

## TOPICAL REVIEW

# The Metaverse: Applications, Concerns, Technical Challenges, Future Directions and Recommendations

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**ABSTRACT** The Metaverse is all about expanding connectivity amongst users and objects and seamlessly delivering information and services to the right user at the right time. Its potential advantages are virtually limitless, and its applications are progressively changing the way we live, and are opening new opportunities for innovation and growth. It is crystal clear that the Metaverse can enable fully immersive experience, elements of fantasy, and new degrees of freedom. However, it is still considered controversial since it will also open up opportunities for misconduct and crime. Furthermore, the industry lacks the capacity to carry out a comprehensive study of the potential risks that will come along. This paper highlights the current and envisioned Metaverse applications along with the main concerns and challenges faced by the Metaverse stakeholders. Furthermore, it examines the strengths, weakness, opportunities and threats of the Metaverse technology. Finally, the paper presents the future directions and highlights the most important recommendations for developing the Metaverse systems.

**INDEX TERMS** Metaverse, Internet of Things (IoT), wearable technology, virtual reality.

## I. INTRODUCTION

The Metaverse has been a hot topic of discussion recently, with Facebook and Microsoft both staking claims. We have all heard that the Metaverse is going to change the way we live, so what exactly is the Metaverse?

The Metaverse is a hypothesized rendering of the Internet, where the real and virtual worlds are fused together through conventional computing via virtual and augmented reality (VR/AR) headsets, giving users a persistent online 3-D space to meet, work, shop, and do everything one can on the Internet and more. The Metaverse provides an experience so people can interact with one another in a more immersive fashion, but not physically [1].

While wearing a VR/AR headset, the user is able to virtually attend a business event or even a concert, as if they were there in person. Aspects of the Metaverse have already been

implemented in virtual world platforms of popular games such as Roblox.

The concept of Metaverse is not new. It was first mentioned in the 1992 novel *Snow Crash*. Later on, a plethora of companies attempted to develop online communities based on the concept, most notably, the game “Second Life”, which was released in 2003 [2], [3].

In nowadays somewhat primitive Metaverse, people employ avatars to portray themselves, communicate, and build out the virtual community. Users roam a virtual world that mimics aspects of the physical world using technologies such as VR, AR, Artificial Intelligence (AI), haptics, and blockchain. Digital currency is used to buy items such as clothes, skins, or weaponry in the case of video games. Users can also virtually explore educational spaces, and travel the world using a VR headset and controllers [5].

The ever-growing internet has given rise to many services that are advancing the creation of the Metaverse. Conversely, many see the Metaverse as a successor to the Internet;

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however, the Author does not see the Metaverse as the next Internet or posing as its competitor, but rather builds on it and utilizes it to operate. The Internet is something that users “browse”, while, to a certain degree, people can “live and perform tasks” in the Metaverse. According to a recent market report, Credit Suisse defined the Metaverse as “a more spatially immersive, compelling and frictionless Internet which comprises five essential components: infrastructure, hardware, content, platforms or communities and payment mechanisms.” [6].

The concept of the Metaverse has already sneaked to the business world and captured the imagination of innovation leaders. Metaverse technology is making its remarkable presence not only in business, but also in education, shopping, fashion, and even the real estate market. The marvelously wide range of applications and potential benefits of the Metaverse means it is only a matter of time before the concept becomes mainstream and a part of reality, and will no longer be limited to gaming and entertainment [7].

The Metaverse has already cemented itself as an investing theme of the future with giant companies actively investing efforts, capital, and time in developing Metaverse projects. Grand View Research anticipates that this industry will grow at an annual rate of 39.4% through 2030 and reach a market size of \$678 billion. Another study by PwC estimates the increase in global economic output through VR and AR to be over \$1.5 trillion by 2030 [8], [9].

Meta (formerly Facebook) has spent \$10 billion on Metaverse technologies in 2021 alone. The company’s endeavors included ventures in its VR hardware, social VR apps like Horizon in addition to its AR wearables. Roblox’s protometaverse world generated \$454 million in the second quarter of 2021 with more than 43 million daily active users. In 2018 and 2019 alone, Epic has made more than \$9 billion with Fortnite. It’s worth noting that Apple has remained away of the Metaverse hype, however, it’s evident from the company’s tremendous investments in AR hardware that it wants to be part of whatever the future will bring [10].

