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Metaverse: Fission the architecture

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Abstract

Modern technology comes with new opportunities and difficulties since it is constantly evolving. The technology that has generated the utmost buzz and intrigue in recent years is Metaverse. Although Metaverse is not an entirely new word, it has attracted more attention because Facebook changed its name to Meta. However, despite the enormous interest and prospects, it still needs to be determined how ethical issues will be addressed and how users' privacy will be protected in the Metaverse system. Furthermore, the Metaverse system must earn the confidence and acceptance of its user by fulfilling the main criteria of Trustworthy AI. Therefore, this paper focused on making the Metaverse system trustworthy. This paper covered Metaverse's history, essential elements, the current business market, future opportunities, and challenges. Further, the manuscript discussed the pillars of trustworthy AI, its factors, and the way of trustworthiness. Finally, the paper combined these concepts and identified elements contributing to Metaverse's credibility.

Keywords*:* Metaverse; Trustworthy Artificial Intelligence; Privacy; Blockchain; Transparency; Virtual World; Digital Twin; Virtual Reality; Extended Reality; Augmented Reality; Mixed Reality; Formal Verification

1. Introduction

HE world we are living in is now extended to a world that combines the coexistence of our natural world and virtual places [1]. At the same time, education, communication, and daily activities are shifting toward a world where everything interacts digitally. Metaverse combines "Meta" and "Verse," where Meta means beyond, and the verse tells the universe. In other words, it is a 3D virtual world of an integrated network where everyone can exist in both the natural world and virtual places through avatars at the same time [2]. The current concept of the Metaverse differs from the earlier Metaverse in many ways. For example, deep learning helps improve vision and language recognition accuracy and creates a more mesmeric environment and natural movement where the complexity and processing time are also reduced. At the same time, now it is easier to access Metaverse from anywhere and anytime [3]. As a result, Metaverse is now considered the next marvelous thing and the next version of the internet. The concept of the Metaverse is not new, as it was first described by Neil Stevenson in 1992 in his novel Snow Crash [4]. However, the film "Ready Player One" brought the concept of Metaverse into the limelight of cutting-edge conversation again, where the film introduces a virtual world called "OASIS" where everyone can use their customized avatar to connect and do whatever they want based on the rules [5]. Now, Metaverse is one of the most trending topics among researchers and investors where people invest a lot of money. Metaverse Group, a Metaverse investment-based real estate company, recently bought virtual land for a hilarious price of 2.43 million on a decentralized virtual reality platform familiar as Decentraland. Metaverse's overall revenue opportunity is expected to rise from USD 500 billion to USD 800 billion from 2020 to 2024 [6]. On the other hand, in the world of gaming, different examples of Metaverse, like Roblox (www.roblox.com), Fortnight (epicgames.com/fortnight), and Sandbox (www.sandbox.game), are increasing at a tremendous rate [7]. At the same time, an enormous number of audiences started to explore Metaverse in detail after the press briefing of Marc Zuckerberg, where he announced the name change of Facebook to Meta [8]. As of May 2022, according to google trend

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reports, in the search engine of google, there has been a considerable increase in searches on Metaverse. Facebook and many leading tech companies like Nvidia Omniverse and Microsoft are also jumping into the world of Metaverse. In addition, famous consumer brands like Coca-Cola and Gucci are selling their non-fungible tokens (NFTs) on the Metaverse platforms [9]. Non-fungible tokens are cryptographic tokens where the details of virtual asset ownership are coded to be used to own digital assets [10]. The most crucial factor about Metaverse is that it is not for any specific age group or region but for the entire world. Therefore, it can change the looks of the current world and bring a new dimension to our culture and life. With this rapid growth and interest in Metaverse, it is also essential to build and maintain the trustworthiness of Metaverse and its application to ensure the user's acceptance and trust [11][197]. Nowadays, with good user experience and efficiency, users also want a system they can easily trust and use without any doubt about losing their privacy. For this, the trustworthiness of a system is significant to gain user interest. page.

When it comes to the trustworthiness of Metaverse, it not only points to the ethical perspective but also a wide range of factors that should be maintained [12][198]. These qualities include the fairness of the system, how robust the system is, if the system can protect personal information and data, if the system is explainable to everyone, and how transparently the system works. In 2019, the European Commission presented the official interpretation of the code of ethics for AI systems, which visualizes a framework to understand the total life cycle of trustworthy AI. The framework represents four ethical principles of trustworthy AI: human autonomy, fairness, non-discrimination, a safe and reliable system, and interpretability [13] [14]. These rules and principles will help the end user get a good user experience and will provide a fair environment among all parties. As Metaverse is a complex and vast area, to cover the whole scenario, we need to understand the overall ecosystem of Metaverse and its functionality.

However, it is not easy for a general user to understand everything; some users will need to learn what Metaverse is. For users like this, it is essential to have a clear and transparent overview of the entire system so that users of all types can easily believe it; therefore, Metaverse's trustworthiness is crucial. By applying and maintaining the basic principles of the reliability of AI in Metaverse, it will be much easier to gain the user's trust and build an ecosystem that all will accept. The approach of this paper looked at providing a way to implement the trustworthiness of AI in Metaverse and improvements among existing structure, current policies, and regulations, as well as Metaverse is a complex and colossal platform that combines many advanced technologies to provide an entirely 3D experience to users so that they can interact and collaborate with others in real life in the virtual world. Metaverse includes complex and important technologies like blockchain, 5G, XR/VR, etc., which deal with users' data and personal information. This paper conducted a comprehensive survey of the application and importance of trustworthy AI in the Metaverse from both application and technical perspectives and further discussed their role in future Metaverse. Briefly, the main contributions of this paper are summarized as follows-

First, it briefly discussed what Metaverse and Trustworthy AI are and their main characteristics and features. In a word, the whole picture of Metaverse and Trustworthy AI was discussed.

This paper also reviewed trustworthy AI techniques, including the main pillars of Trustworthy AI and different principles of Trustworthy AI from various organizations. Based on that, the role of Trustworthy AI in the Metaverse and the importance of trustworthiness in the Metaverse were discussed.

Finally, existing studies on the trustworthiness of Metaverse were investigated, and future research areas for more promising research were proposed.

