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Abstract: The concept of a metaverse, a shared virtual space that brings together the physical and digital worlds, has been a topic of interest for decades. With recent advancements in technology, particularly in virtual reality (VR), augmented reality (AR), and blockchain, the metaverse has become a rapidly evolving and promising ecosystem. This paper provides a review of the metaverse, exploring its history, evolution, and current state of development. The paper delves into the different types of the metaverse, including fully immersive VR metaverses, hybrid metaverses that blend the physical and virtual worlds, and decentralized metaverses that are powered by blockchain. Additionally, the paper examines the impact of web 3.0 on the metaverse, as well as the various technologies used to create and sustain the metaverse, including VR, AR, and blockchain. Furthermore, the paper explores the concept of digital ownership and the potential for marketing and commerce within the metaverse. This paper serves as a review of the metaverse and its various components, providing insights into its history, development, and prospects, and is intended to provide a foundation for further research into this exciting and rapidly evolving ecosystem.

Keywords: metaverse; AR; VR; digital ownership; blockchain; NFT

I. Introduction

The term "Metaverse" is a portmanteau of individual words ``meta" and "universe." The term originated in the 1992 science fiction novel "Snow Crash'' by American writer Neal Stephenson. Although the word came from his novel, Stephenson did not provide a specific definition but rather a description of the term metaverse as a virtual reality-based successor to the internet with a massive online virtual world with humans having avatars. The novel refers to the metaverse as a world for labor and leisure, art and commerce, self-actualization, and exhaustion. The dystopian world by Stephenson is set in the future of the 21st century, where for-profit franchise-based quasi-national entities replace the governments with suburban enclaves ruled over by their constitution [1]. Logically, this dystopian world would create a great rift between the rich and the poor, pushing the masses to live in a metaverse. Films like "Surrogate," "Ready Player One," "Blade Runner," and "Matrix," just to name a few, further defined and popularized the idea of metaverse into the mainstream before in 2021, Mark Zuckerberg's speech blew up the idea. The term, over the years, became the definition of a network of 3D virtual worlds focussing on social connections.

Tech CEOs like Satya Nadella and Mark Zuckerberg have been discussing the term as the next big step and the future of the internet. But advocates from startups have argued regarding the definition of the term as it is still evolving. Like how the internet was defined in the early 1990s, the metaverse similarly, although currently present, only speculations could be made on how it will develop in the next 50 years [2].

By definition, the metaverse is defined as a post-realistic universe based on the convergence of technologies like AR and VR, creating a perpetual and persistent multiuser environment merging physical reality with digital virtuality [3].

The third industrial revolution in the early 1970s introduced the power of electronics and programming. More than 50 years later, we witness how electronics and computer science have enriched human communications, interactions, and transactions. From the perspective of end users, the evolution happened as personal computers, then the internet, and finally mobile devices. The fourth wave of evolution is happening, introducing immersive technologies like AR and VR [4]. This fourth wave is called the metaverse and is expected to form the next ubiquitous computing paradigm transforming finance, business, work, education, and entertainment..

II. History and Evolution

The concept of a Metaverse, a shared virtual world where individuals can interact with each other in a computer-generated environment, has been a topic of discussion and speculation for decades. However, it was only in recent years that technological advancements have made the creation of a Metaverse a realistic possibility. In this review paper, we will delve into the history of the Metaverse and its evolution over time.

The concept of a virtual world can be traced back to the 1960s when scientists and futurists first began imagining a world in which people could interact in a computer-generated environment. In the late 1960s, computer scientist Ivan Sutherland created the first head-mounted display (HMD), known as the Sword of Damocles, which he described as "the ultimate display" that would allow users to immerse themselves in a virtual world [23].

In the 1980s and 1990s, virtual reality technology advanced, and the concept of a Metaverse became more concrete. In 1986, sci-fi author Neal Stephenson wrote the novel "Snow Crash," in which he described a Metaverse as a virtual world where people could interact with each other in a computer-generated environment. The novel became a cult classic and sparked the imagination of many in the tech community [24].

In the early 2000s, virtual worlds like Second Life and World of Warcraft were launched, allowing users to create and interact with each other in a virtual environment. These virtual worlds were the first genuine attempts at creating a Metaverse, but they were limited by the technology of the time and could not provide the level of immersion and interactivity that users desired [25].