It is worth noting that the hype of the Metaverse has waned a bit in the first months of 2023. This is due to a number of factors, including Meta’s Reality Labs unit, which is responsible for developing the Metaverse, recording an operating loss of \$4.28 billion in the fourth quarter of 2022; the high costs of VR development; the slowing down sales of VR and AR headsets; and the association of the Metaverse with struggling Web3 technologies. Moreover, the spotlight has shifted sharply to generative Artificial Intelligence and its endless possibilities, which has made the nowadays talk of the Metaverse largely centers on its demise.

As a result of all of these factors, some experts believe that the Metaverse is dead, while others believe that it is simply going through a period of consolidation. However, Apple’s announcement of the Vision Pro mixed-reality headset on June 5 2023 at its annual Worldwide Developers Conference has been met with much excitement and anticipation. The headset is the company’s most ambitious product launch since

the Apple Watch was released in 2015, and it could certainly be the kiss of life the Metaverse needed.

The authors believe that maybe the “hype” of the Metaverse has waned, but the concept itself is certainly here to stay. The journey to have the Metaverse as a fully established, mainstream technology will be bumpy, and could take some time, as the underlying technologies continue to develop and evolve, on both the hardware and software front, but it will certainly not die.

The motivations behind conducting the current study are:

- **Exploration of Metaverse Applications:** The Metaverse has the potential to revolutionize the way we live, work, and interact. By exploring its current and potential applications, the study aims to shed light on the transformative possibilities of this technology. Understanding how the Metaverse can be utilized in various aspects of life can help uncover new opportunities and enable individuals and businesses to leverage its benefits.
- **Identification of Concerns and Challenges:** While the Metaverse presents promising opportunities, it also raises concerns and challenges. Misconduct and crime are potential risks associated with the Metaverse, and stakeholders need to be aware of these issues. By identifying and analyzing these concerns, the study aims to provide insights into the potential risks and inform stakeholders about the precautions they need to take.
- **Evaluation of Strengths, Weaknesses, Opportunities, and Threats (SWOT Analysis):** Assessing the strengths, weaknesses, opportunities, and threats of the Metaverse technology is crucial for understanding its overall potential and limitations. This evaluation helps stakeholders gain a comprehensive understanding of the Metaverse’s capabilities and drawbacks, enabling them to make informed decisions regarding its implementation and adoption.
- **Exploration of Future Directions and Recommendations:** The study aims to explore the future directions of the Metaverse technology, considering advancements and emerging trends. By highlighting the latest recommendations from researchers, the study provides insights into how the Metaverse systems can be developed and enhanced to maximize their effectiveness. This information can guide stakeholders in making strategic decisions and investments in the field of Metaverse technology.
- **Addressing Controversies and Industry Capacity:** The Metaverse, while showing tremendous potential, is still a controversial topic due to concerns about misconduct and crime. Additionally, the industry currently lacks the capacity to conduct a comprehensive study of the potential risks associated with the Metaverse. By addressing these controversies and highlighting the potential concerns and challenges faced by stakeholders, the study aims to contribute to the understanding of the Metaverse

and promote responsible development and implementation of this technology.

Overall, the motivations behind this study are to provide insights into the current and future applications of the Metaverse, to address concerns and challenges, to evaluate its strengths and weaknesses, and to provide recommendations for its development, with the aim of maximizing its benefits while mitigating potential risks.

The aims of this study are to:

- 1) To report the current and latest applications of the Metaverse, highlighting their potential to revolutionize the way we live, work, and interact.
- 2) To identify and analyze the potential concerns and challenges faced by stakeholders in the Metaverse, including the risks of misconduct and crime.
- 3) To examine the strengths, weaknesses, opportunities, and threats of the Metaverse technology.
- 4) To explore the future directions of the Metaverse technology and highlight the most important recommendations for developing the Metaverse systems.

The potentiality of the Metaverse will virtually touch all areas of our lives and put forward new ways and styles of living. Virtual venues can be laid out for events meetings, and gatherings in the Metaverse, lands and houses can be traded and purchased. Immersive traveling is possible too. It's crystal clear that the Metaverse is here to stay, however, the topic is still considered controversial since it will also open up opportunities for misconduct and crime. Further, the industry lacks the capacity to conduct a comprehensive study of the potential risks. This paper presents the current and envisioned Metaverse applications along with the potential concerns and challenges faced by the Metaverse stakeholders.

