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THE METAVERSE: A VIRTUAL WORLD IN THE PALM OF YOUR HAND

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1. INTRODUCTION

Throughout history, the imagination of virtual worlds had a direct impact on gaming and fiction literature innovation (Dionisio, Burns III, and Gilbert, 2013). This led to an unreal twist in the storytelling and gaming industry. The last decade has witnessed a broad revolution in the design of virtual worlds which presented fantastic realities. This led to the collaborative creation of virtual places combining exploration, education, and marketing in the same location known as the Metaverse (Jaynes, Seales, Calvert, Fei, and Griffioen, 2003).

In this paper, we analyze the latest technologies of the Metaverse, and we focus the probe on the architectural aspect of this virtual place. This platform allows individuals to corporate by coming together in one location to explore and discover. Consequently, it led to a new phase of promotion, marketing, and virtual shopping. The transition from traditional retailing to e-retailing is increasing at a fast pace (Bourlakis, Papagiannidis, and Li, 2009). This necessitated the rise of many VR technologies to deliver to the user an immersive experience. VR tools require special design, modeling, and visualization.

Today, the Metaverse design tools contain elements like CSG, voxel, and G-Rep that provide 3D-based design methods extended from the CAD domain. Instead of using a mouse and a keyboard to generate 3D models, architects can create 3D objects by touching and shaping using haptic and kinesthetic devices (Lee and Banerjee, 2010). All these trending tools originate from Computer-Aided Design (CAD) mechanical and architectural domains. The Extended Reality (XR) has augmented the modeling process with two phases of evaluation and feedback, in addition to the design and modification phases. This approach has bridged the architectural and mechanical designs to construction and manufacturing. So, a complete world available for simulation can be executed in a virtual environment (Lee and Banerjee, 2010).

Of course, this technology is developing the computer field to a new level of activities, including task planning, scheduling, and management. To future demonstrate how things are presented in the Metaverse, technology giants are racing to represent to best experience in a virtual world. This concept urges a lot of challenges like user interaction, commercial simulation, and automation (Lee and Banerjee, 2010).

The following is breakdown of the paper's structure. Section 2 discusses the technical challenges faced by the Metaverse at the level of the digital environment, in addition to the hardware and software challenges. An overview about the historical heritage and collective architecture is presented in Section 3. Section 4 contains some information about the Metaphysics behind the Metaverse world. Section 5 presents a comparison between different Metaverse Platforms. The future of the Metaverse World is discussed in Section 6. The article is concluded in Section 7.

2. TECHNICAL CHALLENGES

Due to the huge progress in networking, the emergence of parallel computing has developed the infrastructure for VR. Using advanced visual and auditory tools, devices can imitate reality by showing High Definition (HD) sequential imagery (Gaafar, 2021). The smooth performance to generate a scene allowed the user to interact inside the Metaverse by special haptic controls. Users can swiftly move, make actions, and draw or modify objects in this virtual 3D space, giving the impressing that this virtual world really exists (Gaafar, 2021). **Figure 1** depicts the main parts of the Metaverse. Sensors, recognition, and user experience are responsible for the interaction of the Metaverse. On the other hand, rendering, scenario generation, and technical methods serve as the operational components of this virtual world. Finally, applications are the different services provided in this artificial universe.

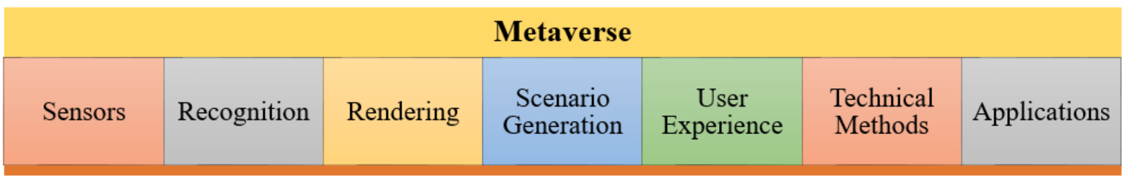

Fig.1: The main parts of Metaverse

The user interaction and applications are important in preserving the level of a stable experience using the Metaverse. The interpretation of multimodal Input/Output (I/O) operability depends on the high performance of the computing infrastructure. To preserve a high quality of service, the Metaverse requires a wide network bandwidth, fault correction, and cybersecurity (Park and Kim, 2022). Thus, the applications' performance relies directly on other components of the Metaverse. For sure, the variance between applications like marketing, education, and games impose different requirements depending on the level of interaction provided (Park and Kim, 2022). Conversely, the level of interactive reality presented to users is the aspect that makes the Metaverse more concrete accordingly. Consequently, this presents tremendous challenges at the levels of the digital environment, hardware, and software.

