensional spacetime can be ignored by some of these unique UGCs. The most representative novels, aside from "Snow Crash," that project immersive experiences are "The Master Key," "Dungeons and Dragons," and "Neuromancer," even though the technologies were not yet developed [33].

The first book about the metaverse was considered pure fiction when it was published. However, programmers used them as inspiration and attempted to recreate the virtual world using whatever technologies were accessible at the time, and we can find similarities in the characteristics of today's metaverse technologies with earlier attempts as well. The first instance of "space" in cyberspace can be found in WorldChat, a community-based virtual environment with a space station theme that was created in 1994 to promote communication and individual creativity. A year later, Worlds Inc., the company behind WorldChat, developed an improved version called AlphaWorld that offered users a selection of 12 avatar appearances. Because AlphaWorld was primarily concerned with world-building, it stood out significantly from other virtual world projects at the time, and users could contribute by creating their own UGCs. Another example of a virtual world is Habbo, an online community started in 2000 for teens and young adults. Users are given the option to embellish guest rooms, hotel rooms, and business rooms. They can also design new games and role-playing components. As of October 2020, the platform had 316 million overall avatars.

Second Life, one of the best-known virtual worlds, developed by Linden Lab in June 2003, was directly inspired by Snow Crash [43]. Although it is frequently compared to massively multiplayer online role-playing games, its creators refused to refer to it as a game because it lacked artificial conflict or a predetermined goal. Similar to AlphaWorld, Second Life allows users to design their own avatars, but the user has more control because every aspect of the avatar is customizable. Due to the addition of the Linden Doller (L$) virtual currency system, which can be used to buy and rent in-game items, Second Life set itself apart from earlier virtual worlds. The introduction of L$ is revolutionary because it allows for the development of an in-game economy that encourages users to trade and rent their virtual goods and UCG. Although L$ can be interchanged with USD ($), and many users use it to supplement their income in the real world, it has no meaning outside of Second Life.

We can draw a conclusion about the metaverse's characteristics based on all the aforementioned examples: it is the Internet in embodied form. Users will use AR, VR, and the tactile internet (the internet that combines incredibly low latency with exceptionally high availability, dependability, and security) to explore the virtual worlds within the metaverse, much like how we currently navigate web pages with a mouse cursor [75]. This idea is pertinent if we take into account the fictional definition, which states that the metaverse is an imagined version of the Internet that is a single, all-encompassing, and immersive virtual world that is made possible by the use of VR and AR headsets. However, the metaverse, as it is commonly known, is a network of 3D virtual worlds centered on social interaction. According to Mystakidis [42],

> The post-reality universe, also known as the metaverse, is a continuously existing multiuser environment that combines physical reality and digital virtuality. It is based on the convergence of technologies, such as VR and AR, that allow for multi-sensory interactions with digital objects, virtual environments, and people.

Wang et al. [73] presented a more specific definition of the metaverse and described the following,

> The metaverse is an emerging paradigm for the next-generation Internet that aims to create a fully immersive, hyper spatiotemporal, and self-sustaining virtual shared space where users can live like digital natives and experience an alternative life in virtuality.

Today, we have a "lite version" of the metaverse, characterized by early-stage platforms that offer limited yet growing immersive experiences, such as VR spaces and social gaming environments like Fortnite and Roblox [22]. This version is far more advanced than earlier digital environments, which were primarily text-based or consisted of simple 3D virtual worlds, such as Second Life in the early 2000s [76]. The technologies enabling the metaverse extend beyond AR and VR, incorporating cloud and edge computing for real-time 3D rendering, AI and machine learning for personalized user experiences, and blockchain for secure digital transactions like NFTs. IoT integrates real-world data, while digital twins create virtual replicas of physical entities. 5G and emerging technologies, such as 6G, provide ultra-low latency and high bandwidth, which are essential for seamless immersive experiences. Additionally, haptic technologies enhance these experiences by incorporating tactile feedback. Additionally, quantum computing promises faster processing for complex simulations, spatial computing enables 3D interactions with digital objects, and extended reality (XR) integrates physical and virtual environments, helping to realize the immersive vision of the metaverse. The growing public interest in the metaverse has also attracted the attention of major tech players, with Facebook, Microsoft, Tencent, and NVIDIA among those to announce their involvement. To emphasize its dedication to building the metaverse of the future, Facebook even changed its name to "Meta" [37].

3 The Architecture of The Metaverse

As the metaverse evolves, defining a consistent and unified architecture remains a challenge due to its complexity and the rapid pace of technological advancement. However, researchers have proposed various architectures to structure the metaverse from different perspectives. For instance, Duan et al. [16] proposed a three-layer architecture for the metaverse (Fig. 1), consisting of the ecosystem, interaction, and infrastructure.

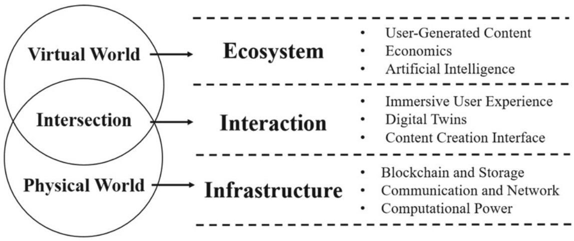

Fig. 1 Three-layer architecture of the metaverse [16]

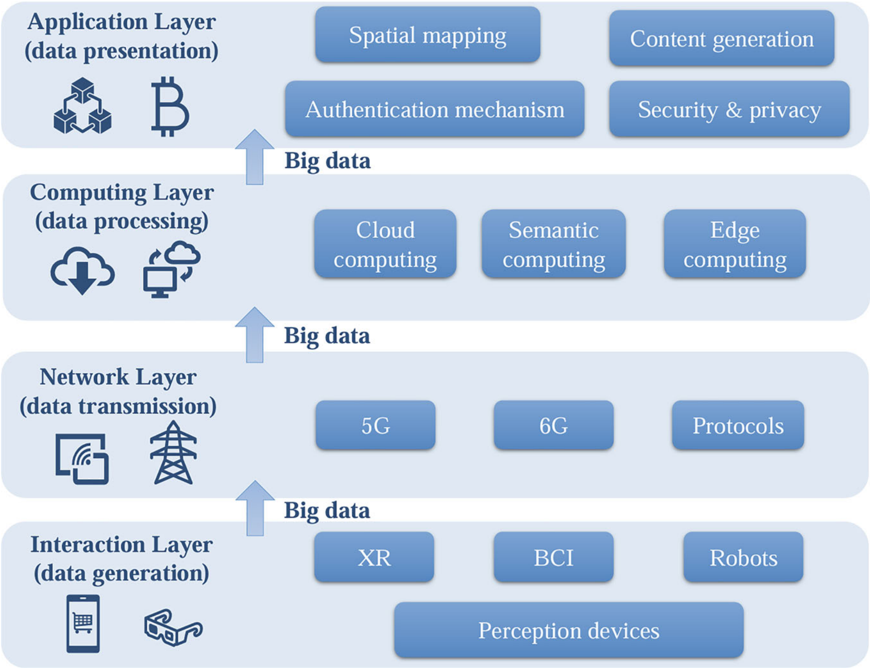

Fig. 2 Four-layer framework of the metaverse [62]

The **infrastructure layer** contains the foundational components required to sustain the operation of a virtual world, including computation, communication, blockchain, and storage. These elements provide the basic technological backbone necessary for running complex, large-scale virtual environments. The **interaction layer** connects the real and virtual worlds, placing a strong emphasis on immersive user experiences through technologies like digital twins, content creation, AR, and VR. This layer enables users to interact seamlessly with virtual content, blurring the boundaries between digital and physical realities. The **ecosystem layer** is crucial as it represents the dynamic, continuously evolving virtual environment that supports the economic and social aspects of the metaverse. This layer can be thought of as the "living" part of the metaverse, where the virtual world's inhabitants—including users, AI-driven non-player characters (NPCs), and digital assets—interact and co-exist. The ecosystem includes the virtual economy, which is driven by UGCs, trade of digital assets, social interactions, and community governance. It ensures that the metaverse is not just a static environment but a thriving, parallel world that supports continuous activity and engagement, fostering creativity, collaboration, and social connections. Consequently, this layered approach helps provide a structured way to understand the complexities of the metaverse's architecture while highlighting the interconnected roles of infrastructure, interaction, and the ecosystem in creating a fully immersive digital universe.

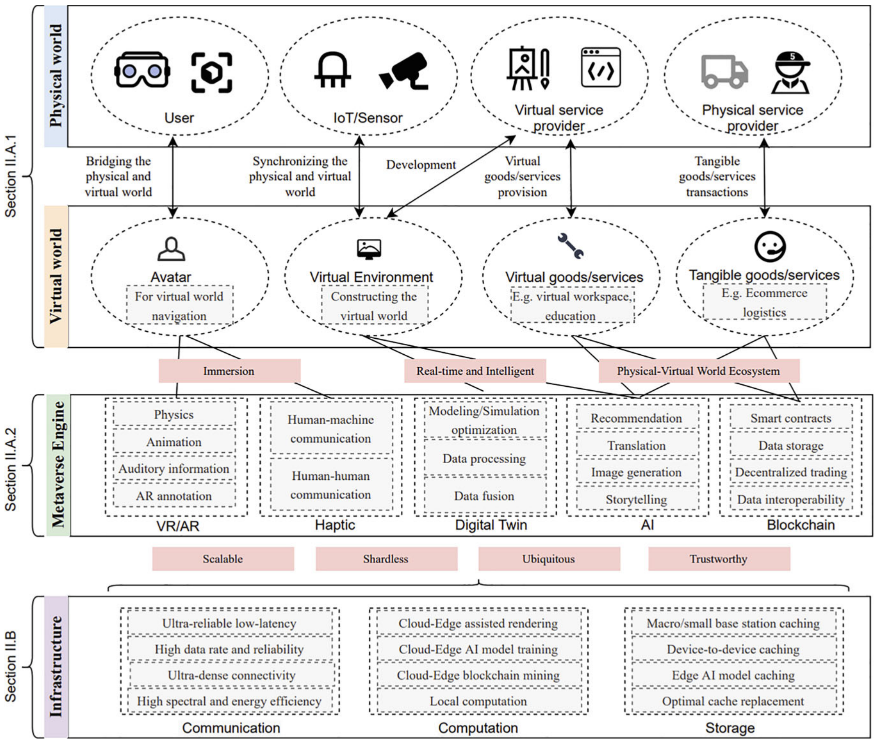

Fig. 3 Modular architecture of the metaverse [35]

Another layered framework was proposed by Sun et al. [62] (Fig. 2), dividing the metaverse's action and computation into four distinct layers: (i) the **interaction layer**, which facilitates interactions between the physical and digital realms; (ii) the **network layer**, which connects the physical world seamlessly with the virtual realm and bridges various virtual worlds; (iii) the **computing layer**, where vast amounts of data from diverse sources are processed and analyzed to achieve interoperability and extract valuable insights; and (iv) the **application layer**, where data presentation occurs. These layers collectively manage the flow of big data, serving as the foundation for the interaction between reality and virtuality, with each layer corresponding to specific functions: generation, transmission, processing, and presentation of data.