Our scientific contributions are listed below:

- 1) We report on the latest applications of the metaverse technology, concerns and technical challenges. Also, we report on the future directions of the metaverse technology and offer recommendations for the researchers to develop and improve upon the metaverse projects.
- 2) To offer a more in-depth coverage of the challenges, we report the technical challenges that are faced by stakeholders when it comes to the development and implementation of the Metaverse technology. This is further supported by real-world examples. Overcoming these challenges requires collaboration, research, innovation, and continuous improvement in the building blocks and infrastructure of the Metaverse to create a seamless and immersive experience.
- 3) We present strengths, weaknesses, opportunities, and threats of the Metaverse technology (SWOT analysis). The Metaverse technology has significant strengths, including its immersive experience, innovation in new areas, global accessibility, and economic growth potential. However, it also faces weaknesses, such as technical challenges, limited user base, cost, and dependence on other technologies. The Metaverse

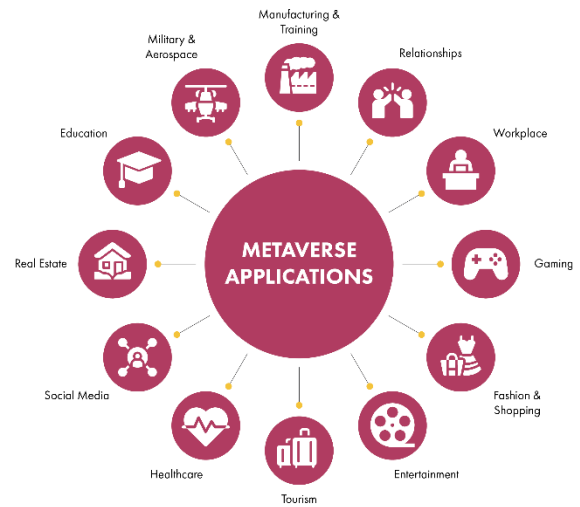


FIGURE 1. Applications of the Metaverse.

presents opportunities for collaboration, new business models, education and training, and social impact. However, it also faces serious threats, such as privacy and vulnerable security, addiction, social isolation, legal and regulatory issues, and competition. A balanced approach is needed to maximize the strengths and opportunities of the Metaverse while addressing its weaknesses and threats.

## II. APPLICATIONS

Gaming and social networking sites are among the most often mentioned use cases of the Metaverse. However, there are several other promising entrants that showcase the real potentials of what the Metaverse can offer in the near future. Let us have a look at the top use cases of the Metaverse across the various industries.

### A. WORKPLACE

The Metaverse is currently being developed by organizations with insight. Virtual Reality showrooms can demonstrate a new truck, automobile, or recreational vehicle instead of traveling to trade shows. A new product in development can benefit from the collaboration of engineers, marketers, salesmen, financial analysts, and creative professionals [11] It's worth mentioning that even governments plan to expand their authority into the Metaverse. For example, while most nations have a relatively traditional presence on the Internet, Barbados plans to open a diplomatic embassy in the Metaverse realm [12]. Further, the increasing popularity of the Metaverse is giving rise to significant changes to the conventional business processes. Projects that are deployed today will enable:

- **Work from Home in a Virtual Environment:** With the adoption of the Metaverse, it will be unnecessary for

employees in certain fields to be present in the workplace on site.

- **In-person Interaction with Co-workers in the Workplace:** In order to keep up with technological advancements, virtual offices are being established. Further, communication and collaboration in working spaces will be accomplished via VR/AR technology simply, conventional office will become obsolete at some point. This is driven by the growing number of users with diverse industry backgrounds that are interested in practical experience. For example, working on system and equipment maintenance, factory production lines, and bringing all required employees into a single room are examples of VR-first efforts in the manufacturing industry.
- **Holding Remote Meetings:** Currently, such meetings are held over Microsoft Teams or Zoom, but as technology progresses and virtual rooms become more popular, they will eventually be hosted in a virtual room where an avatar will represent each participant. At a later stage, these avatars could be replaced by a realistic 3D model of users that reflects expressions and gestures.