2.1 Digital Environment of the Metaverse

Today Digitization is a trend in many industries like business, entertainment, education, architecture, and others. These fields are reaching the maximum potential of service using the capabilities of the digital system (Gadekallu, Yenduri, and da Costa, 2022). But with high expectations of service comes a lot of difficulties. Thus, the demand for high-end interactive capabilities is exponentially increasing. In a matter of fact, users are demanding more immersive experiences from their digital interfaces. Such requirements imposed a digital race among the technology giants to research the emerging tools of VR, taking this experience to advanced levels of Mixed Reality (MR), XR, and even Augmented Reality (AR) (Xi, Chen, Gama, Riar, and Hamari, 2022).

This virtual world is pushing modern technologies to the limit. The challenges are to provide users with avatars to represent their virtual embodiments. This makes those avatars more like digital identities to execute transactions and other business activities using their legal rights (Gadekallu, Yenduri, and da Costa, 2022). Furthermore, access can be granted using VR devices, but headsets and glasses present minimal capabilities. Therefore, full-body haptic suites are being tested and improved to unleash the full potential of an immersive experience (Mystakidis, 2022). Consequently, this imposes more complicated data acquisition techniques.

Eventually, Metaverse data will help a lot of businesses to get better insights into the business model. The digital market will introduce novel marketing and sales methods. Subsequently, massive amounts of data involving collection and gathering will put user privacy and identity in question, especially since avatars may also include physical attributes. Therefore, more social security challenges will raise the suspicion about social cyber-attacks (Xi, Chen, Gama, Riar, and Hamari, 2022). Likely, digital identity impersonation will be a major problem in this open world.

On the other hand, a race between multiple platforms and corporations is clear on who will possess the Metaverse. The presence in the virtual world is imminent. However, the infrastructure of the Metaverse uses a decentralized computation technology (Gadekallu, Yenduri, and da Costa, 2022). Decentralized computing provides all the power available to serve this humongous amount of data and provides all the executive power to build a perfect virtual world. But this requires also decentralized storage that consumes real land space and energy that suppress other real-life sectors like healthcare, education, and others (Mozumder, Sheeraz, Athar, Aich, and Kim, 2022). In addition, a decentralized database is an essential part of the Metaverse structure. This requires a solid base to organize citizens' information, thus the Metaverse must guarantee data availability and protection (Mozumder, Sheeraz, Athar, Aich, and Kim, 2022).

2.2 Hardware Challenges

Hardware in Metaverse plays a crucial role in the immersive experience. However, hardware in Metaverse is still technically a limiting barrier, it still requires some improvements to reach up to the experience of the real world.

One of the most crucial pieces of hardware of Metaverse is a Head Mounted Display (HMD) that blocks the view of the actual surroundings to enable captivating participation in virtual reality. There are some critical factors for physical devices and sensors that define multimodal interactions including the field of view size, resolution, and latency. Latency is of particular importance and thus should be designed taking into consideration the threshold for side effects and time gaps.

2.2.1. Head Mounted Displays

An HMD is a basic input tool of Metaverse. The HMD displays an image and plays sound through the speaker. HMD has the ability to track orientation and position according to head movement. Kinds of HMD include non-see-through HMD, Optical-see-through HMD, and video-see-though HMD. The non-see-through HMD covers the entire screen thus providing a complete inclusion in the virtual world. Optical-see-through HMD is a way of superimposing the virtual world. Video-see-though HMD is used as supplementation to this method. The disadvantages of HMDs are that they are bulky, costly, and have short battery life. Moreover, they are less accurate than the method of the assessment of movement by external measurement, but they are still used since they can save space.

2.2.2. Hand-Based Input Devices

Haptic gloves are devices that can help you can feel and hold things, though they are still working on developing the ability to feel the texture of an object. Depending on the installation of the haptic gloves, they can be attached to the hand or attached to the outside. Sometimes this device is also used to induce the movement of the muscles.

2.2.3. Non-Hand-Based Input Devices

Non-hand-based input devices include head tracking, eye-tracking, voice input device, and others.

2.2.4. Motion Input Devices

Motion input devices are used to give precise motion information using body tracking and treadmills.