In recent years, advances in virtual reality (VR) and augmented reality (AR) technology have brought the Metaverse closer to reality. With the launch of VR devices like the Oculus Quest and the HTC Vive, users can now immerse themselves in virtual environments and interact with each other more naturally and intuitively. The introduction of 5G networks has also made it possible to deliver high-quality, low-latency VR experiences, which is essential for creating a seamless Metaverse.

The history of the Metaverse has been a long and winding road, but with the recent advancements in VR and AR technology, it is now closer than ever to becoming a reality. The Metaverse has the potential to revolutionize the way we interact with each other and the world around us, and it will be exciting to see how it evolves in the coming years.

3. Metaverse associated terminology

The following are the keywords with their definitions in the context of the metaverse.

- Virtual world: a computer-generated environment that simulates the physical world and provides a platform for users to interact and participate in various activities within a virtual environment.
- Shared space: a virtual environment where multiple users can exist and interact simultaneously, creating a sense of community and social connection within the virtual world.
- Decentralized: a system that operates without central authority or intermediaries, allowing for more secure and transparent transactions.
- Immersive: an experience that fully involves and surrounds a person, creating a sense of being present in the virtual environment.
- Interaction: the action of communicating with or participating in an activity together with other people or digital entities.
- Avatars: digital representations of users within the virtual world, allowing for user engagement and interaction within the metaverse.

- Virtual reality: a computer-generated simulation of a three-dimensional environment that can be interacted with in a seemingly real or physical way by a person using special electronic equipment.
- Augmented reality: a technology that superimposes a computer-generated image on a user's view of the real world, providing a blended experience of the real and virtual environments.
- Blockchain: a distributed ledger technology that allows for secure and transparent transfer of ownership by maintaining a tamper-proof record of all transactions.
- Cryptocurrency: a digital asset designed to work as a medium of exchange that uses cryptography to secure and verify transactions and to control the creation of new units.
- Digital assets: any item of value that exists in a digital form, such as digital currency, virtual real estate, or in-game items.
- Digital ownership: the control and rights over digital assets, allowing for secure and transparent transfer of ownership without the need for intermediaries.
- Web 3.0: the next generation of the internet, characterized by a decentralized web, enhanced security and privacy, and more seamless integration of virtual and real-world experiences.
- Decentralized web: a web architecture that operates without central authority or intermediaries, enabling secure and transparent transactions and interactions.
- In-game items: virtual items within the metaverse that can be bought, sold, or traded and have real-world value.
- Virtual marketplaces: online platforms where users can buy, sell, or trade virtual assets within the metaverse.
- Virtual real estate: virtual land or property within the metaverse, which can be bought, sold, or traded.
- Digital collectibles: unique, one-of-a-kind digital assets that are often rare and valuable.
- 3D environments: three-dimensional virtual environments within the metaverse that can be interacted with in a seemingly real or physical way.
- Multiplayer: a feature in which multiple users can participate in a game or activity simultaneously.
- Tamper-proof ledger: a secure and transparent record of all transactions maintained by a decentralized system, such as blockchain.
- Transfer of ownership: the transfer of control and rights over digital assets enabled by technology such as blockchain.
- Digital commerce: commerce that occurs within the digital world, including the buying, selling, or trading of digital assets.
- Personal data: information that relates to an identified or identifiable natural person.
- Synchronous: refers to real-time interaction or communication within the metaverse, where events co-occur for all participants.
- Asynchronous: refers to communication or interaction within the metaverse that co-occurs for different participants, not in real-time.
- Social networking: refers to virtual environments within the metaverse to connect and interact with other individuals or groups.
- Gaming: refers to the use of virtual environments within the metaverse for playing games, whether alone or with others.
- Entertainment: refers to the use of virtual environments within the metaverse for various forms of entertainment, such as watching concerts, attending virtual events, or experiencing immersive experiences.
- Education: refers to the use of virtual environments within the metaverse for learning and education, such as virtual classrooms and training simulations.
- Business: refers to using virtual environments within the metaverse for commercial purposes, such as virtual commerce and remote work.
- Collaboration: refers to virtual environments within the metaverse for team collaboration, such as virtual meetings and co-creation.