## B. FASHION

The fashion business, which is considered one of the most progressive sectors of the economy, is continuously bringing in new trends geared for the Metaverse technology. On Roblox, one of the most remarkable examples is Gucci, which developed the “Metaverse Design” category. Users can now purchase special clothing from the infamous fashion store while on the gaming platform. In fact, there was a recent sale of a digital Gucci bag for \$4,000, showing that the virtual fashion business is already turning into a considerable source of revenue for the market leaders.

Because of the massive popularity of NFTs, the day will soon arrive when unique virtual collections of the world’s most prestigious fashion companies’ will be sold for millions of dollars [10], [12].

## C. SHOPPING

Nowadays, many business owners and entrepreneurs are enthusiastic about the potentials of virtual reality, believing that online shopping will soon expand from a two-dimensional experience into an extraordinarily immersive 3D experience. These benefits, including the opportunity to try on, feel and test the goods, as well as the ability to seek online guidance from a seller, will be preserved even though the experience will be free of real-world constraints.

Furthermore, many experts in the field believe that one of the most potential uses of the Metaverse technology is virtual shopping, which provides the opportunity to own the purchased object or service in the actual world. The need to go to shopping malls will no longer be necessary in the near future. Conventional online shopping will be phased out at some point, and virtual shopping at a Metaverse supermarket will become the norm.

In collaboration with a garment brand from South Korea, Ader Error, the Spanish clothing giant, Zara, has launched a new collection line for both people and avatars. Physical and virtual attires can now be purchased at network stores throughout the world. Nike is also surfing the virtual goods wave with launching “Nikeland”, a virtual showroom on Roblox where visitors can dress up their avatars in Nike clothes and shoes [12], [13].

## D. SOCIAL NETWORKING/ENTERTAINMENT

Metaverse has the potential to completely transform the worlds of social networks and online entertainment in the years to come. This is simply due to the fact that users in the Metaverse will have a lot more immersive experience in the virtual world than they would have in the current social platforms.

Social platforms will soon grow into fully functioning Metaverses and transform into virtual worlds where individuals will spend their time not only conversing or looking through images but also interacting with avatars or realistic clones of users.

A clear indication of where social networks are headed is the fact that Facebook has already renamed itself “Meta”. Also, with the introduction of widely accessible virtual reality capabilities, we can predict a massive development in this area and a significant transition of users away from the regular web and toward the Metaverse [13].

Most games in the Metaverse are based on the “play to earn” concept, which allows users to collect virtual gaming items that they can then trade or sell to get real-world money. Members of the Metaverse may invite their social media friends to join them in playing the games, engage with other users of the Metaverse, and collaborate to enjoy the games as a group. Moreover, players can create goods, sell or purchase them, as well as invest in and compensate other people in the game. As users move through an ecosystem of competing goods, the Metaverse effortlessly mixes games, virtual reality, live-streaming, cryptocurrency, and social media into one seamless experience.

One aspect that has already come to fruition is the fact that real-life musicians is now performing within video games. Minecraft, Fortnite, and Roblox have put up a schedule of concerts by musicians such as Lil Nas X, Royal Blood, 333, IDLES, and Ariana Grande.

Gameplay in a Metaverse setting has the potential to permeate other genres in the future. Examples include the use of VR technology to create a fully-immersive 3D scene for players to walk into at the greatest online casinos in the United States. Like an alternative to choosing a slot game from a list of numerous possibilities, customers may stroll across a virtual gaming floor and insert their virtual chips into the machine as they did in real life [14].

The Metaverse will allow sports organizations to reward their fans by extending events beyond the confines of live games. Fans at digital stadiums in the Metaverse might watch

teams and athletes compete in real-time through live streaming. Viewers may even visit the field itself, stroll with the players, join the football cheerleading and watch the game from a variety of vantage points, thanks to multi-view camera technology. In addition, Metaverse enables people to virtually sit in the same room as their friends, even if they are physically thousands of miles apart.

### **E. TOURISM**

Virtual tourism is one of the most innovative Metaverse applications. Because technology allows you to travel in virtual space, you don't have to go to the destinations that interest you in person to experience them. Experts predict that the development of an immersive digital environment that combines virtual and augmented reality will represent a breakthrough in the tourism field. A digital area loaded with realistic and immersive content has the potential to become a product that will serve a population of tourism enthusiasts who are unable to physically travel.