2. Metaverse

A three-dimensional virtual environment where avatars participate in political, economic, social, and cultural activities is referred to as the “Metaverse,” a composite word made from the words “transcendence meta” and “universe.” It is commonly used to refer to a virtual environment based on everyday life in which the real and the unreal interact [15]. The term “Metaverse,” originally referred to a universe where virtual and real worlds interact and generate value through diverse social activities, was first used in Neil Stevenson’s science fiction book Snow Crash in 1992. There are numerous definitions and related concepts because the Metaverse has a broad and expanding reach. In earlier studies, the Metaverse was primarily used to study the structure of the virtual world itself. Still, in recent times, it has been used to describe a platform for exchanging interests and engaging in content-focused social interaction. History of the Metaverse in one sight in Fig. 1-

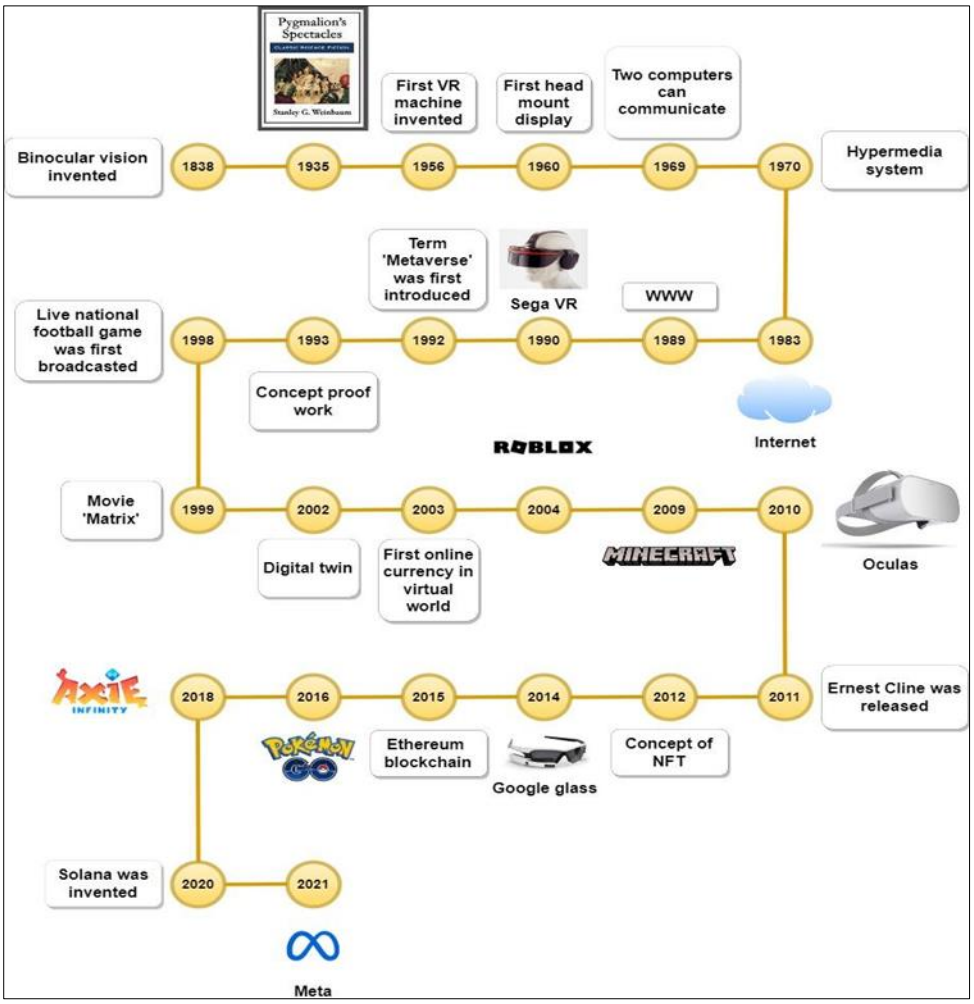

Figure 1 History of Metaverse

In 1838 the metaverse concept emerged when Verhoeff first introduced binocular vision. In this fusion theory, two monocular images were integrated. The entire left and right images melted together to make a new composite. It was a replacement theory, like replacing the real and virtual worlds. However, the Metaverse (The replica of the existing world) was introduced in 1992. In 1993 the proof work concept was first developed. Cryptographic evidence, known as proof work, involves one party (the prover) demonstrating to another (the verifiers) that a certain amount of computational effort has been applied. A well-known fiction film Matrix publicly cleared the Metaverse concept in 1999. In 2002 the digital twin concept was introduced. Using simulation, machine learning, and Reasoning to aid decision-making, a digital twin is a virtual version of an object or system that spans its lifecycle and is updated from real-time data. As Metaverse is an entirely virtual world, virtual currency was needed, and in 2003, the online virtual currency ThereBucks was first introduced. Roblox developed the online gaming platform in 2004. The Metaverse concept got a new dimension when google released the Cardboard device and googled AR glass in 2014. Ethereum blockchain and Decentraland made the Metaverse a revolutionary virtual world in 2015. Oculus, Pokemon go, Microsoft HoloLense, etc., were introduced to enhance the user experience in Metaverse in 2016. Facebook finally changed its name to Meta in 2021, intending to undertake a massive Metaverse initiative.

Metaverse is a mirror world or a replica of the physical world. The term “mirror world” refers to extending information into the virtual world by accurately replicating the real world (e.g., Google Earth, Microsoft Virtual Earth). Mirror World was inspired by David Gelernter’s 1992 book, Mirror Worlds [15] [16]. The actual living environment is digitally replicated together with supplementary simulation data. In other words, although the mirror world has its characteristics and functions, it mimics the look of structures or other items in the real world. Though theoretically similar, the terms ”Metaverse,” “multiverse,” “digital terraforming,” and “mirror world” each have a somewhat different connotation depending on where they are used and share certain notions. Since it has been discussed for decades with the advancement of the Internet and other technologies, the concept of the Metaverse is not new. Metaverse now refers to a networked virtual 3D environment, or even several cross-platform worlds, that may provide consumers with a fully

immersive experience with interactive and collaborative activities [17]. Metaverse can give the sense of some properties and characteristics which make the platform real and enhance the user experience. The Metaverse may convey a feeling of certain qualities and traits that make the platform seem more authentic and improve user interaction.

2.1. Social

In the Metaverse, individuals can design their societies. There are no restrictions, laws, rituals, or social obligations. People have the freedom to establish new communities and pursue their interests. People are given an avatar in the Metaverse to interact and converse with one another, much as in the real world [18]. The Metaverse can advance as a society beyond being a 3D environment and physical applications thanks to interdisciplinary study (Rehm et al., 2015). The Metaverse necessitates a diversity of ideals and fresh ideas beyond straightforward gaming and social networking. A fresh viewpoint is necessary to understand the Metaverse's philosophy, psychology, sociology, culture, economy, and politics. Instead of only adopting formulas from the real world, it is vital to take a progressive viewpoint [19].

Virtual Social Communication: It is difficult to hold private gatherings of several people or eat together at a restaurant because of the ongoing COVID-19 outbreak. In contrast, hundreds of thousands or tens of millions of people could assemble in the Metaverse to hold a festival or attend a concert by a beloved musician. People who were unable to leave their homes owing to COVID-19 now have a new social area to gather and unwind thanks to virtual reality Metaverses like Roblox and Zepeto.

The “Classroom Map” was the most well-liked of the other 3D maps in Zepeto when schools were shut down because of COVID-19 and kids could not attend class. The pupils visited the Zepeto classroom as opposed to the actual classroom. They interacted with their buddies after meeting them. When the idol group Blackpink could not hold a fan signing session in person because of COVID-19, they conducted a virtual event through Zepeto. Blackpink also made their avatar appear in the choreographed music video for “ice cream” [20]. Blackpink hosted a virtual fan signing event where more than 46 million users could meet and take pictures with their favorite musicians. The dance version of the music video for “Dynamite” by the idol group BTS was initially made available on Fortnite as part of a showcase [20]. Users that were present forgot about COVID-19 and had a good time dancing and exchanging impressions.