- Virtual goods: refers to digital assets within the metaverse, such as virtual items, clothing, and accessories for avatars.
- Decentralized applications (dApps): refers to applications built on decentralized networks, such as blockchain, that operate within the metaverse.
- Virtual economies: refers to the economic systems within the metaverse, such as virtual marketplaces and the exchange of virtual goods and currencies.
- Smart contracts: refers to self-executing contracts with the terms of the agreement between buyer and seller being directly written into lines of code.
- Artificial intelligence: refers to the use of AI technologies within the metaverse, such as virtual assistants, chatbots, and intelligent avatars.
- Machine learning: refers to the use of machine learning technologies within the metaverse, such as personalized recommendations and predictive analytics.
- Persistent: refers to the continuity of experiences and data within the metaverse, even after a user logs out.
- Non-fungible tokens (NFTs): refers to unique digital assets, such as virtual real estate or digital collectibles, that are stored on a blockchain and represent ownership of a one-of-a-kind item.
- Decentralized identity: refers to a digital identity owned and controlled by the individual rather than a centralized entity within the metaverse.
- Virtual events: A digital event happening in the metaverse that is designed to provide an immersive experience for attendees. Virtual events can include concerts, conferences, trade shows, and other types of gatherings and are often used to bring people together in a shared virtual space. Examples of virtual events include Second Life's Virtual World Education Roundtable and various music concerts held on VR platforms.
- Virtual meetings: A digital meeting in the metaverse, where attendees can interact and collaborate in a shared virtual space. Virtual meetings can range from informal gatherings to business meetings and can bring people together from all over the world. Examples of virtual meeting platforms include Spatial, Mozilla Hubs, and VRChat.
- Virtual tourism: The experience of visiting digital locations or environments in the metaverse, ranging from real-world locations recreated in a virtual setting to entirely fictional places. Virtual tourism can provide a unique way to explore the world and experience new cultures and is often used for educational or entertainment purposes. Examples of virtual tourism include Rec Room's social VR platform and Sansar's virtual world platform.
- Virtual shows: A type of virtual event that is designed to showcase a particular product or service compellingly. Virtual shows can include product demonstrations, presentations, and other marketing events and are often used by companies to reach a large and diverse audience. Examples of virtual shows include virtual trade shows, product launches, and VR-based events.
- Virtual communities: A group of people who come together in the metaverse to share a common interest or goal. Virtual communities can be formed around topics such as gaming, education, or business and can provide a way for people to connect and collaborate in a shared virtual space. Examples of virtual communities include Roblox's gaming platform, VRChat's social VR platform, and Decentraland's virtual world platform.
- Tokenization: The process of representing real-world assets or virtual goods as a digital token on a blockchain. Tokenization can provide a secure and transparent way to transfer ownership and value between individuals and can be used to represent a wide range of assets, from virtual real estate to in-game items. Examples of tokenized assets include virtual real estate in Decentraland and in-game items in Axie Infinity.
- Digital scarcity: The concept that certain digital assets have a limited supply, which can be used to create scarcity and increase the value of the asset. Digital scarcity is often achieved through tokenization and can be used to represent assets such as virtual real estate, in-game items, and digital collectibles. Examples of tokenized assets with digital scarcity include virtual real estate in Decentraland and in-game items in Axie Infinity.

- Cybersecurity: The protection of digital assets and information from unauthorized access or attack. In the context of the metaverse, cybersecurity is critical to ensure the safety of virtual assets and personal information, as well as to maintain the integrity of the virtual economy and the underlying blockchain.
- Privacy protection: The practice of protecting personal information and data from unauthorized access or use. In the context of the metaverse, privacy protection is vital to ensure the security of personal information and virtual assets and to maintain the trust of users in the virtual world. Examples of privacy protection measures in the metaverse include encryption, blockchain-based data storage, and decentralized identity systems.
- Scalability: The ability of a system to handle a growing number of users, transactions, and data without slowing down or becoming less reliable. In the context of the metaverse, scalability is critical to ensure that the virtual world can accommodate a growing number of users and transactions and maintain smooth operation.