The Metaverse is a promising technology that is offering new levels of social connections and interactions in a virtual world. However, without the hardware technology, these promises will certainly remain as they are. Though we are currently interacting with the Metaverse through our phones and laptops, submerging into the Metaverse requires AR devices.

In the long run, the goal is a light-weighted, convenient, and comfortable device, switching between AR and VR while allowing natural interactions among Metaverse users. The required leap toward the desirable hardware needed to create this hypothetical device is certainly a complex and challenging one. The virtual world is can vary greatly regarding issues such as hardware and software implementations, and communication interfaces, all of which are considered interoperability difficulties.

Compared with the current Internet hardware, the Metaverse requires novel hardware and devices to collect different types of data such as facial expression, eye movement, and head movement, that were not collected previously, to create an engaging user experience. Moreover, hardware in the Metaverse should be able to capture fingerprints, iris biometrics, or other biometric information. Consequently, it poses new challenges in collecting, managing and storing the huge amount of user-sensitive Metaverse data, in addition to the cyber/physical security of Metaverse devices. Other issues of concern include who will be held responsible for collecting, handling, storing, securing, and destroying these data.

By overcoming difficulties such as storage, computational power, and energy, model compression can reduce the hardware requirements of the devices that access the Metaverse.

The Metaverse is right here waiting for the hardware development to unveil the ultimate Metaverse experience.

2.3 Software Challenges

In spite of the promising sign of the Metaverse, the Metaverse faces a number of challenges related to Computer Vision and VR, and AR. Both technologies are persuasive and influencing, but the high cost of equipment is a barrier to mass adoption that is expected to be mitigated in the long run.

2.3.1 Computer Vision and VR

The Metaverse is confronted with a number of obstacles related to computer vision and VR. The commonly reported health concerns include nausea, motion sickness, and dizziness (Mystakidis, 2022). Neck and head fatigue are also a limitation for longer use sessions due to the weight of the VR headsets. Also, VR use can lead to addiction, in addition to social isolation from real life and physical life.

2.3.2 AR

Certain challenges related to AR are currently being faced by the Metaverse. On the physical level, the attention distraction of users in location-based AR applications has resulted in harmful accidents (Mystakidis, 2022). Also, the unauthorized augmentation of biased views is considered to be a moral issue. In addition, a privacy risk occurs when it comes to data collection and sharing.

3. HISTORICAL HERITAGE AND COLLECTIVE ARCHITECTURE

Over the ages, historical heritage and architecture reflected the beauty, power, and cultural image of each society. Each civilization has left a landmark around the globe to forever refer to a certain era or triumph. Today, a digital world is born, therefore the next leap in architecture will be in building the Metaverse. Each trademark is participating in taking place in this virtual world from retail stores to nightclubs, hotels, and malls. Everyone is rushing to have a foot-place and extend their presence from the real world to the Metaverse (Gaafar, 2021). Therefore, researchers are putting all their efforts to bring both worlds closer together. Those attempts are encouraging to design of virtual architecture environments to make a close relationship between the Metaverse and the real economic, industrial, and education sectors (Nevelsteen, 2017). For example, in near future, we may witness a professor teaching his students about the history of architecture in a virtual archaeological site of the pyramids. Therefore, the Metaverse will present both virtualization and extension of real landmarks, which provides an immersive experience for several monumental sites.

To put all those targets in practice, various tools and components must be available to model and operate such platforms. Thus, interactive design methodologies and platforms for extension and simulations must be available (Gaafar, 2021).

3.1 Design Methodologies

Design methodologies are used to provide avatars and architectural components. Through a profound application of computer graphics techniques and practical CAD tools, users may produce virtual models for characters and buildings (Wang, Qin, Wang, and Hu, 2022). Architectural tools will provide the design common ground for the Metaverse. Principles of architecture will satisfy the design scalability and mobility, which presents to the users a more realistic experience.

Although the Metaverse is facing some restriction in resources, memory, and storage, architectural components shared in a decentralized structure is often a good approach to enhance its infrastructure (Nevelsteen, 2017). Therefore, the research aims to use novel technologies of this immersive virtual world, to resolve the service availability of the users in a specific geographic place. Thus, 3D models of certain archaeological sites can be shared on different servers and provide the best audio-visual user experience (Gaafar, 2021).

On the other hand, such monuments, retail stores, and shopping malls may have an extended “walk-through” platform to show all the details required that may not be seen during a physical visit for certain access restrictions (Gaafar, 2021). An architecture based on an interactive interface is very important in those applications. For example, in a scene presenting a visit to a museum, users will enjoy the controls available to touch and examine different exhibited items (Lee and Banerjee, 2010).