However, Lim et al. [35] proposed an architecture (Fig. 3), where the metaverse engine is in the center of all the operations. The metaverse engine supports an immersive interaction of both the virtual and the physical world in real-time. The architecture strongly emphasizes being scalable, shardless, and trustworthy, at the same time enabling ubiquitous access for the users. There are also three layers to this architecture. The metaverse engine and stakeholders make up the top layer. Stakeholders include users, the IoT and sensor networks, virtual service providers (VSPs), and physical service providers. These entities will have control over the physical world components that have an impact on the metaverse. The role of the Metaverse engine will be to gather information from the stakeholders and use it to create, maintain, and enhance the virtual world. Blockchain, digital twins, AI, and AR/VR technologies will all be combined to create the Metaverse engine. Then comes the edge intelligence-powered infrastructure. This layer's primary concerns are storage, computation, networking, communication, and computation. In this layer, edge intelligence and AI are crucial components that support one another and the infrastructure as a whole. Applications and services in the metaverse, such as social and recreational activities, product and service testing, virtual education, the gig economy, the creative industries, and many more, make up the third layer of the architecture.

Finally, we explore the architectural concept of the metaverse proposed by Wang et al. [73] (Fig. 4), which emphasizes a human-centric approach by blending the physical, human, and digital worlds. Their design focuses on the interaction between these three worlds, the core elements of the metaverse, and the flow of information within it.

With the aid of smart devices, the physical infrastructure and human society bring, transmit, process, and cache multisensory data. A crucial part of maintaining the entire infrastructure is a strong network, powerful computation, and storage capacity assisted by cloud-edge-end computing. By utilizing blockchain, AI, digital twin, and interactive technologies, the Metaverse engine is in charge of creating, maintaining, and updating the virtual world using big data from the real world as inputs. Digital avatars, virtual environments, and virtual goods or services all fall under this aspect of architecture, which emphasizes interconnectivity among the virtual worlds. The engine's primary job is to effectively process inputs from the outside world and generate output in the virtual world that corresponds to those inputs. An essential component of this architecture is the information flow, both within the virtual worlds and between the virtual and physical worlds. The data flow is partly maintained by IoT and HCI technologies such as wearable AR, VR and XR devices as well as sensors, smartphones, etc.

The designs proposed by Duan et al. [16] and Sun et al. [62] are simpler designs compared to the latter two, and they are easier to grasp for a wider audience. They provide the readers with a high-level overview of the entire metaverse ecosystem by discussing the physical world, the virtual world, and their intersection. However, the two later architectural designs put forth by Lim et al. [35] and Wang et al. [73], respectively, are more complex and include in-depth discussions of technologies in each phase. For instance, Lim et al. [35] divided the design into four major sections, where the top level is occupied with stakeholders and the lower levels are detailed with essential technologies to keep the metaverse up and running. They also pointed out the interaction between the top three sections (the physical world, virtual world, and metaverse engine). On the other hand, Wang et al. [73] divided the architecture into five major categories where the interaction between digital life, interconnected virtual worlds, the metaverse engine, human society, and the infrastructure of the metaverse.

Even though the four aforementioned architectural designs come from various research angles, it can be comprehended that the fundamental goal of the metaverse

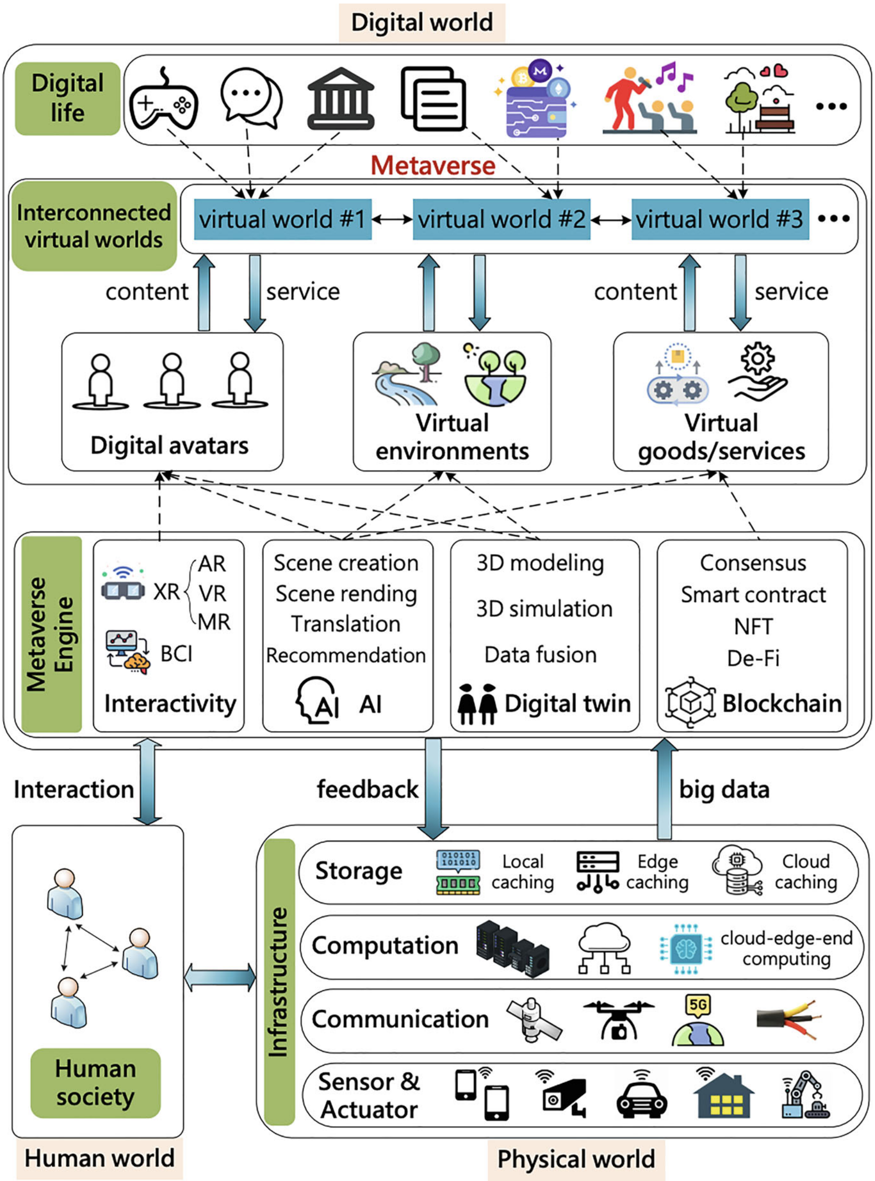

Fig. 4 Decentralized architecture of the metaverse [73]

is to combine the virtual and real worlds, and it does this by creating, maintaining, and updating the virtual world using data from the real world. Furthermore, there are several general design principles that guide the development of metaverse architectures, regardless of the specific models proposed by researchers:

- **Scalability and Flexibility**: The metaverse must be designed to scale efficiently to accommodate millions of concurrent users and vast virtual spaces. Flexibility is essential to support various applications, from social interactions to commerce, education, and entertainment, ensuring that the architecture can adapt to future technological developments.
- **Interoperability**: A key principle in metaverse design is interoperability, which allows different virtual worlds, platforms, and applications to communicate and interact seamlessly. This includes shared standards for digital assets, user identities, and cross-platform content, enabling users to move fluidly between different virtual environments.
- **User-Centric Experience**: The architecture of the metaverse should prioritize immersive and engaging user experiences. This involves designing intuitive interfaces, realistic avatars, and interactive and accessible environments that respond to user input in real time. Technologies like VR, AR, and mixed reality (MR) play a significant role in enhancing user experience.
- **Decentralization and Trust**: Decentralization, often supported by blockchain and distributed ledger technologies, is a core principle that fosters user ownership, data privacy, and security in the metaverse. Decentralized architectures empower users to control their digital assets, create secure transactions, and participate in governance structures, reducing reliance on centralized authorities.
- **Persistence and Continuity**: The metaverse is characterized by its persistent, continuous nature, meaning that virtual environments and digital assets exist and evolve even when users are not actively engaged. Architectural designs must ensure that virtual worlds maintain their state, enabling ongoing interactions and developments in the metaverse.
- **Integration of Physical and Virtual Worlds**: Successful metaverse architectures bridge the gap between the physical and digital realms. This integration is achieved through digital twins, IoT (Internet of Things), and real-time data streams, creating hybrid spaces where physical and virtual elements coexist and interact.
- **Security and Privacy**: Ensuring robust security and privacy is essential to protect users' data, digital assets, and identities in the metaverse. Architectural designs must incorporate secure data management, encryption, and user authentication methods to safeguard the virtual environment.

Beyond the general design principles, there are notable similarities in the technologies used within these architectures. In the virtual world, technologies like blockchain, AI, big data, and digital twins work together to build a comprehensive infrastructure, managed and monitored by the metaverse engine. Inputs from users, facilitated by AR, VR, and IoT, feed into this system. Additionally, UGC plays a key role in shaping the metaverse's economy, alongside AI-generated content. The entire metaverse operates on a fast and resilient network, with edge intelligence and AI addressing challenges related to storage and intensive computation.

3.1 Fundamental Technologies of The Metaverse

The technologies underlying the metaverse are still undergoing modifications and updates. From a variety of perspectives, researchers are attempting to identify the underlying technologies. For example, Lee et al. [32] categorized a few interconnected technologies that they identified as the technology enablers of the metaverse. These include user interactivity, blockchain, robotics/IoT, network, edge/cloud, AI, computer vision, and XR. However, Wang et al. [73] identified six technologies that serve as the Metaverse's enablers: AI, digital twins, blockchain, interactivity, ubiquitous computing, and networking. Notably, Wang et al. classified computer vision as a branch of AI, IoT/robotics as a branch of networking, and XR as a branch of user interactivity, and defined cloud/edge as ubiquitous computing. Building on these categorizations, we will briefly discus several key technologies in more detail to explore their specific roles in enabling the metaverse's development and functionality.

- **User Interactivity**: In the context of the metaverse, user interaction, often referred to as human-computer interaction, involves the engagement between humans and both the physical and digital worlds, influencing both in the process [44, 79]. As the metaverse advances towards full development, the integration of these worlds will become seamless, allowing for mutual interaction. In this future state, humans will utilize avatars for communication in the virtual world, while MR will facilitate continuous interaction in the physical world. Progress in sensor technology, embedded systems, and XR technologies is already driving the metaverse towards this vision. Currently, user interaction with AR occurs through smartphones and computers, while VR is accessed via head-mounted displays (HMDs). The ultimate objective is to create a seamless interaction between the real and virtual environments. For instance, traditional input devices like keyboards, mice, and mobile devices, though commonly used, present limitations such as narrow fields of view (FOV), restricted mobility, and latency. However, these challenges are being addressed by emerging interaction technologies, such as on-body interaction devices and advanced lenses, which are being developed to connect users more effectively with MR environments.
- **Digital Twin**: Michael Grieves introduced this term for the first time in 2002 at the Society of Manufacturing Engineers conference held at the University of Michigan [58]. An empirical model for Product Lifecycle Management (PLM) called a "digital twin" was first put forth as a digital replica of an actual thing. A digital twin can therefore be compared to a 3D model of a facility that includes all the dynamic data to show straightforward visualizations and analysis. Digital twins are highly accurate and conscious representations of digital clones of real-world systems and objects. The physical world and the metaverse are able to interact through digi-

tal twins [34]. Any modification to one of them will result in a modification to the other. A digital twin can be comprehended as an applied field of deep learning (DL) and AI. The mirrored space allows for self-learning and self-adaptation using data that is fed back from physical entities. Additionally, with the aid of AI technologies and the simulation of intricate physical processes, digital twins can produce highly accurate digital models. These models have all the essential properties, which play an advantageous role in the creation and rendering of the metaverse on a grand scale. Digital twins have connections with both the physical entities and their virtual counterparts, which enables predictive maintenance and accident traceability for physical safety, enhancing efficiency and lowering risks in the real world. Future applications of the digital twin could include smart health care, industrial testing, and new IoT sensors and devices.