IV. The metaverse as a connecting point between web 3.0, augmented and virtual reality, and blockchain technology.

Web 1.0, web 2.0, and web 3.0 are not specific technical upgrades to the internet but represent the shifts that happened in how the internet is used. Web 1.0 was the earliest form of the internet, where information from companies was posted for the masses worldwide to consume, just like a digital newspaper or a magazine. Web 2.0 is the current state of the internet, where the content is more user-generated than compared web 1.0. In web 2.0, although the users have the freedom to generate and publish content they desire, however, the publishing platforms are governed, and if the content creator publishes something that goes against their community guidelines, they still can get banned and their account suspended even if they are the top revenue-generating creator of that platform. Web 3.0, unlike its predecessors, allows the users to own a part of the internet that has a certificate of ownership shared with all of the users using the blockchain.

The earliest iteration of the virtual space in the massive context comes from a 19 years old multiplayer interactive game called "Second Life." This later led to massive multiplayer online role-playing games (MMORPG) like the World of Warcraft, Elder Scrolls, Final Fantasy, and Minecraft. To give a perspective on how massive these virtual worlds are, the java version of Minecraft has an area of $3.6*10^9$ square kilometers which, against the area of the earth, is seven times more.

V. Digital Ownership

Digital ownership in the context of the Metaverse refers to the ownership of digital assets and content within virtual environments. This includes virtual real estate, virtual goods, virtual currency, and other forms of digital content created and used within virtual worlds.

In the Metaverse, digital ownership is a complex and evolving issue shaped by the interplay of technology, economics, and social norms. On the one hand, digital ownership provides users with new opportunities to own and control their digital assets in ways that were impossible in the physical world. On the other hand, it also raises new challenges, such as the protection of intellectual property rights, the management of digital scarcity, and the enforcement of digital transactions.

One of the key features of digital ownership in the Metaverse is using blockchain technology to create secure and transparent record-keeping systems. Blockchain can track the ownership of digital assets, record transactions, and enforce property rights in virtual environments. This helps to ensure that digital ownership is secure and verifiable and provides a foundation for digital commerce and other activities within virtual environments.

Another important aspect of digital ownership in the Metaverse is the creation of virtual currencies, which can be used to buy and sell digital assets and services within virtual environments. Virtual currencies are created and managed by the Metaverse platforms, and their value is often linked to the popularity and demand for the virtual world itself. This creates a new form of economic activity that is separate from the traditional physical economy and opens up new opportunities for innovation and growth.

Digital ownership is an important and evolving issue that is shaping the development of virtual environments and the future of digital reality. As the Metaverse continues to grow and mature, it will be important to establish clear and fair rules and regulations around digital ownership to ensure that it remains a secure and trustworthy platform for users to engage in commerce, social interaction, and other activities. Examples of digital ownership include Nike, in late 2021, patented digital goods intending to sell them for the metaverse avatars in the future [5]. This means that as resellers, people can buy and sell digital goods in the metaverse, just like trading stocks. Artists can release and sell their artwork and take in a royalty fee every time their artwork is re-sold into their digital wallet without needing a platform like Spotify or Apple music. Metaverse with blockchain technology redefines owning an artwork without a launching platform.

VI. Extended, Virtual, Augmented, and Mixed Reality

Extended Reality (XR) is an umbrella term covering all different forms of computer-altered realities. Extended reality, also known as cross-reality, includes a collection of immersive technologies where data is represented and projected. XR includes MR, VR, and AR [6].

Virtual reality(VR) is a simulated experience that can or cannot be similar to the real world. Virtual reality is a three-dimensional generated environment that can be explored and interacted with by a person or a group of people. Roblox is one of the most popular metaverse VR platforms in 2022. There is a range of systems that are used for VR immersiveness, like headsets, omnidirectional treadmills, special gloves, and body attachments for haptic feedback. The collective working of these devices stimulates the senses and creates the illusion of reality. Users in VR, when immersed, may forget that they are in a VR simulation [7]. With the aforementioned multisensory specialized equipment, the experience is enhanced with the modalities of the human senses [8].

Augmented Reality (AR) overlays digital information in the real world in real-time. Unlike VR, AR does not create a totally virtual environment but rather augments the real world by overlaying digitally generated perceptual information on top of the real world. A typical example of AR is the use of google image translation using the digital camera on a mobile phone. If you have played Pokemon Go, you have used AR. In essence, AR keeps the real world at the center and enhances it with digital details that supplement the environment [9].

Mixed Reality (MR) is the merging of the real world and the virtual world where physical and real objects co-exist and interact in real-time. MR, by definition, is an advanced AR iteration in the physical environment that interacts in real-time with the projected digital data [10], making MR the hybrid of augmented and virtual reality. Mixed reality has applications in design, entertainment, military training, and remote working.