2.2. Persistent

The typical lifespan of a person is 80 to 90 years, which can be depressing for some people. However, the Metaverse is a universe in which people always exist, whether online or offline. As a result, the avatars will always exist alongside the actual users. Therefore, people can fully enjoy life possible, as no rules govern death.

2.3. Reactive

Real-time responses and reactions from the virtual world’s inhabitants and inhabitants themselves will be possible. The avatar must react in real-time otherwise the user experience will be diminished.

2.4. Interoperable

Experiences, possessions, and identities are not confined to any one platform they move freely between them.

2.5. Creative

A place where people actively participate with content rather than passively consume it, catalyzing inspiration and creativity. As a result of the COVID-19 outbreak and the subsequent transition to an untack society, the recent Metaverse mania has resurfaced. The use of the Metaverse is increasing as it develops into a new category of convergence service thanks to the four existing Metaverse types: augmented reality, lifelogging, mirror worlds, and virtual reality. Additionally, it dissolves the distinctions between these many Metaverse subtypes. Activities that were once believed to be solely possible offline are now being transformed into virtual reality and are quickly growing into numerous industries such as education, medical care, fashion, and tourism as face-to-face contact becomes more challenging due to the expansion of COVID-19.

2.6. User defined

Owned and shaped by the individuals who reside in, connect with, and engage with it. User can purchase house, sell house, rob the bank whatever wants he can do.

2.7. Decentralized

The ownership is distributed by which user can easily store their data in the blockchain with the topmost security. A public decentralized blockchain network can offer financial products through a mechanism known as "Decentralized Finance" or "DeFi." Anyone can use DeFi wallets like MetaMask and Trust Wallet. Unique identifiers like a government-issued ID, Social Security number, or proof of address are not required to use a DeFi wallet, boosting privacy and anonymity compared to going through mediators like banks or brokerages.

2.8. Everyday

It is seamlessly incorporated into our daily endeavors and engagements. The Metaverse can be utilized daily to improve learning and research skills for enjoyment and unexpected entertainment.

Fig. 2 portrays the acceptance of the virtual experience by the consumers. 44 percent of consumers prefer to connect virtually. In addition, 28 percent of people want to explore the digital world virtually, and most customers and clients want to collaborate with colleagues and attend meetings virtually. Some people also prefer to invest in NFT and purchase and monetize virtual assets.

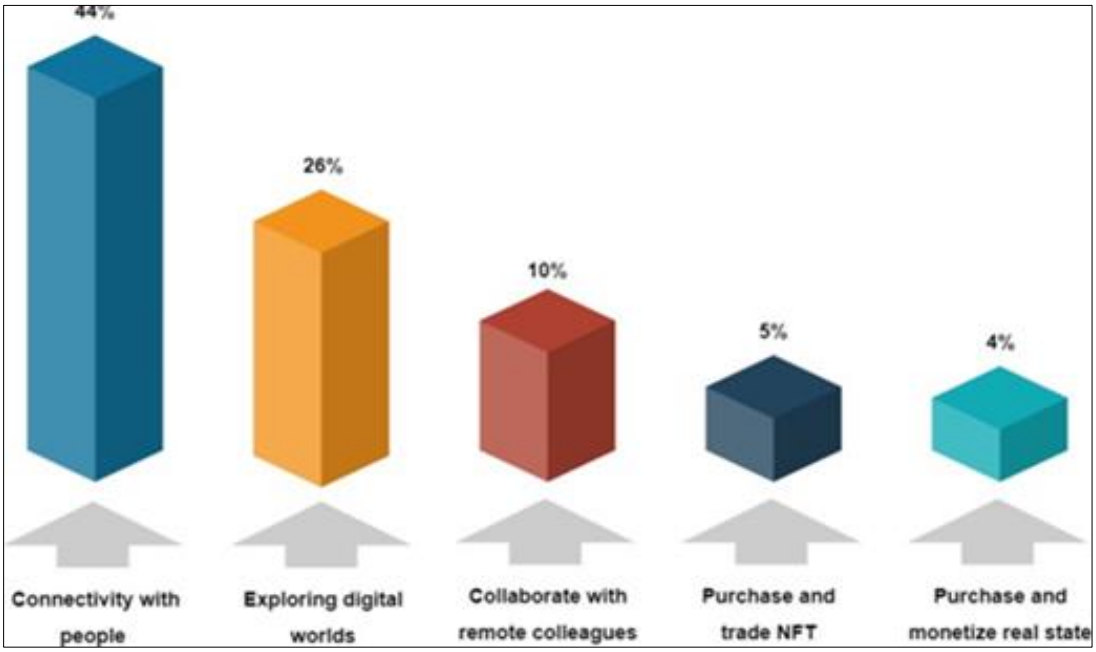

Figure 2 Percentage of Consumers Who Prefer Virtual Experience over Activities in Physical World (Intelli Metaverse Consumer Survey in Europe, the Middle East, and Asia (EMEA) and Asia–Pacific (APAC) (April 2022))

- *Educational:* Video conferencing tools like Zoom, Webex, Google Meet, and Teams exemplify the virtual world. In the post-COVID-19 age, these video conferencing systems act as the classroom in the real-time operation of non-face-to-face distant classrooms. Gathertown is a platform for online video conferences that enables communication and business in a virtual setting [21]. Chatting, interacting with external networks, and designing areas are some of its primary functions. The mirror world Metaverse has enormous educational potential since it may effectively develop the knowledge and skills needed for learning while displaying the outside world as it would appear in a mirror [20].
- *Virtual Lab:* The 2019 COVID-19 coronavirus pandemic further triggered the mirror world Metaverse. In other words, the user is the main factor in enabling the mirror world. In the mirror world, users interact and play games with remote players while doing important chores. All users have the chance to participate in scientific research through games thanks to the Foldit platform. This virtual lab has been utilized by David Baker's team at the University of Washington to train participants in folding protein amino acid chains. The protein structure for an AIDS (acquired immunodeficiency syndrome) treatment is discovered through this game, where the protrusion structure matches well, and the player receives points and ranks up if they succeed. The accomplishment of 60,000 participants in 10 days was detailed in a journal publication [22]. The idea behind a virtual lab is to facilitate student learning and research while decentralizing the lab administration system. The virtual lab's components enable teachers and learners to participate and complete assignments at any time,

from any location, and for any fee. The components of the virtual lab have enriched modern learning and laboratory operations so quickly and risk-free. Real-time control: The lab system has response constraints and a set response time. The work is not affected by any lag or delays that may halt the workflow. The students and learners are easily drawn to Studying and working on new innovations by the real-world experience. The virtual lab components are-

- Simulation**:** The students may quickly replicate an activity before applying it to their projects. Real-time simulations help grasp how things function as well as for completing tasks flawlessly. Risk-free tasks may be completed quickly when students and teachers use the simulation. In addition, simulation helps to see and duplicate the operations in the remote workshops.
- Collaborative tool: Helps to organize and share trials with many partners globally. Students may collaborate using the same tools as in a real-world laboratory by connecting from anywhere.
- Distant management: The teachers and lab assistants can efficiently handle the students and the lab work. No one must be reached to demonstrate how to use tools. The assistant or instructors can decide whether the equipment needed to complete a task will be available.
- Decentralized workflow: The workflow for the assistants, pupils, and teachers is distributed. Any time can be used to alter the workflow. The workflow is not constrained by any guidelines or schedule set by any organization. No unified framework exists to set limitations on the administration of laboratories
- Safety measures: Due to the virtual nature of the laboratory activity, there are no safety concerns. The user's avatar does the work, and the user may manage the avatar in real time, giving the user a realistic experience without worrying about their safety.