- **Blockchain**: Blockchain can be compared to a public ledger in which a chain of blocks contains the records of all committed transactions. When additional blocks are added to the chain, it continues to grow. Blockchain has the potential to be a crucial part of the virtual economy and value system in the metaverse. In addition, blockchain technology can be used to store, manage, and share data with an additional layer of security and privacy that guarantees data interoperability [73, 75]. As an illustration, smart contracts can be set up on top of the blockchain to enable the automatic function execution among suspicious parties in a predetermined way and the data can be accessed from anywhere in the metaverse by specific users. In the metaverse, non-fungible tokens (NFTs) and UGCs are regarded as assets, and the blockchain protects their ownership and identification. Blockchain technology can additionally be used by decentralized finance, also known as de-fi, to provide secure, open, and sophisticated financial services, such as stock and currency exchange in the metaverse.
- **Robotics/IoT**: The significance of IoT or robotics in the metaverse is obvious given that it is intended to be a vastly interconnected physical and virtual world [34]. IoT devices are sweeping the globe and creating new opportunities for innovation. Users are currently using IoT devices to interact with virtual environments while also gathering data from their surroundings that is later used by AI [39]. Although these devices still have a number of shortcomings, engineers and researchers are working to improve them. For instance, most IoT devices cannot support tangible interfaces, but XR (AR/VR/MR) technology integration can help solve this problem. When combined with IoT, AR can be used especially effectively to interact with virtual objects in the real world, which will enhance user interaction. Additionally, research is being conducted on how to integrate robots into the virtual world and integrate the IoT with vehicles.
- **AI**: AI can be referred to as the brain of the metaverse. AI is defined as a collection of various algorithms and techniques that can draw on prior knowledge and apply it to new situations, just like an intelligent creature would. Since its inception in 1956 [47], AI has matured and is now successfully applied in a number of fields, including computer vision [28], decision-making [17], natural language processing (NLP) [80], and recommendation systems [78]. The metaverse is going to be an environment where NPCs, avatars, and UGCs will exist symbiotically. All of the

inputs that are provided to the metaverse are essentially provided to AI, which tries to learn about and comprehend its environment in order to create a virtual one [24]. AI is also responsible for the creation of these NPCs and autonomous avatars, using the knowledge it has gained from previous experiences. For instance, AI has been effective at replicating user behavior in addition to creating avatar faces and designs. Drivatars, a product of Forza Motorsport [66], makes use of this method. The AI replicates a player's driving abilities during all of the times they are actively playing, and later, other players can race against the player's avatar even when the real player is not present on the other end. Due to AI's widespread success, it can be used to improve the user experience (e.g., shopping, user movement systems, removing language barriers, and improving interaction with NPCs) in the metaverse.

- **Computer Vision**: Computer vision is an area of AI that enables computers to process, examine, and have a deep understanding of inputs such as images, videos, and other media [63]. As the name implies, computer vision is often referred to as the eyes of the computer [71]. XR devices depend on the ability of computer vision to collect and comprehend visual data from user's action and their surroundings, which further aids the creation of more accurate and dependable virtual and augmented environments. Additionally, it is used in XR applications to pinpoint the location and orientation of the user and device, as well as create a 3D reconstruction of the user's environment. Users' bodies and poses need to be tracked by the XR interactive system. The metaverse will likely use computer vision algorithms to track human users, who will then be visualized as avatars. On top of that, scene-understanding techniques will be used by the metaverse to comprehend and perceive the user's surroundings. Finally, issues with object occlusion, motion blur, noise, and low-resolution image/video inputs must be addressed in augmented and virtual worlds. Image processing is therefore a crucial area of computer vision, which aims to improve the metaverse by restoring and enhancing image/video quality.
- **XR**: XR is a combination of AR, VR, and MR. Although AR and VR are absolutely different technologies they all can be considered under the umbrella term XR. We can understand this concept better if we look at Milgrim and Kishino's [38]

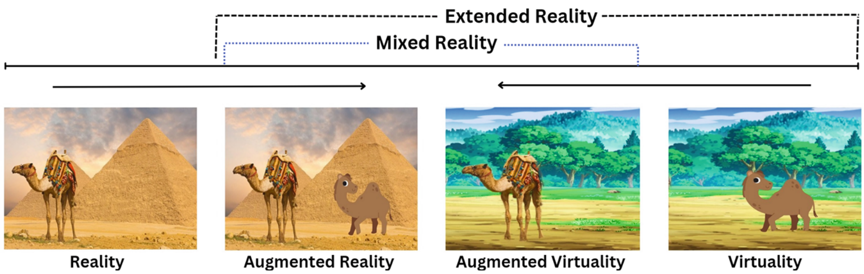

Fig. 5 Milgram and Kishino's reality-virtuality continuum

reality-virtuality continuum (Fig. 5). The technologies under XR enable users to experience the metaverse in both physical and virtual environments. Among these, AR is closest to reality, integrating virtual elements into the physical world through sensory channels like sound, vision, and haptics. AR bridges the digital and physical worlds, allowing users to interact with others, avatars, and NPCs, while receiving audio-visual feedback tailored to their surroundings rather than a fully virtual environment. AR facilitates data transmission from the virtual metaverse to the physical world, enabling AI to manipulate digital twins of physical objects and adjust the virtual environment based on users' tasks. However, current AR devices primarily offer audio and visual feedback, neglecting sensory dimensions like smell, taste, and advanced haptics, limiting the immersive experience of the metaverse.

VR is the most remote from reality in the continuum. In VR, users utilize UI tools like HMDs to interact with virtual objects in a virtual environment that is entirely isolated from the real world. With the help of VR technology, several users can interact in a single space while experiencing a shared sense of time and presence. In this way, they can manipulate a digital twin or UGC and interact with NPCs in the metaverse. However, managing and synchronizing the dynamic environment on this scale remains the biggest challenge, especially when we take into account that an infinite number of concurrent users will interact with one another and act on virtual objects collectively without any discernible latency, where latency could have a negative impact on the user experience.

The concept of MR is a little abrupt; some researchers see it as a hybrid of AR and VR [19], while others consider it a more advanced form of AR [23]. Unlike AR, which primarily provides visual and auditory feedback, MR enables virtual objects to interact with tangible objects in various physical environments through enhanced environmental awareness. For example, Wang et al. [72] developed an optical see-through MR system to aid individuals with hand tremors by stabilizing their virtual hand movements, allowing accurate typing on small targets like keyboards. This system overlays the trembling hand with a stabilized virtual hand, simulating a steady real-world experience. MR represents the convergence of reality and virtuality within the metaverse, merging digital objects with physical surroundings, although its full potential in the metaverse's evolution remains to be seen.

- **Network**: Connecting users to the metaverse at any time and from any location in the world is one of the metaverse's primary objectives. In order to deliver a seamless experience that combines the real world and the virtual world, it must also process a significant amount of data and perform extensive computation. It is clear from looking at the metaverse's backend that it has to constantly send massive amounts of data between sub-metaverses, interact with automated systems, and access large databases. A networking system that combines 6G, software-defined networks (SDN), and IoT can make this possible [64]. The development of 6G and Beyond 5G (B5G) technologies will help realize the concept of omnipresence in digital environments. Meanwhile, SDN facilitates dynamic and programmable network configurations, improving performance and monitoring. This approach aligns more with cloud computing principles than traditional network management techniques. Real-time communication and data distribution between submetaverses, the physical and virtual worlds—can be accomplished in this way effectively. Additionally, IoTs, with various software, sensors, and communicating components, can work as the bridge, fulfilling the goal of connecting, exchanging, and processing data between things, systems, clouds, and users over the Internet.

- **Cloud/Edge**: Cloud computing has been the solution for IT infrastructure that was located locally in the past. These kinds of infrastructure took up a lot of space and created security concerns, along with other risks. These problems are solved by cloud computing, which enables an organization to access data and software programs online rather than on a hard drive. The metaverse will keep expanding and will demand more computation and storage space. Although cloud computing can act as a solution for storing data, it is a centralized warehouse where accessing data might be a challenge. In contrast, edge computing is a more flexible, responsive, and distributed computing paradigm that moves data processing and archiving close to the data's original sources. This is expected to improve response times and save bandwidth. With better mobility support, real-time local multi-user interaction, and an improvement in privacy and security for metaverse users, edge computing can decrease user-experienced latency for task offloading in the metaverse [9]. When used together, cloud computing and edge computing are frequently referred to as "ubiquitous computing," which fosters a setting where users can access computing at any time and from any location. Instead of using handheld or embedded devices, this technology enables seamless adaptation to user interactions with the physical environment, network access in the environment, and real-time immersive metaverse services. According to Kai et al. [27], the combination of heterogeneous edge computing infrastructures, which are located closer to end users or devices, and cloud-edge-end computing, which entails complex inner and inter-layer cooperation, is the key to highly scalable cloud infrastructures that guarantee strong computation and storage capacity. This makes it possible to allocate resources in a flexible and on-demand manner to meet the various needs of end users and/or devices in various metaverse applications.

4 Types of The Metaverse

As the next generation of the internet, the metaverse will be heavily used for business purposes by different stakeholders. According to President and CEO of Nokia Pekka Lundmark [31] the metaverse can be divided into three distinguished categories from the business perspective and they are as follows:

1. The consumer metaverse
2. The enterprise metaverse
3. The industrial metaverse.

Users congregate in the consumer metaverse to communicate with one another, socialize, and play games. They can shop for virtual goods here and use them while playing games or at social gatherings. The contents in this metaverse are highly diversified, low cost, and of uneven quality. On the other hand, the enterprise metaverse mimics the digital environment to connect important organizational components and enhance user experiences and decision-making. This type of metaverse facilitates a collaborative workplace that allows the company to collaborate with its customers. It tries to reduce the gap between the virtual and physical worlds while leveraging the tools of the metaverse to expand the usage and efficiency of the company's external and internal uses. Contents in this metaverse are mainly produced by professionals and AI, but sometimes by users. These contents are often not as diversified as those from the consumer metaverse, and they cost more to create; however, they are of higher quality than the aforementioned ones.