To aid with the comprehension of these immersion technologies, Milgram and Kishino illustrated one dimension reality virtuality continuum. The illustration is a straight line with two ends, with at one end lying the natural physical environment and at the other end lying the fully artificial virtual environment [6]. This makes AR at one end, VR at the other, and MR a superset of both.

VII. Multimodal Metaverse Interactions

To make the virtual environment as immersive and interactive as possible, the metaverse uses technology that mimics the physical sensations of devices. One of the significant parts of the five human senses is vision, and the representation fidelity of the XR system is achieved by wearable stereoscopic displays that convey the perception of depth. The XR displays are manufactured to display high resolution enabling a wide user field and spatial resolution of view that spans from 90 to 180 degrees [11]. Next to vision is the auditory component, which the XR systems offer superior high-resolution 3d spatial binaural audio that allows soundscapes and further enhances immersion [12]. In the case of passive sensory inputs, the sense of smell is further being researched. The human olfactory sensation is a complex system developed and evolved over millions of years; hence the molecules of fragrant particles which attach to the hair-like sensors can differentiate between thousands of fragrances. This extraordinary human capability challenges researchers to create

artificial fragrant compounds to mimic the environment. In the case of active sensory inputs, XR systems allow the use of motion controllers for interacting with the virtual world. These wearable or handheld input devices are an evolved form of game controller like the gamepads and have buttons, grips, analog sticks, D-pad triggers, and accelerometer-based inputs. This allows them to touch, grab, manipulate, and operate virtual objects [13].

Interactions in XR-based environments involve human participants engaging their entire bodies for movements and interaction. The physical movements are registered by positional and rotational tracking. KAT walk C2 is a commercially available personal VR treadmill that provides a complete 360-degree natural movement because of its convex surface and waist harness. The tracking movements can either be tracked optically using an array of cameras or can be tracked using internal sensors or a combination of both. The supported degree of freedom of an XR headset is a vital specification that reflects upon its motion-tracking capabilities [14].

VIII. Types of the metaverse

There are two types of metaverses, centralized and decentralized. The centralized metaverse, like the meta by Facebook, is owned by mark Zuckerberg and provides access solutions like the Oculus-based devices, which are owned by the parent company meta. So when users use Oculus devices, they are essentially accessing the centralized metaverse and will interact with games and applications developed and maintained by the meta group. Other examples of centralized metaverse platforms are Roblox and Fortnite. On the other hand, decentralized metaverses are the ones that are not owned by a company or an individual; hence they lie on blockchain technology. Decentraland, owned by the Decentralized Autonomous Organization (DAO), is an example of a decentralized metaverse that works on the Ethereum blockchain. According to the CEO of Epic Games(developers of Fortnite), Tim Sweeney sees the metaverse as a potential "multi-trillion dollar part of the world economy." Similarly, other tech giants like Microsoft, Apple, and Nvidia are developing tools to pave the way for the metaverse.

IX. Opportunities in the metaverse

A. Metaverse and Education

Metaverse has been the center of attraction for educationists for quite some time. Over the years, the education sector has been the one that has developed the least and evolved. When Facebook changed its name to meta, the idea further attracted and gave a new life to researchers and people working towards implementing it. In education, the concept of the metaverse is not novel. Several researchers and educators have researched and discussed its implications for learning. Collins, in 2008 [15], theorized about the use of metaverse in creating a virtual space where individuals can socialize and learn higher education, making learning proactive. In 2006 [16], Kemp and Livingstone conducted a study researching the use of metaverse in creating a virtual world "Second Life'' with learning management systems to enhance the learning process. Furthermore, in 2006, a summit held at the Stanford research institute international drew the roadmap for the future of metaverse where academicians from different domains, including educationists, took part [17].

With an increase in technology, several researchers have implemented the use of XR in creating applications for education. One of the advantages of metaverse concerning education is the use of VR for creating a one-on-one learning environment that is practical-based and much closer to reality. Students in a metaverse can create avatars and interact with classmates and with their instructor in real-time without being present physically. This creates an uninterrupted interaction between students and teachers, motivating both to be more proactive. Siyaev and JO [18] investigated the use of mixed reality to train maintenance trainees for aircraft maintenance by providing an interactive learning experience.