We have already witnessed the beginnings of 360-degree virtual tours. Instead of just watching a video tour recorded by a guide, you will be able to experience being there at the destination site. Furthermore, you can go to this location with your family members and friends, which will make your trip much more genuine and enjoyable.

Since its inception, virtual reality has already gained major traction in the tourism arena. For instance, enabled by the Visualize technology, Thomas Cook introduced the Virtual Reality Holiday 'Try Before You Fly' service, which allowed prospective tourists to experience holiday locations via VR before making the decision to go. After using this service, the client might make a more informed decision about whether or not they wish to go to the destination under consideration. The result was fascinating; for example, after participating in a 5-minute VR excursion in New York, the number of tours booked in the city more than doubled [15].

### **F. HEALTHCARE**

Using augmented reality to train and educate future medical professionals provides significant benefits in terms of improving their skills and knowledge base and also to lower expenses. In order to facilitate and speed up surgical operations, physicians use medical assistive technologies such as Microsoft HoloLens. Additionally, AR headsets are being utilized to view critical patient data such as pulse rate, body temperature, heart rate, and respiratory rate, in real time. Additionally, images from CT, MRI, and 3D scans can also be accessed.

In order to improve vein identification, medical staff are increasingly using augmented reality. This solves the issue of many people having difficulty locating a vein, especially if their skin is very pigmented or if they have small blood vessels. Although the use of visual-driven technologies such as X-rays and CT scans exist, AR will further assist medical professionals in diagnosis and treatment of a variety of conditions. It is also worth mentioning that studies show

that using VR in training surgeons has led to a performance improvement of more than 230% [16].

### **G. MILITARY**

The field of military has also witnessed significant advancements when it comes to utilizing augmented and virtual reality. Night-Vision Goggle (NVG) is a kind of technology that lies under the umbrella of Tactical Augmented Reality (TAR), but it has far more capabilities. It could show the precise location of troops and the locations of allies and opposing forces on a map. The device can be integrated with the helmet which would eliminate the need for soldiers to look at their GPS position while on the battleground.

On the other hand, Synthetic Training Environment (STE) is an AR system that simulates combat scenarios to offer troops more realistic and immersive training experiences by placing them in harsh and more physically and mentally demanding battle settings. One of the primary goals of STE is to provide a training alternative that will allow commanders to construct adaptive units that have a greater level of preparation [17].

### **H. REAL ESTATE**

The main benefit here is providing prospective customers with a realistic and engaging property showing experience. The real estate business can make use of this to enable customers to virtually visit the property before making a decision to see it in person. Several multimedia aspects, such as music in the background, narrative, and light-and-sound effects, may also be incorporated into virtual reality tours. Such elements provide a sense of realism and excitement in the experience and boost the customer's enthusiasm and confidence before they commit. Through the use of virtual tours and supervised walkthroughs, clients may get an immersive look at the property and its surroundings. This gives prospective buyers and renters a peace of mind regarding a variety of choice criteria, such as traffic conditions or the atmosphere of a location, while simultaneously cutting travel time down to zero. Real estate professionals also save time and money by eliminating time-consuming showings and face-to-face interactions with potential buyers and sellers.

Contrary to traditional tours, virtual walkthroughs may be customized to appeal to a wide range of client tastes and preferences. Customers who are very visual will benefit from the lighting, interior design, and zooming features, among other things. Pop-up information windows may be also included to provide more details, statistics, and space measurements for data-oriented clients [10], [12].

### **I. MANUFACTURING, TRAINING AND OCCUPATIONAL SAFETY**

People learn substantially faster and retain more information when studying in a hands-on setting. Because VR training takes care of everything, manufacturing enterprises do not

have to spend extra money or time on training and onboarding new employees. Workers can also understand safety procedures and take part in simulations of dangerous situations and scenarios. These technologies also contribute to developing more effective items in the marketplace. By just putting a VR goggle on, every aspect of the product can be evaluated. Further, it's shown that virtual and augmented reality technologies make it much less likely for accidents to happen in such applications.