The industrial metaverse, which also includes human enhancement for industrial applications, combines the physical and digital worlds. It contains digital representations of actual industrial environments, systems, assets, and spaces that people can interact with, control, and communicate with [52]. Digital twins and simulation-based applications are primarily regarded as elements of the industrial metaverse. To simulate the physical system and quickly identify, analyze, and resolve issues, the industrial metaverse mirrors real machines, factories, buildings, cities, grids, transportation systems, supply chains, and logistics processes in the virtual world. The industrial metaverse can be extremely useful for designing and producing products as well as streamlining processes by bridging the gap between the physical and digital worlds. The contents of the industrial metaverse are designed by professionals and AI and are highly sophisticated.

In this chapter, we will draw attention to one of the largest global industries, real estate. If we want to fit the real estate industry into the mentioned categories, we will find that it is a mix of all three. The industry needs content from the industrial metaverse to leverage it in the metaverse, on the other hand, it needs components of the enterprise metaverse to collaborate with consumers in projects and enable virtual workplaces for the employees. Last but not least, components from the consumer metaverse will help the consumers interact with their virtual property and products in an immersive environment.

5 Real Estate and The Metaverse

The physical and virtual worlds will seamlessly converge in the metaverse's final state, and decisions made in one world will impact the other. To incorporate every aspect of the physical world into the virtual one, we will need to enable business and professional activities in the metaverse as well. And that requires integrating technologies to enable the massive industries that we have in the physical world to operate seamlessly in both. One such giant industry is real estate.

Real estate is generally defined as "the land and any permanent structures, like a home, or improvements attached to the land, whether natural or man-made" [10]. To emphasize the engagement of humans, according to Albert and Arianna [54], besides the infrastructure, real estate also includes "the social relationships that are formed and take place therein," such as learning, working, and socializing. Given that the metaverse is still in its early stages, the definition of "real estate" is still unclear. While some describe the metaverse's real estate as "just some pixels on a computer screen," others try to characterize it as a collection of extremely important digital assets that will become increasingly valuable as the metaverse develops and reaches maturity.

However, we believe that the concept of real estate in the metaverse should be expanded beyond the traditional understanding of physical assets. It should encompass not only physical entities like land, buildings, and resources but also their digital counterparts (digital twins) in the virtual world and purely digital assets created within the metaverse, such as UGCs. Furthermore, the definition should include the interconnectivity between these physical and digital elements, reflecting the unique nature of property in the metaverse.

Being one of the largest global industries, real estate has a market size of USD 3.69 trillion in 2021 and a projected CAGR of 5.2% from 2022 to 2030 [49]. While most global industries are attempting to integrate disruptive technologies[1] in order to transform into a more innovative and adaptable form, the global real estate industry requires improvement and is currently falling behind the technological curve. Nevertheless, there are a number of innovations in the area that are already in use, offering great support to the stakeholders and potentially helping to bridge this sector to the metaverse in the future.

Real estate needs to evolve from its traditional form into smart real estate (SRE) by adopting nine disruptive technologies, known as the Big9[2]: drones, IoT, cloud computing, software as a service (SaaS), big data, 3D scanning, wearable technologies, VR and AR, and AI and robotics [40, 67, 69, 70]. Notably, many of these technologies closely align with the fundamental technologies enabling the metaverse. In fact, the same technologies that power the metaverse are also key to modernizing the real estate sector. For real estate to operate and thrive in the metaverse, it must leverage these innovations. Likewise, the metaverse must ensure that real estate businesses can seamlessly perform core activities—such as planning, development, sales, marketing, and management—in both virtual and physical environments without disruption.

In the following two sections, we will discuss the current technologies available in real estate that might be helpful for its transition into the metaverse and disruptive technologies, where they fit within the metaverse's fundamental technology category, and how they can further help real estate move ahead in the metaverse in the future.

[1] "Disruptive technologies" is a term first used by Professor Clayton Christensen and colleagues [13]. They defined it as a collection of innovations that challenge established practices or technologies, upend an industry, and create new opportunities for innovation and business growth.

[2] "The Big9" technologies represent a recent concept that explores and advocates the adoption of nine essential technologies for integration into smart city development [67, 68, 70].

5.1 *Current Technologies in Real Estate*

Real estate is a broad field with numerous sub-areas that each have different application requirements. For instance, real estate planning and construction are two distinct real estate processes with related objectives: While real estate construction prioritizes safety and thus necessitates building information visualizations, real estate planning requires architectural design, demonstration, and collaboration. We provide an overview of these technologies in real estate with three segments in order to give a complete picture of the technologies, how they are used in real estate, and how they would affect this industry.

1. Planning and Development
2. Sales and Marketing
3. Trade and Management.

This segmentation aligns with the real estate formation process, from planning and construction to selling and maintenance. We will see that the same application or technology can serve significantly different functions in various real estate sectors. For instance, we will find applications and software using AI, AR, and big data in almost all three of these segments, but for each of the segments, they perform and operate differently.

Planning and Development

The decision-making process is required before real estate development, and this includes urban planning and architectural design. Demonstration and visualization of potential designs are crucial in this process. AR is the technology that has been used most frequently in the planning and development fields because it enhances the physical environment by integrating virtual objects into it. This is because these sectors are more rooted in the physical world than others.

Compared to traditional techniques such as paper models, blueprints, or photomontages, the 3D interactive virtual models in AR applications could better visualize the final result in a convincing manner. More importantly, urban planning and architectural design involve highly collaborative tasks. To ensure a user-friendly outcome, many real estate projects consult locals during the decision-making process. For this reason, real estate planning should not be restricted to the professional team (e.g., architect, designer, planner, investor, etc.). Instead, real estate planning could benefit from a citizen-centered process. We will also observe that most of the applications that support collaborative and citizen-centered planning in this subarea involve AR technology. On top of that, they have proven to be more intuitive and provide a user-friendly interface for all users, especially those with no previous technical experience.

Take the AR application Square AR, as an example, which was designed for a real estate study in 2011 [5]. Aiming to involve local citizens in real estate planning decision-making, Square AR can demonstrate the virtual scene of unexploited public spaces in cities and enable the manipulation of 3D objects in the virtual location. In this way, Square AR can support users in investigating the space of real estate and efficiently seeing the potential, looking at it from a first-person point of view. The described application, Square AR, was installed in a well-lit exhibition kiosk and was open to the public. To make the user interface easier to operate, future works of their study suggest using mobile devices such as mobile phones, tablet PCs, etc. Recently, more AR applications have been introduced to support collaborative design, where stakeholders and designers can work together to create the design of the end product. Sandor and Klinker [55] proposed one such AR system named ARCHIE. ARVita is another tabletop AR environment presented by Dong et al. [15] where users can simultaneously plan and review the designs. ARki is another application directed toward designers for sharing and viewing designs in an AR environment. It uses superimposition technology to create 3D versions of the designs and place them in real-world space. Assemblr [7] is another AR design platform that can be used for architectural, interior, and furniture design. It is an easy-to-use platform where users can create, view, and share designs. Morpholio Trace [36] is another smartphone application for sketching and designing. It is particularly useful to give the clients a better visual sense of a floor plan.

More recently, with the maturity of handheld technology, AR applications for real estate planning are commonly geared toward mobile usage. For instance, in a 2021 study [56], they developed a smartphone-based AR application with Unity3D. Taking advantage of the AR application's higher degree of interactivity, use cases have achieved "great acceptance through transparency, to share information and visualizations with citizens, and to collect new ideas from citizens." Furthermore, AR applications play an important role in information visualization in real estate development. In real estate development, "the dynamic, complex interaction between workers, machinery, and the environment" would lead to dangerous risks [48]. Thus, risk prevention is extremely crucial in this process. The traditional approach to risk assessment is a visual inspection using a checklist, the effectiveness of which depends on the quality of the safety advisor's inspection. In order to guarantee the accuracy of the risk assessment, previous work proposed an AR application with Building Information Modeling (BIM) technology as a 3D viewer to assist safety advisors during the real estate development process. Besides risk assessment, the latest study in 2022 developed a handheld mobile AR application to support facility engineers in visualizing all underground utilities with inspection data using BIM technology [65].

Moreover, AR is actively involved in several aspects of planning, monitoring, and safety during construction. Safety Compass is an application that works by scanning an area and letting the user know about the possible safety hazards regarding the site using superimposition AR. It does so by using superimposition technology and pointing at the exact portion of the threat that can be seen through a handheld device's screen. For detecting the progress of a construction site and if the work is on or behind schedule, Golparvar-Fard et al. [21] proposed an AR system that automates the monitoring of progress. Gamma AR is a smartphone application that allows the user to compare current work with planned design and information about the site through BIM and AR. The aim of this application is to reduce the rework of the same project. Dalux is a Danish company offering multiple applications to cater to the needs of developers. The tools in the application can be effectively used to transform 2D designs into 3D designs and superimpose the design on the original site. It helps its users manage the projects smoothly and assures the uninterrupted flow of data from 2D to 3D to AR.

Sales and Marketing

After real estate construction is completed, some real estate (e.g., residential housing) is ready for sale. The Internet has replaced in-person meetings with real estate agents as the primary method for clients to find the new property they purchased. The use of automated rental and purchase property platforms has significantly increased over the past year, and this trend is expected to continue in the years to come. On the mobile device screens of our smartphones, they provide excellent information and insights about the property. These platforms can provide their users with a lot more information than just insights like interested buyers, best offers, location, etc.

AI and big data play important roles in the sales and marketing sectors as well. Both of these technologies help the realtors to get more sales and the clients to find what they are looking for. AI assistants have rich sets of capabilities and carefully protect the privacy of their clients. Virtual assistants, chatbots, and voice bots are some of the instances and they can immediately assist consumers with their queries. They help to keep up the contact channels 24/7 with a fast response rate and an error rate near zero. However, data is yet another resource that real estate agents can use. Data analysis has become a key component of real estate technology companies' long-term strategy development. Big data is assisting businesses in predicting trends, opportunities, and strategies in real estate.

Organizations can make decisions supported by data. According to research conducted by McKinsey [6], machine-learning applications for real estate can predict changes in rent rates with an accuracy of 90%, compared to only 60% for other property metrics. That can be of much assistance to the clients in determining whether a commercial or non-commercial property is the better option for their investment. For instance, Realestate.com.au, Zillow.com, and Domain.com.au are a few of the real estate websites that use big data to enable their customers to access essential data about their residents, and neighborhoods, and give them important insights like average property prices, crime rates, market accessibility, and sales patterns.

Using AR for sales and marketing purposes has been extremely efficient, and it has also been proven through numerous studies. Alimamy et al. [3] proposed that AR can help generate more meaningful customer insights, which will further reduce customer-perceived risk factors. Specifically, AR applications with an immersive 360-degree view of the real estate for sale can enhance information searches and expedite the time consumers spend evaluating purchase options [57]. Sulaiman et al. [61] conducted a case study amidst the global pandemic on "Matterport", one of the most popular online software for virtual tours of properties. Along with being lifesaving and profitable, they found out that the technology enhanced the marketing strategy of the real estate field by several folds and helped the clients make quick decisions. There is also an application called Realtor for finding house prices and features just by defining the area and scanning the house in real-time. Additionally, through AR tours and walkthroughs, stakeholders would have a better understanding of the property, which would help them make decisions about the current and future renovation of their properties. The idea of a virtual tour is more time and resource efficient, so it would help the realtors cut costs. As the clients would have a better understanding of what they would be buying or renting, they could make faster decisions, which would drive more sales for the realtors.