Crespo et al. analyzed a virtual education environment application providing knowledge in the form of free courses using metaverse and OpenSim [19]. Similarly, to aid in the teaching efficiency of

challenging courses like mathematics, Reyes [20] in 2020 developed a metaverse using AR and mobile learning.

On the medical side of the spectrum, Stanford Medicine has developed. He uses new software that collects the Data from 2D scans like MRI, CT, and angiograms. He creates a 3D model for both physicians to manipulate and better prepare for the course of actions and for patients to understand better before the surgery making them less anxious [21]. According to the surgeons, the technology helps them get better prepared for the surgery, lessens the chances of errors, and produces safer procedures for the future. In early 2022, a group of 100 medical professionals gathered together to separate conjoined twins from Brazil. The experts, while being at a hospital in London using VR, guided the surgeons in Rio De Janeiro to carry out the surgery. The surgeons used VR to practice beforehand and successfully separated two-three years old conjoined twins sharing the same vital veins in their brains [22]. At present, there are more than a dozen companies providing solutions for medical professionals dealing with VR-based technologies.

B. Metaverse and Entertainment

With the profitability of cryptocurrency dropping at an unprecedented rate, the last generation of high-end graphical processors utilized in the miner rigs have flooded the used market. With ample availability of high-end GPUs at relatively reasonable prices, the use of VR-based games will increase. The metaverse in the gaming industry is expected to make gaming more organic and interactive. The evolution of open-world games like Minecraft has created a new gaming genre in which gamers create their virtual world. This makes the games a platform on their own. The digitally created entities in these games can then be traded off for virtual currencies making the gaming experience profitable. The metaverse also diminishes the gap between developers and users who can "Play to Earn."

Fortnite, a metaverse, organized Marshmello and Travis Scott's Avatar-based virtual concerts for more than 20 million Fortnite attendees. This gives a profitable and broader reach to performing artists without the hassle of being physically present. The facility not only limits itself to artists existing in the real world but also to the artists who passed away. Take the example of Tupac Shakur, who had so much unreleased music that 7 of his winning albums were released after he passed away. Michael Jackson also has a presence on social media even after he is no more. The metaverse can benefit the artists who have unexpectedly passed away to have a virtual presence for their millions of fans and followers and, in a sense, never die from the virtual world.

C. Metaverse and Business

When the Covid 19 pandemic peaked, most of the office-going population moved to virtual office spaces soon to realize how efficient this move was. Nations like Japan, where office culture is significant, although at first reluctant to move away from the office environment for work, soon realized the added benefits in the form of fewer electricity bills, bills associated with renting the office space, expenses, and allowances given to employees. On the other end of the spectrum, the employees also benefited from being around their family while working online and saving time by renting a home nearby to the office and commuting to the physical workplace. Continuing with this trend, the Metaverse platform Decentraland has a virtual space where individuals can participate in online auctions of NFTs. In the future, as the popularity of the metaverse grows, Decentraland is going to organize live events, concerts, and sporting events. With the help of VR headsets, the events can be attended live by buying a ticket.

OpenSea.io is another online resource serving as a marketplace for metaverses. It contains virtual worlds for individuals to surf, compare and buy virtual lands. The "stats" utility on the website lists all the available decentralized metaverses with the number of individuals currently owning a digital space, the number of items in the exhibition, and the current value in Ethereum of the whole metaverse. Again "Decentraland" holds the first place in terms of value, followed by "The Sandbox." The Sandbox, at the moment, is quite popular and is already partnering with Adidas, Hell's Kitchen, Snoop Dogg, and Atari, just to name a few.

D. Metaverse and Work

Game engines like Unity and Unreal Engine are also engaged in developing the XR platform for their game developers. This helps the developers more in developing the environment for it to be as close to reality as possible rather than going back and forth to render and fix the bugs while sitting in front of a desktop.

OpenXR is one of the royalty-free, open standard VR-based solutions that provides API for XR applications supporting most of the available VR devices, including Oculus, Steam, and Windows Mixed Reality. This will motivate both professional and indie developers to develop better-optimized solutions for the end users that are not only limited to games. The LIDAR sensor in most Apple and Google devices can be used to create a 3D digital map of physical items that then can be used in the XR-based game engines to create an environment with superior realism theoretically of anything.