- *Virtual Recreation:* The term "mirror world" refers to a virtual representation or "reflection" of the real world that has had its informational quality increased [23]. The appearance, content, and physical organization of the real world are translated into virtual reality in the mirror world, which is a Metaverse. However, rather than saying that these systems "reproduce the real world," the phrase "efficient expansion" is preferable [20]. A mirror-world Metaverse is a place that makes real-world existence simple and effective. All operations in the real world can be carried out via the internet or mobile applications. Creating "virtual educational spaces" and "digital laboratories" in various mirror worlds are examples of representational mirror worlds used in education.

2.9. Limitless

There is no limit to privacy or life expectancy, so eternal life in the Metaverse can be enjoyed by all users [19]. Like the Internet before it, the Metaverse is a virtual environment that connects individuals, organizations, and goods in both virtual and physical settings to provide new business opportunities. The foundation has already been built. Jumping results in individuals and businesses getting priceless experience, connecting with clients, creating new revenue streams, and even influencing Metaverse culture.

In a groundbreaking examination of how to find the best options in this quickly changing cosmos, a group of Silicon Valley thinks leaders Getting Around the Metaverse A Manual for Endless Business Opportunities in the Web 3.0 Era. The Metaverse can lead to limitless possibilities-

- To dispel any skepticism that the Metaverse is the next great thing, data and market research will be used.
- Web 3.0 will change the world economy that will be used in the Metaverse in a replacement of the current websites.
- The vital link between Metaverse enterprises, communities, and digital goods is what gives the Metaverse economy its strength.
- A thorough examination of non-fungible tokens (NFTs) and suggestions for maximizing the resources.
- Frameworks that support the discovery, promotion, evaluation, and exploitation of innovation in the Metaverse.
- Examining these trends' most recent developments reveals a push effect, where new technology encourages significant changes in society and industry. This is evident, for example, in the ways that cloud computing affects organizations [24].
- We believe that Virtual Worlds can serve as platforms to facilitate the integration required by CPS. Recent applications, such as e-retailing [25], or use of Virtual world for learning home or business simulations, serve as forays into developing such integration.

3. Explicit Industrial Sight of Metaverse

Since the Metaverse's invention, several tech companies, including Microsoft, Facebook, Nvidia, and Epic Games, have worked to make it a reality [80]. How far have they come, in any case? Because gamers build their worlds, gaming has some of the first Metaverse experiences. The Metaverse is a natural progression for the game industry since it provides a believable virtual experience. The Metaverse can facilitate increased game engagement, virality, and monetization. Consider Fortnite by Epic Games as an example. They planned full events for fans to attend where they could talk to performers like Marshmello, Travis Scott, and Ariana Grande [81]. Fans may traverse the game environment and approach the artist's avatar in these time-shifted interactive interactions during these recorded and animated concerts [82]. Even digital merchandise is available, precisely as during a live performance [83].

Microsoft and Meta have chosen very different paths. For example, a new method for office employees to interact with VR using an Oculus headset has been presented by Meta called Horizon Workrooms [84]. Up to 16 people can attend a VR conference, each represented by an avatar. Conversely, Microsoft wants to change business and the workforce by developing a digital simulation of the actual world with which users may engage in mixed-reality interactions.

Mark Zuckerberg, the CEO of Facebook, caused a stir when he unveiled Meta. The new brand is designed to unite people and contemporary technology in novel and exciting ways [91]. AB InBev's Stella Artois collaborated with Zed Run to create a Tamagotchimeets- Kentucky Derby experience. This was done because AB InBev's Stella Artois is a huge supporter of athletic activities, mainly horse racing. Therefore, it seems like a logical next step for them to create an online platform where non-fungible token (NFT) horses may be bought, sold, raced, and bred [100].

Adopters provide immersive experiences to their consumers, such as a Lil Nas X performance in Roblox, Gucci Garden experience visits, and Warner Bros' marketing of In the Heights with a virtual replica of the Washington Heights area [102]. Collaborations with the Roblox Metaverse and other Metaverses have lately shown new income sources for brands [104]. Table 1 provides a brief insight of tech giants investments in Metaverse.

Table 1 Tech Industry's Investment in Metaverse

Tech Industry	Investment
Amazon	In an effort to solidify its hegemonic position in the market. Amazon has been working on a new VR shopping experience since 2018 and is attempting to leverage Metaverse to build a virtual store where customers can interact with digital goods.
Roblox	The only restriction is one's imagination; players can design their own virtual environment or other games. To improve user immersion. Roblox supports VR devices. Roblox has grown to be the biggest user-generated content (UGC) game platform in the world, supporting IOS, Mac, and more platforms.
Facebook	Facebook released the virtual reality social platform Facebook Horizon in September 2019 and opened a public beta in August 2020. Facebook said that it will take over as the Creating a Metaverse firm within five years and investing at least $10 Billion in its reality Labs are the goals of the Metaverse project team. Facebook announced in October 2021 that it would change its name to Meta.
Epic games	Epic Games made a $1 billion investment announcement in April 2021 to create a metaverse and bought Skethfab the biggest model site. To take over Skethfabs's user traffic and expand its market share in the metaverse.
Disney	Building a "theme park metaverse." according to Disney's chief technology officer Tiak Mandadi will be the next development in the company's theme park.
Snap chat	In order to saturate the globe with digital content. Snapchat created personalized avatars and filters. The Bitmoji service, which allows users to pose for real-world photos and make their own 3D Bitmoji characters was just introduced by snapchat.
Nvidia	Nvidia released the Nvidia Omniverse plan on August 11, 2021, with the goal of developing the first virtual collaboration and simulation platform.
Microsoft	Microsoft is cautious about Metaverse. Wei Qing; The "Metaverse" has practical value only when it returns to the physical world.