Trade and Management

In the area of real estate trade and management, notable technologies include AI, AR, IoT, and cloud computing. IoT has made it possible for technology to be found in everyday objects like windows, doors, light switches, appliances, and more. Things can be made simple to use and manage with the right sensors and equipment. IoT is the technology of the future for smart homes. Additionally, IoT in real estate offers insightful data about the property that can be used for compliance, real estate management, and insurance. Managing multiple properties simultaneously can be made easier with AI. Since AI assistance is always available for clients, they can ask for help with their properties and get a prompt response. IoT and AI can collaborate to find solutions to problems before they become a customer inconvenience. However, all of these technologies can be accessed remotely and shared over the internet thanks to cloud computing. Cloud computing made it effortless for websites like PropertyMe to grant remote access and share information like financial details of a property, renovation details, and maintenance information among the stakeholders.

AR applications can be beneficial in great length to provide information and issues about properties that can help the managers with property management and troubleshooting issues effectively. InfoSPOT [25] is an AR system proposed by Irizarry et al. to help users accomplish facility management tasks by providing them with information about BIM. Resonai [50] introduced an AR application named Vera [51] which is an extensive application/software that reconstructs a building layout from the inside out. The application can synchronize and track all the devices equipped with the space, help manage and resolve issues for clients from one workspace, and clients can give feedback and create tickets for their issues as well. It is directed toward the employees and managers of the industry.

5.2 Big9 of Real Estate

Earlier, we introduced the nine disruptive technologies that are crucial to transform the real estate sector to SRE. In this section, we will discuss these technologies in depth, demonstrating how they align with the foundational technologies of the metaverse. In addition, we will explore their potential to drive the evolution of the real estate industry from the physical world into the digital metaverse, providing practical examples and scenarios to demonstrate this transformation.

Drones

Drones are extremely precise unmanned aircraft that are operated remotely or by a ground control station. High-resolution images of the area can be provided by drones with high-resolution cameras that have aerial and wall-climbing capabilities. With the ability to view a property's expansive views and determine the distances to nearby homes and amenities without physically visiting it, consumers can significantly shorten the inspection process and increase sales. Additionally, inside the home, sharp, zoomable images can display finer details at angles that would otherwise be inaccessible to customers, which improves user satisfaction. This could be a useful tool for real estate marketing and sales.

Furthermore, drones can capture comprehensive 3D models of properties by scanning the exterior and interior from various angles. For example, a drone equipped with LiDAR (Light Detection and Ranging) [29] technology can fly around a construction site, capturing precise measurements and surface details to create a highly accurate digital twin of the building. These models can then be imported into the metaverse, allowing users to interact with a virtual replica of the property that mirrors the physical structure in every detail, from layout to material textures. This capability is particularly useful for architects and engineers who need to assess construction progress, make design adjustments, or visualize future developments within a virtual environment before physical execution. With their wide range of capabilities for capture and enhancement of images, they can provide information about a property, including where it is located, how it looks from different angles, and information about neighboring places. Drone images can accurately depict both the property's physical attributes as well as how they should appear and feel in relation to their surroundings. They can show sun-paths, nearby greenery, locations, and distances to parks, schools, and amenities. In this way, a digital representation of the property that is identical to the real one in the real world can be created in the metaverse.

Additionally, drones can serve as input devices for metaverse applications, capturing real-world images and videos that enhance the accuracy of computer vision algorithms [41] used in virtual environments. For example, drones can map the exterior and surroundings of a property, including nearby parks, streets, and landmarks, and feed this data into computer vision models to improve scene recognition and environmental simulation in the metaverse. This enables the AI engines of metaverse platforms to better understand and simulate real-world physics, lighting conditions, and spatial relationships. For instance, a drone can capture the sun path around a property, which can then be replicated in the virtual model to simulate natural lighting conditions, giving users a realistic experience of how sunlight would interact with the property at different times of the day.

IoT

IoT is a fantastic technology for interconnecting and communicating various devices, and it is crucial for the development of smarter cities, secure routers, and enhanced AI. IoT is currently used in the real estate sector for management purposes, and it is used to continuously monitor buildings and their surroundings in order to control the levels of temperature, relative humidity, indoor air quality, and lighting. Building management systems can thus be linked to the systems of tenants, enabling a new level of control and effective monitoring. Real-time monitoring and control of air conditioning, security, power, and fire systems is a definite benefit for brokers, tenants, and property owners. The ability to comprehend an occupant's behavior and respond to it, preventative repair and maintenance, the connection of security systems to wearables and smartphones, digitalized logistics management, push notifications that improve security, and sensor-based dust bins that alert local authorities to the need for a clean-up are some of the key applications. Furthermore, IoT can support the development of intelligent neighborhoods, communities, and homes. Such thorough connectivity is not only beneficial for the realtors but also provides customers with more complete information, which can help consumers avoid information-related regrets. It keeps users more immersed and connected to the environment, fostering a sense of home and ownership that, in turn, encourages stakeholders to have a positive outlook and lessens regrets.

Since IoT is a fundamental technology for the metaverse, it can play a crucial role in integrating real estate into virtual environments. IoT can connect physical and virtual properties through interconnected sensors and devices that function as input and output sources, capturing changes in the physical world and reflecting them in the metaverse in real time. This immediate feedback loop can enhance user engagement and interactivity, creating more immersive and responsive experiences in the metaverse. Furthermore, IoT devices can greatly enhance user interactivity in the metaverse by creating smart environments that respond to user actions. For instance, smart home devices like lighting, thermostats, and security systems can be connected to their digital twins in the metaverse. When a user adjusts the lighting or temperature in their physical home, the changes are mirrored instantly in the virtual environment, providing an integrated experience. In a virtual office setup, IoT-enabled smart furniture can adjust in real-time based on user preferences, like changing the desk height or lighting based on personal settings, allowing users to experience their personalized space in both the real and virtual worlds seamlessly. Additionally, wearable devices such as smartwatches can track a user's health data and provide feedback within the metaverse, enhancing personalized interactions and virtual well-being.

In addition, IoT can play a pivotal role in creating and maintaining digital twins of real-world assets in the metaverse. For example, IoT sensors embedded in a smart building can continuously stream data on energy consumption, air quality, occupancy, and equipment status to its digital twin. This allows property managers to monitor and control the building virtually, simulating real-world conditions without physical intervention. A practical application could involve a smart office building where digital twins can simulate various scenarios, such as adjusting HVAC systems based on real-time occupancy detected by IoT sensors. If sensors indicate high CO_2 levels in a conference room, the metaverse's digital twin can automatically suggest opening windows or boosting ventilation systems in the real world, enhancing air quality and comfort for occupants. This real-time mirroring helps optimize building performance, predict maintenance needs, and reduce operational costs.

Moreover, robotics and IoT integration within the metaverse can transform property management and construction processes. IoT sensors in the real world can guide autonomous robots in the metaverse to perform virtual inspections, maintenance, or cleaning tasks, simulating their real-world counterparts. In particular, construction drones equipped with IoT sensors can scan a building site and relay real-time data to robotic systems within the metaverse. This data is used to update the digital twin of the construction site, allowing virtual robots to simulate tasks like bricklaying, welding, or structural inspections. These simulations can help construction managers detect issues before they occur in the real world, improving project efficiency and safety. Another example includes robotic lawnmowers or cleaning robots whose actions in the metaverse are informed by real-world data gathered from IoT sensors, ensuring the virtual models reflect ongoing maintenance activities in real-time.

Clouds

Data preservation over the internet, resolving local storage issues, ensuring data security, and enabling remote access are all made possible by cloud computing. Without clouds, archiving and storing data for priceless assets would be very expensive. Cloud computing has many advantages that relate to expensive items, longer time periods, and various industry actors, in addition to drawing potential investors. Furthermore, cloud computing makes it possible for owners, buyers, and sellers to collaborate on important tasks like sharing financial information about the upkeep and improvements of the properties as well as information about maintenance and renovations. In fact, cloud computing is much more popular among the younger generation, and they are working towards reinforcing more usage of it in the industry.

In the metaverse, cloud computing will play a crucial role in ensuring that the virtual environment remains up-to-date with its physical counterpart. For example, a smart building equipped with IoT sensors can continuously stream data to the cloud, where it is processed and used to update the building's digital twin in the metaverse. Cloud computing will ensure that any changes in the building, such as occupancy levels, energy usage, or maintenance needs, are immediately reflected in the virtual model, providing users with a real-time view of the property. This real-time synchronization will allow property managers and owners to monitor the status of their assets from anywhere, enhancing decision-making and operational efficiency. Furthermore, cloud computing can support AI algorithms that analyze vast amounts of data generated by IoT sensors in properties to provide predictive insights. For example, cloud-based AI can process data from smart buildings to identify patterns in energy usage or detect early signs of equipment failure. In the metaverse, these insights can be visualized directly within digital twins, allowing property managers to anticipate maintenance needs, optimize energy efficiency, and make data-driven decisions that improve asset management.

Additionally, metaverse platforms will require enormous amounts of data processing and storage capabilities to host virtual worlds and user-generated content. Cloud computing can provide the scalable infrastructure needed to support millions of users interacting in virtual spaces simultaneously. For example, a metaverse platform hosting a virtual city with thousands of digital twins of real-world buildings can leverage cloud computing to store and render these models dynamically based on user location and interactions. Edge computing can be used alongside cloud services to manage latency-sensitive tasks, such as real-time avatar movements and instant interactions, ensuring a smooth and responsive user experience. Moreover, cloud computing enables secure, collaborative environments where stakeholders, including real estate developers, architects, and buyers, can access and work on shared data in real time. For example, during a property renovation project, all parties can access design plans, financial records, and project timelines stored in the cloud, making updates and decisions collaboratively. This centralized data management not only speeds up the process but also ensures data integrity and security, as cloud services often provide advanced encryption and access controls. Additionally, virtual workspaces can be facilitated with cloud computing where real estate professionals can conduct meetings, collaborate on designs, and perform administrative tasks entirely within the metaverse. For instance, an architect can use cloud-based software to design a virtual building while sharing real-time updates with clients and engineers across the globe. Cloud storage allows for easy access to design files, project updates, and feedback, streamlining the entire workflow. Edge computing can optimize the performance of these virtual tools, reducing load times and ensuring that real-time changes are reflected instantly. Furthermore, cloud computing can support virtual showrooms and property tours by hosting high-resolution 3D models and interactive environments that users can access from any device. For instance, a real estate company can store detailed digital twins of their properties on the cloud, allowing prospective buyers to explore homes virtually through VR headsets or web platforms without geographical constraints. Edge computing can complement this by handling the immediate rendering of images and interactions, providing a seamless and lag-free user experience, especially in high-demand scenarios like property exhibitions or live virtual tours.

Big Data

Data is one of the most important resources in the modern era. Data is required everywhere, and for more accurate performance, it is needed in massive amounts, whether it be for AI or machine learning. Real estate, like any other giant industry, contains a vast array of data that is crucial for more pertinent and easily accessible decision-making to increase productivity. Although it takes a lot of time and effort for humans to analyze such a large volume, there are a number of reliable data mining techniques that can speed up the process. Big data will allow the sector to integrate financial, marketing, sales, e-commerce, and consumer survey data in order to get a comprehensive picture of business performance and meet overall organizational objectives.