Thus, in the Metaverse, similar components may exist in one virtual layer. Then, common components are extracted upon request to be used as a virtual library (Nevelsteen, 2017). A lot of basic objects can be used as reference models in many scenes retrieved from a common library layer. For example, in industrial fields, the designer can recall any basic model to construct a new proposed product for manufacturing. Even, more advanced applications including complex models like computer design grouping components from the library may be possible for designers or students in the Metaverse (Lee and Banerjee, 2010).

Table 1 depicts various design activities in the Metaverse. It describes how architects and designers can model the Metaverse components based on real-world objects. As shown, there are 6 main subfields to construct the Metaverse architecture. Each process represents a small manufacturing system to build the assets of this virtual space (Lee and Banerjee, 2010).

Table 1: Metaverse Design Activities.

Level	Metaverse Design Activities
1	Identifying components from real-world
2	Designing components to model virtual objects
3	Clustering objects in libraries
4	Grouping same objects in a collection
5	Mapping objects to the virtual space
6	Modeling objects interaction in the virtual space

3.2 Real World Virtual Extension or Simulation

Real-world virtual extension or simulation is a virtual development concept that uses the internet to extend the presence of a certain space to any electronic device like computers and smart phones (Bourlakis, Papagiannidis, and Li, 2009). This practice reflected a fast development in the e-business and e-commerce sectors since the 90s, but today the Metaverse propose a more advanced experience to play, learn, work, and live using novel immersive users control devices (Nevelsteen, 2017). This technology has extended to reach more sectors like e-learning, e-health, and e-government. This leap in services requires a new generation of management and control of this huge “e-space”. Therefore, this synthetic world adds a new dimension for socio-economic and leisure activities (Bourlakis, Papagiannidis, and Li, 2009).

Thus, a fully immersive experience of world heritage, historical sites, universities, and commercial places can achieve the necessary augmentation in both physical and virtual individual presence. Consequently, people can come together and team up to reach multiple activities that previously required onsite presence (Gaafar, 2021). Accordingly, the progress in the IoT domain can change the odds to a more beautiful and unique experience that matches physical presence. Furthermore, it may serve the objective of research and exploration like restoring a historical tomb or archeological site. Even more, many historical moments though the ages can be revived and studied so we may walk on the steps of our ancestors (Gaafar, 2021).

On the other side, from an economic point of view, the Metaverse offers great opportunities but with some challenges. First, e-retail will change the business model and the investment requirements. For example, instead of focusing on physical assets, a big interest will be diverted to the IT infrastructure to provide the services. Even more, the collection of virtual models and user data is becoming critical to building future insights (Bourlakis, Papagiannidis, and Li, 2009). Unlike traditional business processes, the staff must have computer-enabled talents. Such a shift also inquires open-minded senior management that supports innovation and creativity without hesitation (Park and Kim, 2022).

The problem of space lacking is another issue that may face some businesses. It is true that platforms may provide limitless spaces in the Metaverse but for sales purposes they keep zone availability limited to preserver virtual land values. For example, representing a certain brand in the Metaverse and providing a virtual office is a necessary footstep for many retailers. Others, like gaming companies, are giving game elements and stages, which offer to the user a reward in cryptocurrency (Park and Kim, 2022). This idea of reward may extend in near future to take place in exchange for work services. Nevertheless, some countries like Barbados are extending their presence to the Metaverse, even establishing a Metaverse Embassy. Many digital companies are aiding in the design of virtual embassies and infrastructure to acquire virtual visas. In addition, the ability to teleport users' avatars will be available between different Metaverse Platforms (Xu, Ng, Lim, Kang, Xiong, Niyato, Yang, Shen, and Miao, 2022).

Of course, such abilities may require enhancing Metaverse components and avatars with a self-reconfiguration property. Some design characteristics should be common to provide a uniform data structure. Dynamic reconfiguration of interaction and simulation processes is essentially needed in this virtual domain. Although, platform upgradability must be a constraint to such conditions like exchanging avatars between platforms (Lee and Banerjee, 2010). For sure, this will affect different layers of the Metaverse not only the ones related to object rendering.

4. METAPHYSICS

Metaphysics was defined by Aristotle as the "science which investigates being as being and the attributes which belong to this in virtue of its own nature". With regards to VR, metaphysics is a combination of illusion and reality. It is a user-generated multilayered metaverse containing hyperreal content.