Decentraland	The first fully decentralized virtual world owned by users is a VR one built on Ethereum. Decetraland's primary focus is art and it has a section for the display of the digital work.
Tencent	Tencent has made a number of investments in the Metaverse ecosystem such as the "Avakinlife" game, Spotify music streaming service e.t.c. In September 2021 Tencent requested the registration of the "King Metaverse" and "TiMi Metaverse" trademarks.
Alibaba	Alibaba submitted applications to register trademarks like "Ali Tobacco Metaverse" and "Metaverse". The Metaverse is divided by XR Lab's director Tan Ping holographic construction in L1, holographic construction in levels L2, and L3 (virtual and actual fusion), L4(virtual and real simulation, linkage).
Byte Dance	Byte Dance has invested in visual computing and AI computing platforms.
NetEase	The design of Metaverse by NetEase is centered on the gaming industry and offers simple tools for game creation. The business made investments in both the IMVU virtual character platform and IMPROBABLE's meta-computing technology which enables third parties to create virtual worlds.
Shenzhen Zqgame Co.Ltd	A leading Chinese game studio is Zqgame. Zqgame published the Brewmaster preview on September 6, 2021. Players can launch enterprises in this game and see how will affect real-world situations.
Wodershare Technology Group Group Co.Ltd	Realbox has received funding from Wondershare Technology to improve its business model in the AR/VR space and give a strong technical foundation the Metaverse's initial development basis.
Sony. Hassilas	The first Japanese Metaverse platform is called Mechaverse. On this platform, businesses may swiftly launch new products and give participants access to 3D model tests and video introductions.
Gree	GREE's subsidiary reality manages the Metaverse business. By 2024, it is projected that 10 billion yen would have been spent on acquiring more than 10 million users worldwide.
Avex Business Development, Digital Motion	The partnership between Avex Business Development and Digital Motion intends to offer virtual artists activities, advertise existing animated or video game character and virtualize real-artist performances and other events.
Samsung	Samsung has launched the" Samsung Global Metaverse Fund"
SK Telecom	In July 2021, SK Telecom unveiled "ifland" a virtual setting where users can host and take part in meetings using animated characters.
Urbanbase	A 3D spatial data platform for the creation of interior design and real estate is called Urbanbase. In the B+ funding round the organization raised 13 Billion won about (450 million yuan). The cash will be employed to create the 3D and VR/AR technologies Urbanbase must go into the Metaverse.
Metaverse Alliance	25 organizations and businesses have been established by the Korean Information and Communications Industry Promotion Agency to the "Metaverse Alliance" to create the Metaverse ecosystem with the assistance of the public sector creating an open Metaverse platform in various spheres of reality, and virtuality and fostering commercial collaboration.
Sotheby's	53 works from NFTart collections were on display at once as part of the "Natively Digital 1.2: The Collectors" special auction, which was staged by the British auction house Sotheby's
Maze Theory	A "fanMetaverse" based on well-known IPs and fan universes will be developed by the renowned British VR studio Maze Theory.
Meta Dubai	In order to create the most comprehensive virtual world pictures, economic systems and applications feasible, MetaDubai is developing a Metaverse city in Dubai based on blockchain, NFT, AI and decentralized data storage.
Ripple	Ripp;e a blockchain payment business has announced plans to open a regional office at the Dubai International Financial Center (DIFC).

Stage 11	The European venture capital firm Otium Capital led a 5-million-euro investment round that Stage11, a French Metaverse music platform closed to produce immersive metaverse music.
RIMOWA	RIMOWA a German luxury luggage company announced in May on Instagram that it would collaborate with design form NUOVA to release four NFT artworks titled “outline from the Metaverse”
Gucci	Gucci an Italian luxury brand has introduced virtual athletic footwear. Customers can utilize the Gucci bags after purchasing the shoes. Try then out on the gaming site Roblox the VR social platform VR CHAT or both.

The regulations that will regulate the Metaverse and let it smoothly meld into our lives are still being developed [85]. Like the internet, the Metaverse has no owner, operator, or inventor. Suppose the system is open source and based on community standards; that would be fantastic. Although there are still many unanswered questions regarding the Metaverse, one thing is sure: it is boundless, enabling programmers to build and construct whole universes.

Mark Zuckerberg is concentrating on creating social Metaverses and investing in Facebook's AR and VR platform, Oculus [108]. In August 2021, Zuckerberg announced an Oculus work Metaverse that allows users to collaborate, sit in a conference room, and communicate as if they were in an office [109]. This is timely, given that more and more offices are switching to work-from-home policies. Silicon Valley has placed more bets on Metaverses as another wave of the internet than on Facebook [110]. Several games are implementing Metaverse-like aspects on their platforms right now. Concerts, for example, are permitted in Fortnite and Animal Crossing. Furthermore, HTC focuses on business rather than consumer-based VR technology [111]. This indicates that virtual reality technology is becoming more than simply for entertainment. If nothing else has persuaded us, this will: people are buying real estate in the Metaverse [112], notably on Earth 2. That is a clear indicator that technology is here to stay.

4. Architecture Of Metaverse

4.1. Dependency of Metaverse on Immersive technology

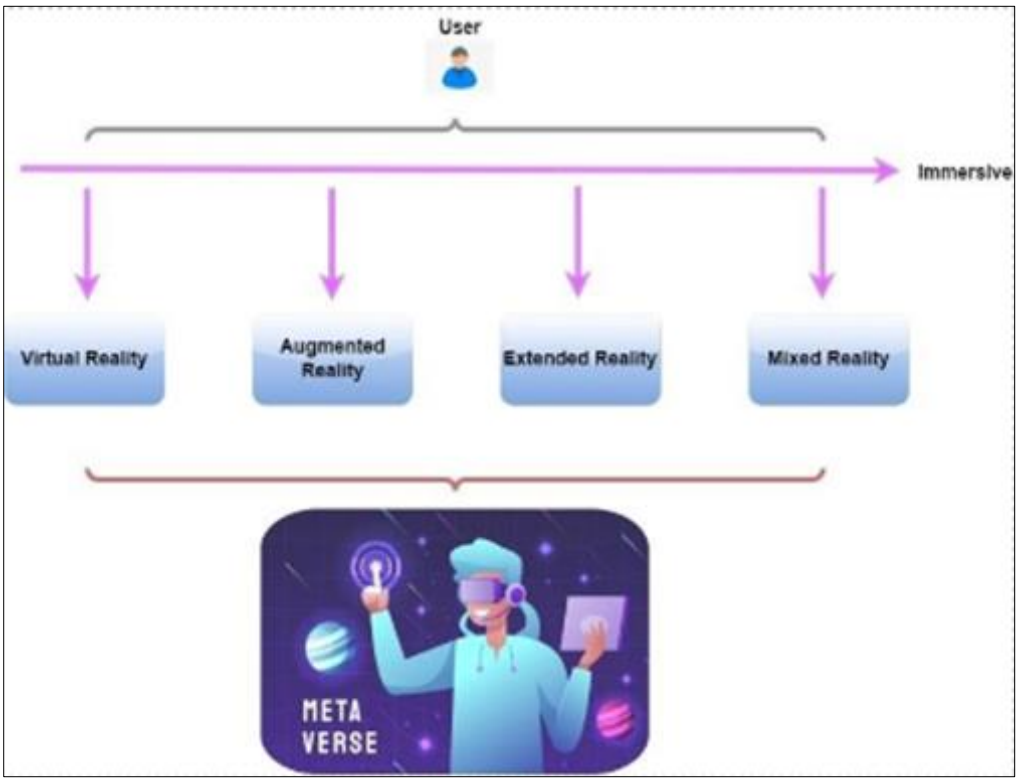

Figure 3 Immersive Technologies to Get into Metaverse (IEEE Young professionals)

The mirror world, or Metaverse, is a universe that exists parallel to the real world. However, replacing the real-world environment and making the environment a real-time user response is challenging. A bridge between the actual and mirror worlds can be created using specific technologies and concepts. "Virtual Reality (VR)," "Augmented Reality (AR)," "Extended Reality (XR)," and "Mixed Reality (MR)" [158]. These are all primarily used and popular reality technologies that either improve or substitute a simulated or virtual environment for the actual world. These technologies give a cutting-edge approach to engaging and interactively immersing people and enhancing the personal experience.