Data is a valuable asset, as we already mentioned, and it is even more crucial for the metaverse because the metaverse is built on technologies that are completely data-centric—the metaverse's entire operation would depend on the data that it will gather from both the virtual and physical worlds, analyze, and output in accordance with [62]. In the metaverse, Big data will power AI algorithms that provide personalized property recommendations to users based on their preferences, behaviors, and historical data. For example, AI can analyze millions of data points related to user interactions, search history, and demographic information to suggest properties that closely match a user's needs, such as price range, location, and design style. This data-driven approach not only improves user satisfaction by offering tailored options but also increases conversion rates for realtors as clients are more likely to find their ideal property quickly. For instance, if a client consistently searches for properties with waterfront views, AI can prioritize and display these listings prominently, enhancing the client's experience in the virtual marketplace. Moreover, big data will allow AI models in the metaverse to perform predictive analytics, helping stakeholders forecast market trends, property valuations, and investment opportunities. For example, AI can analyze vast datasets that include historical property prices, economic indicators, and user engagement data to predict future real estate market movements within the metaverse. Realtors can use these insights to adjust their pricing strategies, identify high-demand virtual locations, and make data-driven decisions on where to invest in virtual properties. This predictive capability can enhance financial planning and reduces the risk of investment in virtual real estate. Additionally, virtual staging and design decisions in the metaverse can be enhanced by big data analytics through leveraging insights from user feedback and interaction data. For instance, AI can assess which virtual staging styles receive the most engagement during virtual property tours, allowing realtors to refine their approaches to match market demand. If data shows that properties staged with modern minimalist designs have higher viewing and engagement rates, realtors can adjust their staging strategies accordingly. Additionally, Big Data can provide feedback on specific design elements, such as color schemes or furniture arrangements, helping designers make data-backed decisions that resonate with potential buyers.

Digital twins in the metaverse are highly dynamic and require continuous data feeds to mirror their real-world counterparts accurately. Big Data plays a crucial role in updating these digital models with real-time information from IoT sensors, maintenance logs, and user interactions. For instance, a digital twin of a smart building can use Big Data analytics to monitor energy consumption, detect anomalies, and suggest adjustments for optimal performance. If sensors detect increased occupancy in a particular area of the building, the digital twin can simulate adjustments to HVAC systems in real-time to enhance comfort and energy efficiency. This data-driven approach allows property managers to predict maintenance needs, optimize resource usage, and improve tenant satisfaction, ultimately enhancing the property's value.

Furthermore, big data can enable the simulation of consumer behavior within digital twins, providing valuable insights into how users interact with virtual properties. For example, data on how users navigate a virtual shopping mall can help property owners optimize store layouts, identify high-traffic areas, and improve overall user experience. By analyzing data from user interactions, such as time spent in specific areas, AI can suggest design changes that enhance engagement, like adjusting virtual storefronts or modifying pathways to encourage more foot traffic. These simulations help real estate developers create more appealing and functional virtual environments, ultimately driving higher occupancy rates and sales.

VR and AR

The technologies that are currently used most frequently in the real estate sector are VR and AR. Even though it may seem expensive to adopt AR and VR (high end computers, VR headsets), in the long run, the cost is optimized by effectively saving time and resources for all industry stakeholders. Realtors have opportunities to reinvent the market by using AR and VR to advertise their products to target audiences for better reach. Virtual tours of a property, for instance, give customers a better idea of what they are getting, which ultimately affects the customer experience and review of the agency. Additionally, the ability of the customers to visualize what they are buying eliminates any misunderstandings and post-purchase regrets [69]. Additionally, when using AR and VR for real estate businesses, realtors can view more valuable data about their clients. For example, data analytics can determine where customers look first and what grabs their attention when they take tours of virtual homes. As a result, businesses can enhance their presentations and provide more high-quality goods. Utilizing data analytics also assists in removing accommodations and presentation formats. As a result, it raises client satisfaction, sales, and the profit margin.

AR and VR can be useful to test different design models for various technologies in the metaverse. Especially in the virtual environment, it will be a lot easier to test technologies that are still in the production stage; for example—testing robots that are designed to sustain extreme environments and finding out the design flaws will be much more convenient in the virtual realm of the metaverse. Similarly, the designs and constructions of a project made in the virtual environment can be transmitted into the real environment, and with the help of AR technology, the consumers can have an immersive experience with the project. Additionally, AR will enable users to interact with UGCs in the physical world. Furthermore, AR and VR can facilitate a low risk training environment where the consequences of an error can be less harmful. Similarly, the instructor can give guidance remotely, and the trainee can be adequately taught without compromising the standard of the knowledge.

Furthermore, AR and VR can be utilized to revolutionize real estate and construction by enhancing traditional practices and driving innovation. In modular construction, AR and VR can enable real-time visualization of how off-site manufactured units fit together, improving precision and efficiency. VR tools can be used to empower DIY and on-the-fly remodeling by allowing homeowners and professionals to design, modify, and visualize changes in real time, reducing errors and costs. AR-guided construction can be useful in several ways, such as-overlaying plans onto job sites, guiding workers with precision, while AR maintenance tools visualize hidden infrastructure, simplifying repairs, etc. Integration with smart technologies and IoT enhances real-time interaction with building systems, and interactive blueprinting tools would allow architects to explore designs in 3D, improving communication and decision-making. These technologies can merge the physical and virtual environments, reshaping how the industry operates, and enhancing efficiency, accuracy, and user engagement in real estate development.

3D Scanning

3D scanning is a technology for data collection that transforms real-world objects into exact digital models so that users can precisely record their shapes and geometries. In the real estate industry, it can be used in the planning and construction phases for revising drawings, maintenance, and renovations. With this approach, clients receive more trustworthy and dependable property information that is advantageous to all parties involved. The technology can be beneficial for the property managers to understand the client's requirements and design a collaborative model with the clients for the construction plan. Clients with minimal technical expertise can work alongside professional designers for any additions, changes, or renovations. Any misinterpretation will be avoided in this way, and the satisfaction rate will rise, leading to more sales.

Additionally, 3D scanning can capture not just buildings but also the surrounding environment, including landscapes, vegetation, and nearby infrastructure. This data can be integrated into the metaverse, providing a realistic context for virtual properties. For example, a real estate developer planning a new residential community can use 3D scanning to digitize the existing topography, trees, and water features, creating a digital twin of the entire site. This detailed virtual model allows potential buyers to visualize how their future homes will sit within the actual landscape, including views, sunlight exposure, and proximity to natural features, enhancing the buying experience and helping clients make informed decisions. Moreover, 3D scanning can provide rich, detailed data that enhances computer vision algorithms used in the metaverse. For example, when scanning a property, 3D scanners can capture precise measurements, textures, and spatial relationships, which can be used to train computer vision models to recognize structural features, materials, and design elements accurately. This data can help AI systems in the metaverse analyze how properties are constructed, detect potential flaws, and suggest improvements or repairs. For instance, a scanned model of a building can be analyzed by AI to identify cracks in walls or structural weaknesses, which can then be visualized and addressed virtually before real-world intervention, improving safety and efficiency.

In creating highly accurate digital twins of physical properties, 3D scanning can play a pivotal role in the metaverse. For example, a commercial real estate developer can use 3D scanning to capture every detail of an existing office building, including the exact dimensions of rooms, hallways, and structural elements, to create a digital twin that mirrors the real-world structure with incredible accuracy. This digital twin can then be used for virtual walk-throughs, maintenance simulations, and real-time monitoring, allowing property managers to test different layouts, plan renovations, or optimize space utilization without disrupting the physical building. A scanned model of a historic building can be preserved as a digital twin in the metaverse, providing architects with a reliable basis for restoration projects or virtual tourism. Furthermore, UGCs created in the metaverse can be accurately transferred back into the physical world using 3D scanning technology. For instance, a virtual sculpture designed by an artist in the metaverse can be 3D scanned and then recreated as a physical object using 3D printing, ensuring that every curve and detail of the virtual model is preserved. In the context of real estate, this capability allows architects and designers to bring digital models of property layouts, interior designs, or customized furniture from the virtual space to the physical world. For example, a client might design a custom kitchen layout in the metaverse, and 3D scanning can ensure that the virtual design is precisely replicated during the actual renovation, minimizing errors and ensuring the end result matches the client's vision. 3D scanning can also enable for a seamless feedback loop between the physical and virtual worlds, facilitating collaboration among designers, property managers, and clients. For example, during a renovation project, property managers can scan the current state of a building in 3D, upload the model to the metaverse, and allow designers and clients to make virtual modifications. As changes are made, the updated design can be continuously scanned and compared with the original to ensure alignment with the client's vision. This iterative process reduces the risk of costly mistakes, improves communication, and fosters a collaborative approach to real estate development and remodeling.

Wearable Technologies

IoT devices that can be worn by the user are referred to as wearable devices. Glasses or smart eyewear, rings, fitness jackets, bracelets, hats, cuffs, and walkie-talkies are some examples of these devices. Similar to other IoT devices, these devices enable users to stay connected to their property all the time and as result, they can get updated about maintenance or any hazards related to the property in real-time. This makes it easier for customers to make daily decisions about their property and feel confident about its condition. These gadgets enable users to stay constantly connected to their homes, enabling the recording and storage of useful information for potential buyers. Additionally, the gadgets can monitor equipment and maintenance, and prospective buyers can get see the publicly available data and get alerts for building components. As-built drawings can be extracted from building management systems, and fault detection is another advantage of gadget integration. These provide customers with more information, allowing them to make better decisions.

Wearable devices also have the potential to function as a metaverse input and output method, bridging the gap between the physical and virtual worlds. Technologies like smart glasses are integral to creating immersive XR experiences in the metaverse. For instance, AR smart glasses can overlay digital information onto the real world, allowing users to view virtual property information, such as floor plans or maintenance needs, while physically present on-site. In the metaverse, these glasses can display virtual walkthroughs of properties, enabling users to interact with digital twins and visualize potential renovations or changes. A real estate agent can use smart glasses to show prospective buyers how a room would look with different furnishings or wall colors, enhancing the buying experience by blending physical and virtual elements seamlessly.

Additionally, wearable devices integrated with IoT sensors can continuously monitor environmental conditions within a property and provide feedback to the metaverse. For instance, a smart ring equipped with sensors can track air quality, temperature, and humidity levels, sending this data to the virtual counterpart of the property in the metaverse. If the air quality inside a building drops below optimal levels, the metaverse engine can simulate the impact on the virtual model, and the wearable device can alert the property owner to take corrective actions, such as adjusting ventilation. This real-time synchronization enhances property management by providing actionable insights that bridge the physical and virtual environments. Moreover, wearable technologies can also be used to control robotics in the metaverse, providing intuitive and responsive input methods. For example, a construction manager can use wearable haptic gloves to remotely control a robot performing maintenance tasks in a virtual model of a building. The gloves provide tactile feedback, allowing the manager to feel the robot's actions in real time, such as turning a valve or manipulating tools. This sensory feedback helps ensure precise control and allows the user to make adjustments as if they were physically handling the task themselves. In property management, wearables can track a robot's real-time progress in cleaning, security checks, or repairs, offering a seamless connection between human operators and robotic systems.