Moreover, virtual reality may be used to develop flooring for manufacturers to use on their production lines. They can immediately suggest the most suitable position for installing the equipment while still maintaining the appropriate distance between them. It contributes to the enhancement of safety as well as the proper placement of equipment on the job.

The use of VR and AR have helped companies making processes more efficient at lower costs; for instance, BMW utilize these technologies to design vehicle concepts. A virtual tour of a manufacturing plant, for example, was created by Siemens in collaboration with VRdirect. Workers can actively participate in the realistic manufacturing setting by exploring the interactive training environment and interacting with it. Also, Ford employees utilized VR and AR technologies to access their locked-down vehicles when the coronavirus pandemic forced them to stay home.

Lastly, the health and safety of personnel is a major concern for businesses, particularly those that run sophisticated systems and heavy machinery. Employees must be kept informed regularly on industrial security and occupational safety procedures. Here, VR can be used to facilitate training and practicing safe operations with dangerous machineries and equipment. Workers can virtually conduct tests safely before performing it in real life [18].

### J. EDUCATION

When it comes to highlighting ideas via graphics, traditional teaching techniques will never be as effective as they are in the Metaverse. Regardless of their age, students would always choose to watch a video than read a book. Virtual reality technology has the potential to create fascinating experiences that could never be "experienced" in real life which deem students more motivated in studying if they have access to this technology.

It is incredibly challenging for today's teachers to create a productive and engaging learning atmosphere in the classroom. As virtual reality technology becomes more widely available in schools, the severity of this problem can be significantly reduced since most students will be encouraged to share and speak about their virtual reality experiences. Virtual reality could also assist in the discovery of flaws in the material, as well as providing superior editing capabilities which is becoming more popular. It also eliminates the language barrier which is a substantial obstacle to the educational progress for many students [19].

### K. INTIMATE RELATIONSHIPS

Technology has changed all walks of life, and the COVID-19 pandemic has made that evident. Living and working in the digital world is not only here to stay, but also to change the way we interact, and that includes intimate and sexual relations, which for sure will have their space in the Metaverse.

If one can attend virtual business meetings, concerts, and venues to interact with others, the possibility would also be for adult intimacy. Also, in order not to lose that physical bond and keep the relationship lively, individuals in a long-distance relationship could also have immersive intimacy in the Metaverse [20].

Human-Machine Interface (HMI) is already undergoing an incredible transformation. Just recently, Meta's Reality Labs division showcased a prototype of a haptic glove with ridged pads that allow the user to "feel" surface textures. Optics and displays are also taking an innovative leap. In fact, transparent lenses of combiner optics can now overlay the real world with virtual images, which will make AR glasses more practical. See-through waveguides on high-refractive-index glass can also be enabled by surface relief waveguide technology, which will support 3D sensing, and automotive heads-up and VR displays [21], [22].

To conclude, such technologies along with the fast-paced world of haptics and "real-feel" experience, virtual intimate interaction could reach its greatest potential.

## III. CONCERNS

### A. PRIVACY

Information privacy is one of the biggest concerns for Wearable Technology and IoT. The Metaverse is no exception since it is enabled by these technologies. According to a study, 55% of U.S. adults said the tracking and misuse of their personal/biometric data is a major concern. Meta is planning to employ targeted advertising within their Metaverse platform, raising further concerns related to spreading misinformation and compromising user privacy [23].

### B. ADDICTION

User addiction is another big concern. It is well documented that Internet, social media, and videogaming addiction can have negative mental and physical consequences over a prolonged time, such as depression, anxiety, and various other disorders related to inactive and seat-bound lifestyle (i.e.: an increased risk for obesity and cardiovascular diseases). A marketing professor, Andreas Kaplan, who studied the user experience of the game "Second Life" believes that the Metaverse may have an overall negative societal impact due to their considerably addictive prospects.

Psychologists and social experts are also expressing concerns that the Metaverse could be used as an 'escape' from reality similarly to what is happening currently with existing Internet technologies. Moreover, being inside a virtual space, a user may perceive time and space differently. Similar to gaming, fully engaging in the Metaverse can motivate users

to spend much more time than they initially had planned, raising the question of how the user will perceive reality while experiencing a distorted version of time during a Metaverse session. As for spatial perception, the issue here is that the Metaverse space is theoretically infinite, which implies that new users will find it challenging to adapt to the massive volume and diversity of data [24].