These are all primarily used, and popular reality technologies are shown in Fig. 3 either improve or substitute a simulated or virtual environment for the actual world. These technologies give a cutting-edge approach to engaging and interactively immersing people and enhancing the personal experience.

Metaverse dependency on Virtual Reality (VR): A VR headset device or other reality technology is used in virtual reality to virtualize the world [159] entirely. It simply implies that the VR equipment controls VR users and that VR enhances a fictitious experience. VR is a different, entirely artificial environment that was produced digitally. Users of VR feel engrossed, as though they are in a new environment, and behave similarly to how they would live in the real world. This experience is enhanced by specialized multisensory devices like immersion helmets, virtual reality headsets, and omnidirectional treadmills, which combine the senses of sight, hearing, touch, movement, and natural contact with virtual things.

- To render the virtual universe through a VR simulation is the bridge between the natural and mirror worlds. Through the VR simulation, the users from the real world can interact with the Metaverse in real-time. However, VR simulations are dependent on VR key components [160].

Critical components for creating VR simulations-

  - Visual display: Visual display components help to connect visually with the Metaverse. The components allow users to engage visually with the Metaverse through simulation and observe the real-time virtual environment.
  - Audio components: A user genuinely connected to the virtual world through the visual components and trackers receives a real-time experience from audio instruments [161]. Users of VR simulators get an immersive experience because of the 3D sounds.
  - Trackers: Usually employed to detect finger motions. This method might also detect elbows, knees, and other joints. The most common method of evaluating diminished light transmission through bent fibers is fiber optics [162].
  - Sensors: The user can feel the virtual world objects by connecting through the VR simulations. If a user collides with a wall in the virtual world, he can feel the collision in the real world in real time through the sensors.

The entire simulation follows a flow to do the processes simultaneously, as shown in Fig. 4.

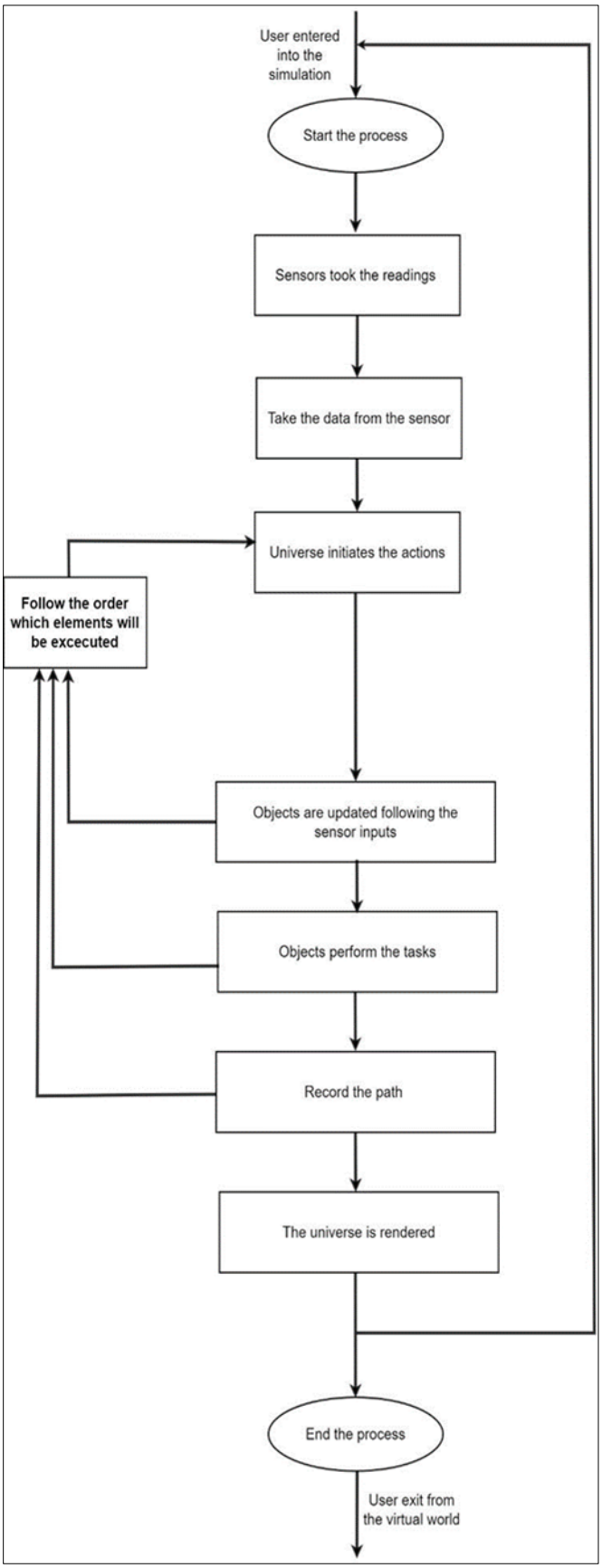

Figure 4 VR Simulation Flowchart to Connect with the Virtual World. (Source: WorldToolKit Reference Manual (R9))

- M *etaverse dependency on Augmented Reality (AR)*: With augmented reality, a real-world environment may be improved or replaced with a simulated or virtual one using a reality technology (such as a smartphone with an AR mobile app) [167]. AR improves both the actual world and the virtual world [166]. Users of AR have control over both their physical and virtual presence.
  The most popular software and applications for augmented reality run smoothly on mobile devices [168]. They help users to access a digitally augmented world in a few simple processes. All they have to do is turn on the cameras on their smartphones, look around them through the phone's screen, and rely on augmented reality software to improve the experience. Digital overlays are used for this in a variety of ways, including

The presence of labels

  - Superimposing digital images, 3D models, and other data
  - Real-time instructions are inserted into navigation applications
  - Changing hues according to environmental changes
  - Using filters on Snapchat, Instagram, and other platforms, users can alter their appearance or surroundings [169].

AR working procedure is-

  - A device with a built-in camera and AR software are needed for augmented reality to overlay digital elements on a real scene. Smart glasses, a tablet, or a smartphone are all options.
  - To process the camera's video feed, the program uses computer vision. This makes it easier to identify things in the actual world. The method aids the AR channel in projecting digital content to a specific location.
  - The tool then uses the display device to simulate a real-world setting by superimposing the virtual pieces on top of the original environment.