Wearable devices can also enhance safety and security in the metaverse by providing real-time alerts about potential threats in both physical and virtual spaces. For example, a smart wearable could notify a property owner of a security breach detected by sensors in their virtual property, allowing them to take immediate action, such as remotely locking virtual doors or contacting security services. In a construction scenario, wearable helmets equipped with sensors can detect hazardous conditions, such as high levels of dust or noise, and send alerts to workers both in the physical site and their digital twins in the metaverse, ensuring that safety protocols are followed. Furthermore, devices, such as smartwatches and fitness trackers can be used to monitor the health and well-being of users while they work in virtual environments. For instance, a smartwatch can track a user's heart rate, movement, and stress levels while participating in a virtual meeting or property tour in the metaverse. If the device detects elevated stress or prolonged inactivity, it can suggest a break or provide guided breathing exercises through a virtual avatar. This integration ensures that virtual workspaces are not just functional but also conducive to maintaining users' physical and mental health.

AI and Robotics

AI and robotics are two popular technologies that are currently being adopted by various industries. In real estate, AI can be used by designers to render 3D versions of a property from different angles. Furthermore, it can be used by property managers for screening potential customers, reevaluating and improvising their marketing strategies, and reaching potential clients through digital marketing. With the help of an AI-based search system, consumers can filter properties according to their requirements and find what they are looking for very easily from numerous listings. Robotics combined with AI can be a great help on construction sites. It can monitor the sites for any potential hazards before, during, and after construction. Tasks that are risky for humans on the sites can be done precisely with the help of these robots. Robots can keep track of the maintenance of a property, and popular uses include waste management, cleaning hard-to-reach places, and recycling.

AI is already a core technology for the metaverse engine, and robotics can be a potential technology for the metaverse. AI algorithms can analyze real-time data from IoT sensors embedded in properties to predict maintenance needs in digital twins. For example, AI can continuously monitor the health of building systems, such as HVAC, electrical, and plumbing, within a digital twin model in the metaverse. If AI detects anomalies, like increased energy consumption or unusual equipment vibrations, it can alert property managers in advance, allowing them to schedule maintenance before issues become critical. This proactive approach minimizes downtime and reduces repair costs, making property management more efficient. The same AI can simulate various maintenance scenarios within the digital twin, testing different solutions to optimize outcomes before implementing them in the physical property. Furthermore, in the metaverse, digital twins of construction sites can be used to simulate robotic workflows, allowing developers to test and refine automated construction processes. For instance, a construction company can use robotic simulations to plan the precise movements of autonomous bricklaying robots, ensuring that each step is optimized for speed and accuracy. These simulations help identify potential bottlenecks or inefficiencies before deployment on real construction sites. This virtual testing ground enables construction managers to adjust robot programming, improve coordination between multiple robots, and predict how they will perform in complex, real-world scenarios. By perfecting these processes in the metaverse, companies can reduce errors, save costs, and speed up project timelines when applying robotics in the physical world. On top of that, the metaverse offers a platform to test collaborative robotics in construction projects, where multiple robots work together to complete tasks. For example, a team of robots can be programmed in the metaverse to assemble a virtual structure, with each robot assigned specific roles, such as material handling, welding, or quality inspection. AI algorithms can monitor the robots' performance, adjust their tasks in real-time, and coordinate their movements to avoid collisions or delays. By using the metaverse as a testing and training ground, construction companies can develop highly coordinated robotic teams that work efficiently together, reducing the need for human intervention and increasing construction speed and safety.

Additionally, AI-powered virtual assistants and NPCs can act as property managers, guides, or customer service agents, interacting with users and providing valuable information in the metaverse. For example, a virtual real estate agent NPC can guide potential buyers through a property tour in the metaverse, answering questions, highlighting key features, and suggesting other similar listings based on the user's preferences. These AI-driven NPCs can offer a personalized and interactive experience, making the virtual property viewing process as engaging and informative as possible. Additionally, AI can be used to simulate different scenarios, such as fire drills or emergency evacuations, within digital twin environments, training NPCs to respond appropriately to various situations. Moreover, robotics integrated with AI can be used in the metaverse to simulate smart property management tasks, such as automated cleaning, security, and logistics. For example, a robot vacuum cleaner modeled within a digital twin can be programmed and tested in the metaverse before being deployed in real properties. AI can optimize the robot's cleaning paths based on real-world data, ensuring maximum efficiency and minimal resource usage. Similarly, security robots can be tested in virtual replicas of office buildings, learning to navigate complex layouts, monitor for unauthorized access, and report suspicious activities. These simulations allow developers to fine-tune robotic behaviors and adapt AI algorithms to specific environments, enhancing performance and reliability in the physical world.

SaaS

Software as a service, also known as SaaS, is a term that refers to any service that is accessible to users remotely over the internet. Instead of existing on a single device, the primary purpose of SaaS is to ensure remote access to the software's functionalities through web-based network services. These services are designed for both clients and real estate agents in the field of real estate. Benefits include the integration of massive multifamily organizations across portfolios through the networking of various software, which is beneficial for clients and property managers. SaaS is currently used in real estate development, planning, management, marketing, and retail.

The metaverse itself can undoubtedly act as the ultimate SaaS for a variety of sectors, including the real estate market. SaaS platforms that leverage AI can provide highly personalized services within the metaverse, such as tailored property recommendations and dynamic pricing models. For instance, an AI-driven SaaS platform can analyze user data, preferences, and market trends to recommend properties that best fit a client's criteria, much like a virtual real estate agent. AI algorithms can also simulate various market scenarios to help agents and investors make data-driven decisions on pricing, marketing strategies, and investment opportunities. A practical example includes using AI-powered SaaS tools to offer virtual staging options that adapt to a buyer's tastes in real-time, enhancing the appeal of properties and speeding up the sales process. Furthermore, data-intensive operations of the metaverse can be supported with SaaS utilizing edge and cloud computing. For instance, a

SaaS-based digital twin management platform can use cloud computing to store vast amounts of data from IoT sensors embedded in physical properties, such as energy usage, maintenance logs, and occupancy data. Edge computing can then process this data locally to deliver real-time insights and updates to digital twins in the metaverse, minimizing latency and ensuring that virtual models accurately reflect current conditions. This setup allows property managers to monitor and optimize building performance remotely, making quick adjustments to lighting, HVAC, or security systems as needed. Moreover, SaaS platforms equipped with advanced data analytics can enable real estate professionals in the metaverse to make better-informed decisions. For example, a cloud-based SaaS platforms can aggregate data from multiple sources, including market trends, user behavior, and property performance, to provide comprehensive insights into the real estate market. These insights can be used to identify high-demand virtual locations, optimize marketing campaigns, and forecast future property values. Data analytics SaaS platforms can also help property managers track the effectiveness of maintenance strategies, ensuring that resources are allocated efficiently to maximize ROI.

In addition, networking-enabled SaaS solutions can enable seamless communication and collaboration in the metaverse, bringing together agents, clients, and service providers in a unified virtual environment. For example, a SaaS application that combines video conferencing, document sharing, and project management tools allows stakeholders to work together on property designs, renovations, or marketing campaigns without leaving the metaverse. Networking SaaS platforms also support virtual co-working spaces where agents can host virtual open houses, schedule client meetings, and provide live property tours, all within an immersive, interactive environment. This reduces the need for physical meetings and enhances the overall efficiency of the real estate process. Besides, SaaS integrated with blockchain can provide secure, transparent, and decentralized transaction services [53] within the metaverse. For example, a real estate SaaS application can use blockchain to manage digital ownership records, ensuring that property transactions are recorded securely and verifiably in a distributed ledger. This reduces the risk of fraud and ensures that buyers and sellers have access to tamper-proof records of all property transactions. Smart contracts can automate the process of buying, selling, or leasing properties in the metaverse, automatically transferring digital ownership upon completion of predefined conditions. A blockchain-enabled SaaS platform could also allow for fractional ownership of virtual properties, making real estate investment more accessible to a wider audience.

6 The Cross-Impact of Real Estate and the Metaverse

The metaverse will open new horizons for its users to interact, socialize, and collaborate with each other. The requirement for such a virtual space came to the forefront during the global pandemic. There have been several instances of concerts and gatherings in virtual spaces during the COVID-19 pandemic, which the users could attend from the safety of their homes without being concerned about their physical well-being. Similarly, the metaverse aims to bridge the physical distance between its users and give them a shared space for creativity. And with the rising popularity of the metaverse, industries are turning towards it to claim their presence in the metaverse and reach the users. As one of the world's largest industries, real estate's demand is not going to disappear any time soon. However, it still needs to adopt numerous technologies in various subsectors to enter the metaverse and keep up with other massive industries. Similar to other industries, the adoption of new technologies in real estate will have a variety of effects, both positive and negative. It is also crucial to consider how real estate itself integrates into the metaverse and how virtual properties are valued in this new digital economy. In light of this, in this section, we will discuss the impact of the metaverse on real estate from various perspectives.

6.1 Economical

Real estate is a business field, and like any other industry, all of its functions are centered around bringing in a profit. The main goal behind entering the metaverse is to enhance the industry from a technological standpoint so that the return on investment (ROI) gets higher. But we have to keep in mind that for utilizing a high-tech tool like the metaverse, the industry needs to integrate all the technologies that are working behind the metaverse. We have already discussed the IoT, wearable devices, drones, and robotics, and these are highly sophisticated devices that are not low-priced. Furthermore, a large quantity of these devices is needed to fully integrate all the projects. On top of that, cloud-edge-end computing and storage need micro, and nanotechnology along with physical data warehouses, which are costlier compared to current storage and computation technologies. As a result, the initial investment in integrating these technologies is going to be very high. However, once they are accommodated, they need occasional maintenance and updates, which require a lesser cost.

Even though making the metaverse accessible for all the subsectors of real estate may seem like a very costly venture for the industry, it is going to be cost-effective in the long run [18]. It will significantly reduce commute time and cost for all the stakeholder parties, as there will be options for virtual tours without sacrificing the quality of the experience for the consumers [8]. As the metaverse will offer a shared space for all the users, meetings, events, and collaborative works can take place without issue [42]. In fact, the concept of a virtual office and remote work has gained more popularity during and after the COVID-19 pandemic period. This type of setting has enabled employees to have flexible hours from the comfort of their homes, has ensured their physical well-being in an environment where gatherings are inconvenient, and has reduced the cost of renting office spaces.

As a large portion of maintenance, upkeep, and even construction work can be handled by robots, humans will be excused from these mundane or sometimes dangerous tasks and instead will be assigned to operate these devices. Even though this will ensure a safer work environment, these tasks will demand higher levels of mechanical and technological knowledge. So there remains a possibility of unemployment issues in the labor-heavy sectors but a shortage of competent employees in the maintenance and operations sector.