Multilayered metaverse can overflow with hyperreal objects and content such as faces, bodies, plants, animals, and other objects that can be rearranged in endless ways by users to create unique experiences.

The lack of barriers in the Metaverse has attracted architects interested in overcoming the barriers of what space can be. Architects and engineers have abided by the safeguard requirements of the physical world for centuries.

However, in the Metaverse, there are no gravity or material constraints.

The Creative environment in the metaverse world has attracted architects interested in building virtual designs in virtual lands without laws or any barriers.

5. COMPARISON BETWEEN DIFFERENT METAVERSE PLATFORMS

A Metaverse platform is a connection between the digital world and the physical world. It allows developers to build anything from VR to AR.

5.1 Decentraland

As mentioned in (Gadekallu, Yenduri, and da Costa, 2022), Decentraland is a virtual reality platform powered by the Ethereum blockchain. The Ethereum blockchain is a decentralized blockchain that is powered by its native cryptocurrency, Ether (ETH). Such a platform allows users to create, experience, and monetize hyperreal content, economic assets, and applications. In Decentraland, the community permanently owns a certain virtual land with full surveillance and control. Also, the virtual land in this platform is non-replaceable and non-transferrable. Unlike other Metaverse platforms, Decentraland is not managed or supervised by any organization.

5.2 Sandbox

According to the work presented in (Gadekallu, Yenduri, and da Costa, 2022), Sandbox is a virtual world where users can build, own, and monetize their gaming experiences using SAND, its utility token with ERC-20 (Ethereum Request for Comments 20). In such a platform, the gaming experience is uplifted from a 2D mobile pixel environment to a 3D world using a voxel gaming platform.

5.3 Omniverse

Omniverse is a scalable, multi-GPU real-time reference development platform for 3D simulation and design collaboration (Xu, Ng, Lim, Kang, Xiong, Niyato, Yang, Shen, and Miao, 2022), developed by NVIDIA. This platform can be used by content producers for integrating their 3D workflows. The platform enjoys being flexible and sustainable.

5.4 Unity

Unity is a 3D content development platform that comes with a built-in 3D engine and studio design (Xu, Ng, Lim, Kang, Xiong, Niyato, Yang, Shen, and Miao, 2022). Such environment facilitates the creation of virtual reality, augmented reality, and Metaverse experiences. Unity components store includes features like edge computing, microservices, AI agents, and blockchain, which helps in providing decentralization options.

6. THE FUTURE OF THE METAVERSE WORLD

No one can deny that many aspects may interfere with the future of the Metaverse. Some concerning the problem of security and privacy related to data collection and user behavior, others like user conversations and browsing history. Thus, Avatar authentication should secure both data transmission and interaction (Park and Kim, 2022). For sure this may not control the evolving techniques of cybercrime that may appear in the Metaverse. Furthermore, IoT devices extending the Metaverse to the real world also may be targets of inappropriate surveillance or privacy-invading activities (Gaafar, 2021). Therefore, some law enforcement regulations may extend to cover human behavior in this virtual world. Ethical consciousness and principles are necessary to guide this young generation of users in their virtual experience (Park and Kim, 2022). However, despite the challenges here are some design and research suggestions that may be helpful in building the Metaverse include extending the presence of the cultural organization and touristic site so that the world heritage, culture, and monument are displayed, which impose a lot of audio-visual work. It is also recommended that schools and universities start building their virtual classes and experimental labs. Therefore, academic staff should plan the transfer of their knowledge to a new level of graphical explanation. More immersive VR equipment is required to extend the Metaverse from a virtual gaming platform to a more serious level where real work can be achieved like architectural design, virtual medicine, teaching, etc. At the communication level, people must be able to come together at one virtual pace where they are able to share their thoughts and knowledge and have fun. An augmented interpersonal interaction platform must be available to serve various aspects of human life.

7. CONCLUSION

The construction of this large virtual world is inevitable. Soon, we will witness virtual educational, medical, and manufacturing environments where people come together and fulfill their tasks. A set of collaborative infrastructure will be provided by technology giants to achieve maximum interaction between different platforms. Next, we will experiment with a revolutionary architectural and historical extension of real-world sites in the Metaverse (Lee and Banerjee, 2010). The known social and economic aspects of real life will totally change on many levels based on the objectives and interactions of this virtual world. The social behavior through the Metaverse will reflect a different intuition of mankind and their behavior when acting from behind an avatar. Thus, we should expect untraditional approaches from a large group of interacting audiences.

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