- *Metaverse dependency on Extended Reality (XR)*: A broad term known as "extended reality" or "cross reality" (XR) refers to several immersive technologies that create electronic, digital settings in which data are represented and displayed [170]. Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality are all parts of XR [171]. In all of the XR aspects outlined above, people view and engage with a totally or partially artificial digital environment created by technology [199].

  Technologies that provide multimodal interactions with digital people, objects, and settings are the foundation of the Metaverse. The stereoscopic displays that can transmit the sense of depth allow the XR system's representational fidelity to be achieved [172]. Displays that simulate sight in actual situations and are different for each eye make this feasible. High-resolution XR screens provide an extensive user field of vision, ranging from 90 to 180 degrees [163]. Furthermore, compared to 2D systems, XR systems provide better audio experiences. In AR and VR, soundscapes may be created using 3D, spatial, or binaural audio, significantly improving immersion.

  XR systems use motion controllers to enable direct contact with virtual objects. They have a grip, buttons, triggers, thumbsticks, and portable input devices. Users may touch, grab, move, and control virtual items with the controllers [164]. They become active participants in any educational experience thanks to this potential. On this front, creating comprehensive hand tracking will enhance the user interface toward a more natural experience. Additionally, research is being done on touch-responsive wearables such as haptic suits and gloves.

  Users do not need to be seated to interact with XR settings. Instead, users may make their whole body active. Positional and rotational tracking are used to translate physical movement into XR settings. Movement can be monitored using either exterior, fixed cameras (outside-in), or internal headset sensors and cameras (inside-out), which measure changes in position concerning the surrounding environment. The latter is utilized in wireless, standalone headphones. A crucial metric representing an XR headset's ability to monitor motion is the supported degrees of freedom, or DOF [165]. Early, simpler headsets support three rotating head movement DoFs. All six DoFs are supported by modern, high-fidelity headsets, which also offer lateral body movement along the x, y, and z axes. Perpetual movement translation using unidirectional treadmills is one horizon for occluded VR worlds.
- *Metaverse dependency on Mixed Reality (MR)*: Real-world and virtual (digital) objects can interact in mixed reality thanks to the combination of elements from AR and VR [173]. Mixed reality (MR), which unifies these two ideas, is a technology that unifies VR and AR. The idea behind MR is to create virtual objects that let users interact with the 3D environment while immersed in a virtual world with VR or overlaid with virtual content

with AR [174]. Because the hardware is relatively simple and accurately reflects reality, like glasses, AR offers a more realistic solution, but it is only appropriate for brief content [175]. On the other hand, VR involves physical fatigue despite covering the entire field of vision, having an immersive feeling, and being appropriate for long-form content. In some situations, MR is being explored as a solution that can be converted to AR and VR with a single device since it combines these benefits and drawbacks. The extended reality, or XR, is a concept that refers to VR, AR, and MR. Indirect experiences mediated by computers are made possible by XR in virtual commerce or v-commerce [176].

4.2. Dependency of Metaverse on Modern Technologies

Metaverse dependency on Blockchain: The blockchain serves as the base on which the Metaverse is now expanding. Imagine if Facebook and Google, two of the biggest technological names, desire to combine their platforms. The users can communicate across all boundaries in this fashion. However, the platforms and technology used by the companies differ. Additionally, they require a practical solution to control their connectivity within the Metaverse.

Decentralized applications, accessing blockchain data without owning a user node, streamlining Web 3.0 development, using web sockets to access real-time transaction data, and accessing massive amounts of data are all made possible by Web 3.0's RPC layer and blockchain as shown in Fig. 5.

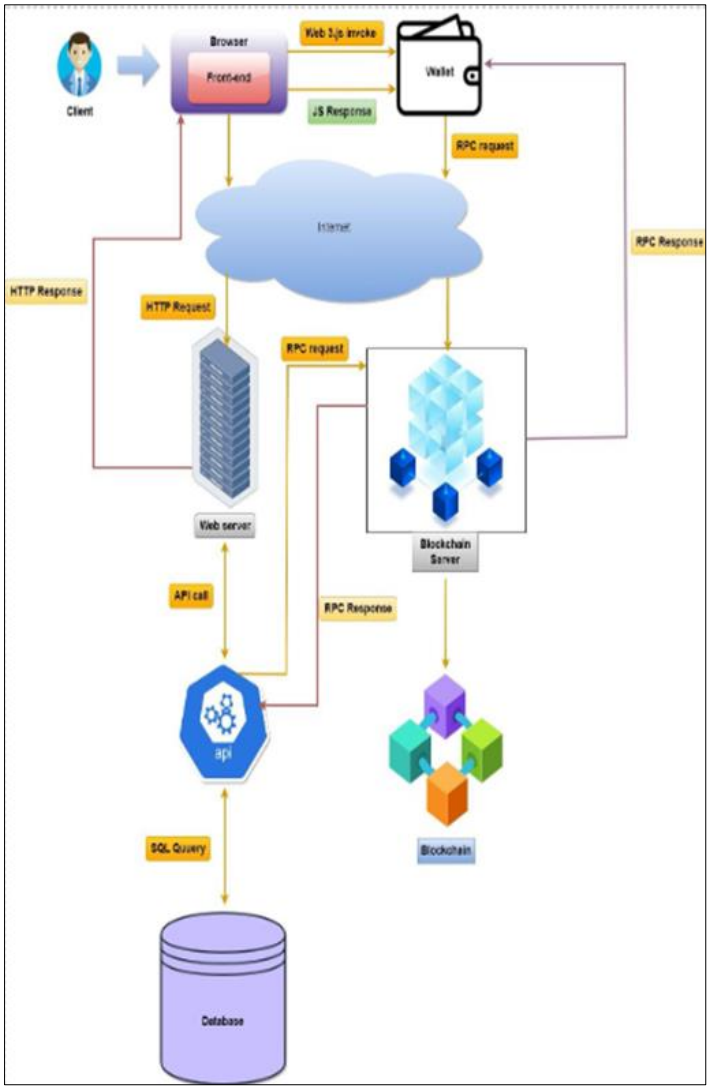

Figure 5 Decentralized Data Driven Technique Using Blockchain in Web3.0

Blockchain has developed as a platform on which the Metaverse may develop and coexist [177]. Several of the Metaverse's present components utilize blockchain technology-

- Transaction recording: A network of autonomously operating computers operates the distributed ledger known as the Blockchain [178]. Due to the Blockchain's autonomy, many parties can conduct transactions among themselves and record those transactions on the Blockchain without the need for a centralized authority [179]. In addition, the Blockchain is transparent and immutable, which means that once information is recorded, it cannot be changed [180]. So Blockchain is significant for owner transfer and financial recording [181]. Blockchain technology is significant for storing transaction data with highest level security in a decentralized way following-
    - Digital asset collectability: Issuing digital assets may take less time than paper-based or physical assets [182]. The electronic nature can help speed up the transaction process, cutting down on administrative and physical storage expenses. These are a few explanations for why both central and private banks are considering utilizing digital assets and blockchain technology.
    - Proof of ownership: The original blockchain was intended to function as decentralized, meaning that no bank or regulatory body would regulate who transacted, but transactions still needed to be verified. This is accomplished with the use of cryptographic keys, a string of information similar to a password that identifies a user and grants access to their system "account" or "wallet" of value [183]. Each user has a private key that is unique to them and a public key that everyone can view. Combining the two creates a secure digital identity, allowing users to be verified via digital signatures and to "unlock" the transaction they want to complete.
    - Blockchain Interoperability: Blockchain interoperability, or simply the ability of blockchains to communicate with one another and perform tasks like accessing and sharing data, executing smart contracts, transferring digital assets, and improving collaboration, is the integration of the operations of multiple blockchain networks [184].