Additionally, UGCs are important assets in the metaverse. Users can individually and collaboratively design and build these UGCs that can be sold, bought, and traded. 3D architectural designs, digital models of properties, and interactive interior and exterior designs are some of the instances of UGCs. With the aid of blockchain, virtual ownership, and transaction histories will be recorded and kept secure [20, 60]. It will also assist in decentralizing the economy so that all the users of the metaverse can have equal opportunities in the economy, rather than all the valuables and assets going to a select few.

Integrating real estate into the metaverse creates new economic opportunities by establishing digital property markets where virtual land, buildings, and event spaces can be bought, sold, developed, or leased. Virtual property values are influenced by location, user engagement, and monetization potential, similar to traditional real estate. High-traffic areas near popular virtual landmarks command premium prices, driving demand for strategically located plots in platforms like Decentraland and The Sandbox [20]. This democratizes access to property investment by enabling new business models such as digital storefronts, virtual events, and advertising spaces. Tokenization and fractional ownership through blockchain technology further enhance accessibility, allowing investors to own shares of high-value virtual assets, promoting liquidity and broader participation in the digital property market.

However, integrating real estate into the metaverse also presents challenges. Regulatory uncertainties around virtual property rights, taxation, and transaction standards can lead to market volatility and speculative bubbles. Additionally, the shift towards virtual spaces could impact traditional real estate markets, especially in sectors like commercial office space and retail, as businesses explore cost-effective digital alternatives. Addressing these challenges requires clear regulatory frameworks and efforts to ensure inclusivity, preventing digital inequalities from mirroring those in the physical world. By leveraging partnerships, data analytics, and AI-driven insights, real estate stakeholders can navigate the evolving landscape, balancing innovation with economic stability in the metaverse.

6.2 Environmental

Integrating real estate into the metaverse offers significant potential for reducing the environmental impact of real-world development projects [45]. One of the most promising approaches is the use of digital twin, where virtual replicas of buildings are created within the metaverse. These digital models can simulate a building's energy consumption, test its performance under extreme environmental conditions, and optimize design choices before actual construction begins. This not only minimizes waste and resource consumption during construction but also allows for more efficient, sustainable designs that reduce the long-term energy footprint of the real-world structure. According to a study by international professional services firm Ernst and Young [77], building a digital twin in the metaverse and implementing ML and AI will allow for up to a 50% reduction in energy consumption and costs over the course of the building's life cycle.

Moreover, the metaverse can serve as a platform for collaborative design and testing, reducing the need for physical prototypes and lowering the environmental costs associated with miscommunication and reconstruction. Stakeholders such as architects, engineers, and consumers can interact in a shared virtual environment to refine building plans, ensuring that sustainable practices are followed from the outset. Testing virtual projects under various environmental scenarios helps ensure that buildings are more resilient to natural disasters, reducing the likelihood of rebuilding and conserving resources. For instance, agencies can design and build an establishment in the metaverse to test its sustainability in extreme conditions. Designing it in a shared virtual environment gives the consumers a chance to share ideas with the designers and collaborate with them. In this way, there would be very few chances of miscommunication and rebuilding of the project right after its initial construction in the real world. As a result, actual resources from the real environment would be saved. Furthermore, testing the establishment in dire environmental circumstances will ensure the sustainability of the project and reduce the requirements for rebuilding after sudden natural calamities in the real world.

Additionally, IoT devices and AI-powered systems integrated into real estate in the metaverse can monitor energy consumption and detect inefficiencies in existing buildings. By analyzing big data in real-time, these technologies can suggest maintenance solutions that optimize energy use and reduce the environmental impact of older, less efficient structures. AI can also assist in site selection for new developments, identifying plots that minimize disruption to ecosystems and preserving the natural environment. These advancements would enable the metaverse to play a key role in fostering a more sustainable future for the built environment in the real estate sector [34, 39].

However, environmental concerns around any new technologies are rising currently due to recent climate change and the global warming phenomenon. Research facilities and manufacturing companies are working towards green computing by recycling their technotrash[3] and reducing carbon footprint. It is evident from our discussion till now that, the metaverse needs a massive amount of interconnected devices and storage technology. The carbon emissions during the production phase of these devices are concerning. On top of that, these devices need a good amount of resources from the environment to be up and running, and most of them are not biodegradable. So the manufacturing industry needs to come up with a better process for producing and powering these devices so that they can be more environmentally friendly.

[3] Any broken or unwanted electrical or electronic gadget, also referred as electronic waste or e-waste [1].

6.3 Laws and Social

Even if we are living in the age of technology, all over the globe, digital laws have many murky and gray areas. Real estate is a good example of the situation because there are many laws governing the industry in the real world and all the stakeholders are required to follow them. The virtual world, however, has almost no laws regarding this sector yet. Neither the relators are protected from having their virtual properties unlawfully seized by another organization, nor are the consumers able to find justice after a fraudulent transaction. The absence of law and order can turn a virtual society into chaos in no time.

Therefore, adopting appropriate digital law is a major concern that needs to be addressed before elevating not only real estate but any industry into the metaverse. In addition, blockchain technology can provide decentralized ownership records, verified through smart contracts, while also reducing fraud risks and ensuring transparency. Legal frameworks for dispute resolution and consumer protection are crucial to safeguard stakeholders from fraudulent practices and unauthorized property seizures, creating a reliable virtual real estate market.

Moreover, one of the major visions behind the metaverse is to create an immersive environment for its users where they can interact, socialize, and collaborate with each other [18]. From a social standpoint, the growth of more immersive virtual experiences is assisting individuals in creating communities based on shared values and in finding more genuine means of expression. Similarly, in collaborative real estate projects, stakeholders will be able to share their ideas, socialize, and interact with each other, establishing virtual societies in the metaverse. Based on their similarities in property spaces and design choices, they can build their own virtual neighborhoods, towns, and cities. Virtual communities will be even more enriched with the addition of NPCs, and users can interact with them through their avatars.

However, it is again a matter of concern from a social viewpoint that accommodating high-end devices and establishing the metaverse is costly. As a result, the metaverse and all its opportunities might be out of reach for the social class that is less fortunate. So, to ensure the possibilities of the metaverse for all users, regardless of their financial condition, the technologies and devices behind it are required to be affordable. Ensuring that affordable devices and infrastructure are available is key to preventing the exclusion of individuals from lower socioeconomic backgrounds. Financial equality should also be promoted through decentralized finance (DeFi) mechanisms, ensuring that virtual property ownership is not limited to the wealthy. For example, blockchain can be implemented here as well, to ensure the decentralization of finances and establish a financially equal society. Moreover, the metaverse should be a space where users can express themselves and have equal rights, and financial equality is one of the major ones among them. The metaverse should foster diverse and interactive communities where people of all backgrounds can participate equally, building virtual neighborhoods that reflect real-world diversity.

Furthermore, everyone in the community should be welcome in the metaverse, including children, the elderly, people with disabilities, and others, regardless of race, gender, age, or religion. For establishing inclusivity, there is the question of social acceptance [12]. The metaverse uses sophisticated devices and mechanisms that may be difficult to understand and use for the older generation, unlike the digital natives, who are more enthusiastic about newer technologies. To achieve inclusivity, the metaverse must bridge generational gaps by providing user-friendly interfaces and education for older generations and people with disabilities.

6.4 Individual

Individual consumers are a large part of the targeted demographic of real estate business. With the help of AI-based recommendation systems, consumers can find what they are looking for easily. On top of that, they can customize their searches with filters to find properties according to their needs from numerous listings. They do not have to manually search for properties or agencies anymore. With the help of virtual tours and optimized visualization in the metaverse, consumers can have a better understanding of the property which helps them to make quick decisions.

Furthermore, consumers will get a chance to design their properties with professionals, which will give them a sense that they themselves have designed the project and increase satisfaction. They do not have to continuously look for maintenance and renovation requirements in their property, as they can be notified of those on time. Living in an environment surrounded by interconnected devices will give them a sense of security. In fact, it would be especially efficient for older adults and people with disabilities. Additionally, users can be a part of digital communities and neighborhoods with their telepresence and socialize with one another. This can be particularly helpful for users with social anxiety or individuals with disabilities that keep them indoors.

Consequently, the consolidation of real estate into the metaverse offers individuals a unique and immersive way to experience property ownership, design, and community engagement. For potential buyers, the metaverse allows them to explore virtual properties with realistic 3D tours, providing a comprehensive view of the space that goes beyond traditional photos or videos. AI-driven platforms in the metaverse can offer personalized property recommendations based on user preferences, lifestyle, and budget, streamlining the search process and reducing the time needed to find the perfect home. This integration empowers individuals to visualize potential renovations, test different design concepts, and even interact with virtual models of homes, enabling them to make more informed decisions about their investments.

Moreover, the metaverse creates a space where individuals can actively participate in the design and customization of their properties. Buyers can collaborate with architects and designers in real-time, making changes to layouts, materials, and finishes directly within the virtual environment, which enhances satisfaction and personal connection to the property. The metaverse also fosters digital communities where individuals can interact with neighbors, join social hubs, and participate in community events, creating a sense of belonging and reducing social isolation. This is especially beneficial for individuals with disabilities, older adults, and those who prefer the safety and convenience of remote interaction. However, while the metaverse offers significant benefits, it is essential to establish guidelines for responsible usage to prevent addiction and mitigate health issues associated with prolonged use of AR/VR devices. By balancing innovation with individual well-being, real estate in the metaverse can provide a more engaging, inclusive, and personalized experience for all users.

However, socializing and residing in the surreal metaverse can be addictive, and there are severe possibilities of the users being confronted with a distorted sense of reality. Users need to limit their time in the metaverse for their own well-being. Aside from that, using AR and VR devices such as head-mounted devices, AR glasses, VR helmets, etc. that are needed to access the virtual space for a long period of time can create health issues.

7 Summary

We begin with a brief history of the word "metaverse," with instances of virtual worlds in the past and present that helped to solidify the concept of the metaverse. As the metaverse is still an evolving concept, we tried to grasp the current idea and discussed three architectural designs of the metaverse from different researchers. This discussion led to several fundamental technologies that are essential for the metaverse to reach its full potential. After that, we briefly discussed the three major types of metaverse from a business point of view, and we see that real estate, one of the largest global industries, is a mix of all three categories. Even after having a large market share, we see that researchers have concerns about its technological lagging compared to other giant companies. Later, we briefly discuss the current technologies that are available in the industry and focus on disruptive technologies suggested by researchers that can elevate the industry's transition into SRE, and while doing so, we find out that the disruptive technologies can be fit into the fundamental technology categories of the metaverse. We go through a further discussion of how disruptive technologies can help in different sectors of real estate and help the industry access and operate in the metaverse simultaneously. As the metaverse is a combination of cutting-edge technologies, it is obvious that it will have impacts on the industry from various perspectives. Therefore, as the last segment of the chapter, we discuss the mutual impacts, both positive and negative, of the metaverse on the real estate industry from an economic, environmental, social, and individual point of view.

This chapter emphasizes the close ties between the technologies that could have a significant impact on the growth of the metaverse and real estate. Further investigation may establish the value of these technologies in integrating other massive industries with the metaverse. Additionally, we discussed both the positive and negative impacts of the metaverse on the real estate industry, where there is further scope for research that can optimize the positive impacts and reduce the negative ones.

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