X. Metaverse Challenges

The path to a seamless integration of any new technology is always hindered by challenges, and the metaverse is no exception. One of the biggest challenges is the equipment needed to enter the metaverse, the hardware. Currently, the metaverse is only accessible with VR, MR, and AR technologies. This requires wearable headsets, which are bulky, costly, and require a massive amount of graphical processing power to function. The internal displays need to be high-quality and pixel-dense so that the immersion is realistic. These complex pieces of hardware make the adoption upwards of 2000 USD making the masses unreachable for wide-scale adoption.

The hardware required for rendering immersive VR headset displays requires a lot of power. The associated GPUs available today can consume over four hundred watts while rendering a realistic headset environment. This makes them very power inefficient.

Until VR hardware does not become fully accessible, inequality will be present among the population between those who can afford and access that and those who can't. With most people living in developing countries, to make the metaverse a global technology, the hardware needs to be sold at affordable price points.

The second challenge lies with identity and personification. Like with the real world and the internet, identity theft is a common crime that results in forgery, money theft, and a complex legal procedure after the crime has been done to prove innocence. In the metaverse, your avatar will be interacting, and with advancements in AI, there is a high possibility that bots can mimic your avatar's behavior and commit a crime. So you will need a more robust verification method, including physiological data like facial scans, retina scans, fingerprint scans, and voice recognition for authentication.

Multimedia has always influenced humans. There have been numerous reports of crimes motivated by films. Films with gore desensitize people in the real world, and in the future, when VR will get more immersive, the risk of people becoming more insensitive with their behaviors.

The next challenge relates to the physical well-being of individuals while adopting the metaverse. Humans have evolved for millions of years into our current form based on the physical environment we face on earth. Adopting a metaverse with current technology may result in issues relating to physiology and psychology.   Staring into a small VR headset for a more extended period of time may cause issues like eye fatigue, vertigo, and difficulty switching back to the real world. The convenience of being at your home and still being able to teleport to any part of the virtual world may cause metaverse addiction and neglect of physical well-being. The sedentary lifestyle due to excessive time spent in the metaverse may cause anxiety, depression, obesity, and heart issues.

VR hangover, also known as post-VR fatigue, is a phenomenon in which a person experiences physical and mental fatigue after spending an extended period of time in a virtual environment. The symptoms of VR hangovers can include headaches, eyestrain, dizziness, and general malaise. The cause of VR hangovers is not fully understood, but it is thought to be related to the stress placed on the visual and vestibular systems during VR immersion **[26]**.

Law and jurisdiction are other domains where the challenge lies. Social media is already witnessing virtual crimes. Metaverse will have individual lawbreakers too. Simply banning the

accounts won't be enough since individuals quickly develop new accounts to continue their nefarious activities. The borderless nature of the metaverse raises questions about the enforcement of laws and regulations and the protection of rights such as property, privacy, and freedom of speech. The metaverse isn't bounded by physical space, and individuals are joining in from all over the world, including the ones deployed in outer space. This means that the countries need to come together and develop an international set of rules to ensure a safe space for accessing the metaverse [27].

The development of the metaverse is still in its infancy, and numerous challenges must be overcome to utilize its potential fully. Technical difficulties, privacy, and security issues, compatibility problems, challenges in monetization, regulatory barriers, and scalability challenges are among the challenges that need to be addressed. Brands and marketers must have a well-defined plan to manage these challenges and make sure they are providing value to users while also earning profits [28].

Conclusion

In conclusion, the concept of a metaverse, a shared virtual space that blends the physical and digital worlds, has come a long way since its inception. With advancements in technology, particularly VR, AR, and blockchain, the metaverse has become a rapidly evolving and promising ecosystem. This paper provided a review of the metaverse, exploring its history, evolution, and current state of development. The paper covered the different metaverses, including fully immersive VR metaverses, hybrid metaverses that blend the physical and virtual worlds, and decentralized metaverses powered by blockchain. Additionally, the paper discussed the impact of web 3.0 on the metaverse and the various technologies used to create and sustain it. The concept of digital ownership and the potential for marketing and commerce within the metaverse was also explored. Overall, this paper served as a review of the metaverse, providing insights into its history, development, and prospects, and is intended to serve as a foundation for further research into this exciting and rapidly evolving ecosystem.

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