Imagine a bank whose use is restricted if customers can only conduct transactions with other accounts within the same bank instead of a bank that will allow a user to engage with accounts in other banks. This is an excellent way to visualize interoperability, which is also sometimes referred to as cross-chain interoperability. The majority of consumers will concur that the latter is considerably better.

There are two ways to achieve the blockchain interoperability-

- Cross-Chain technology: Cross-chain technology is designed to facilitate network transactions by serving as a bridge [185]. For example, consider the two distinct networks, Bitcoin and Ethereum, which cannot communicate with one another. Technically, cross-chain technologies and protocols might make it possible to build a network that connects Bitcoin and Ethereum and allows for direct information exchange between them [186]. However, compatibility is still one of the most significant hurdles due to the complexity required to build a network that can adapt to each blockchain's characteristics.
- Side-Chain technology- A "separate blockchain that runs independently of Ethereum and is connected to Ethereum Mainnet by a two-way bridge" is what Ethereum defines as a sidechain. In other words, the technology entails a network that runs parallel to the primary blockchain. In contrast, the sidechain network maintains connections to the primary network for its nodes and code, making it completely interoperable. Sidechains are frequently used to speed up transactions, cut costs, and test network features [187].

The Metaverse is currently in the early stages of development but is continually changing. Leading technologists have predicted that several new technologies would propel the Metaverse's growth in the future and encourage the creation of various use-case portfolios that improve the Metaverse's capacity to provide real-world services. Additionally, as is already evident, the development of blockchain technology is significantly influencing the world of digital assets. As a result, blockchain technology is predicted to play a significant part in realizing the dramatic and noticeable effects of the ever-expanding Metaverse on our daily lives.

4.2.1. Metaverse dependency on NFT: Digital assets known

As Non-Fungible Tokens (NFTs) signify ownership of items like photos, social media postings, movies, artworks, etc. However, NFTs are not limited to pictures, paintings, and movies; they also represent the tokenized form of real-world assets like real estate or structures [240]. On the other hand, the notion of the Metaverse has been given many different definitions by different people. The Metaverse, a 3D virtual environment, aims to replicate and improve the real-world experience online [189]. Many leading blockchain and technology businesses have stated their interest in the Metaverse

and their intention to use it to support the goals of their various companies. For example, since Facebook has evolved into more than simply a social networking platform and Microsoft has been developing an interactive workspace dubbed the Microsoft Mesh, Facebook chose to alter the name of its parent business to Meta [190].

Fields in Metaverse where NFT are used-

- Community buildup in Metaverse: NFT contributes significantly to the Metaverse by enhancing people's interactions with social gatherings and communities. People can better understand the appearance and preferences of their fellow community members by using NFT avatars [191]. Furthermore, by purchasing some NFTs assets, technology project communities can create a community in the Metaverse [192]. This will strengthen the bonds between neighbors.
- Virtual land ownership: The roles that NFTs and the Metaverse play in virtual land ownership complement one another. NFTs may be used to buy and sell lands in the Metaverse since the goal of the Metaverse is to simulate the actual world [193] better. Even online stores for events can be rented out with NFTs, allowing the owners of the digital land to make passive income [194].
- Marketing: By using NFTs to reach larger audiences, businesses finally understand their position in the Metaverse. Businesses now market to or offer digital items to younger audiences even before the physical ones are ready for purchase. As a result, the brand's visibility and audience reach are boosted [195].
- Transfer of ownership: NFTs play a significant role in the Metaverse by making it simple for enterprises to transfer product ownership from them to their clients [196]. Business brands now introduce their goods in the Metaverse and provide interested parties access in exchange for NFTs. In addition, NFTs make it simple for game businesses to claim ownership of skins, tanks, and other collectibles.
- Prevention of counterfeits: Every industry has instances of piracy, which lowers a product's value. By creating digital scarcity, the connection between NFTs and the Metaverse reduces counterfeiting across all industries. Now that companies can introduce their goods into the Metaverse, nobody can invent another.

Gradually new, creative concepts like Metaverse and NFTs are brought into the digital world. The goal of the Metaverse is to duplicate our real world digitally. Many people and businesses have adopted the Metaverse because of its decentralization and interoperability capabilities, and it is also the new face of the internet. NFTs are a crucial part of this 3D virtual environment and play a significant role in the Metaverse.

5. Limitations and Future Research Opportunities

5.1. Cooperation in Between Multiple Sectors

Industries including finance, gaming, information technology, Blockchain, Cloud Computing, Artificial Intelligence (AI), and Virtual Reality (VR) are all debating the idea of the Metaverse. However, the creation and widespread refinement of the Metaverse application scenarios will only occur when all participants are in the same setting and actively conversing.

5.2. Lack of Development in Trusted Infrastructure

With cloud computing, 5G, and explainable artificial intelligence, blockchain may serve as the meta-foundational universe's technology in addition to delivering value and guaranteeing reliable security [200]. In order to address a variety of present issues, such as transmission performance, excessive latency, etc., future uses of the Metaverse will undoubtedly need a substantial amount of infrastructure. In addition to advancements in the comfort and dependability of VR, AR, and MR technologies, as well as wearable technology, the development of major internet platforms, including modeling and rendering, device parameters, 6G networks, etc., is a critical issue.

6. Conclusion

The Metaverse promises an immersive environment without limits and has broad development and application prospects. Metaverse is still taking shape, and brands from all industries are coming in front to play a role in designing it. This paper attempted to provide an in-depth idea about Metaverse, its application, and why it is so important. Then it also discussed the characteristics of Trustworthy AI. Finally, the concept of Metaverse and trustworthy AI have been combined and discussed how to gain trust in Metaverse and why it is so important. With the growing interest and usage of Metaverse in the current world that significantly impacts our lives, it is crucial to understand how to trust it. All the Key factors in the virtual reality space need to work together to achieve common standards and protocols for building

virtual worlds for the Metaverse to become fully trusted and developed. Regulatory bodies should also establish scrutiny and monitor how to make this Metaverse concept fully trusted and a reality.

Compliance with ethical standards

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No conflict of interest to be disclosed.

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