### C. USER SAFETY

Virtual crime and social media misconduct such as cyberbullying and sexual harassment are significant challenges facing the digital social space currently, and will for sure be prevalent in the Metaverse.

In 2022, investigations by The Washington Post and BBC News found under-age users engaging in applications designated for adult activities such as VRChat and Horizon Worlds despite an age restriction (13 years or older). Other major concerns include the potential presence of child predators hiding behind friendly looking avatars in the Metaverse platforms, along with other potentials for child depression and loneliness. In fact, according to the same study reported in the previous section, cyberbullying and online abuse in the Metaverse was the second-biggest worry, with 44% of participants indicating it was a major concern [25], [26].

### D. SOCIAL ISSUES

In 2022, The Guardian newspaper criticized the utopian mentality of tech companies who claim that the Metaverse could be a solution to worker exploitation, prejudice, and discrimination problems. The newspaper reported that they would be more supportive towards the development of the Metaverse if it was not dominated by “companies and disaster capitalists trying to figure out a way to make more money as the real world’s resources are dwindling” [27].

### E. IDENTITY AND REPUTATION CONCERNS

Theoretically, any person or even a bot can easily impersonate other users in the Metaverse. Hence, reputation has to be a crucial authentication element and a certificate of confidence concerning any object or user in the virtual space [28].

### F. SECURITY

With the full emergence of the Metaverse it will be crucial to dramatically raise the cybersecurity measures. There will for sure be further need to create new approaches and techniques to protect personal data, privacy, and digital assets. In order to enhance security and enforce a more accurate identification process, it is anticipated that users in the Metaverse will be required to provide much more personal data (even biometric) than what is currently needed [29].

### G. FINANCIAL SYSTEMS

Just like in the real world, individuals in the Metaverse could engage in financial transactions, and hence major financial companies are focusing on integrating their services in the

virtual space. It is already established that cryptocurrencies will ensure fast and secure exchange in the Metaverse which will carry out its own class of the virtual market. This will drive the need for a system with a more unique transaction verification methodology to safeguard the financial security of users [30].

### H. REGULATIONS AND LEGAL ISSUES

Establishing the regulations and laws that will govern the virtual world is of paramount importance. The Metaverse is extremely vulnerable when it comes to the rights of its participants, since it is not officially regulated as of today. According to one study, 36% of participants indicated that governmental regulations would be key when considering whether they want to be part of the Metaverse, as lawmakers foresee initial regulatory steps for the new technology [31].

## IV. TECHNICAL CHALLENGES

### A. HARDWARE

In this context, hardware includes the physical technologies and devices needed to use, interact with, or develop the Metaverse. This includes, but not limited to, the user-interface hardware (i.e.: VR/AR headsets, handheld controllers, and haptic gloves and body suits), as well as the enterprise hardware used to operate or create the virtual environments such as cameras, projectors, optical equipment, tracking devices, and scanning systems.

Although consumer electronic hardware is constantly improving and getting equipped with more powerful processing capability, more superior sensors and haptics, higher resolution screens, sharper cameras, and longer battery life, industry experts still believe that hardware constraints are what’s holding the Metaverse back from realizing its full potential.

Enabling a 3-D environment in the Metaverse is highly dependent on virtual or augmented reality technologies which already exist today; however, a great deal of work is needed to get them to be mainstream. To that end, companies are actively working towards such improvements. For example, Meta has substantially improved its Oculus VR headsets in recent years by eliminating the need to be constantly wired to a gaming box or a computer. However, even the most advanced models are still not swift enough when it comes to head tracking, and in desperate need for more powerful graphic processor units (GPUs) to solve this issue.

In addition to enhancing and creating more powerful GPUs to be embedded into VR/AR headsets, eye-tracking technology has a great potential when it comes to reducing the load placed on the hardware. Furthermore, VR/AR headsets are still too bulky and heavy to wear for extended periods of time, meaning that users have to keep their immersive sessions brief in the Metaverse. In a nutshell, the market needs lightweight product equipped with a powerful hardware [32].

In addition to the processing power requirements to create device that lets us live in a world that transitions seamlessly

between digital reality and real-life lies a huge leap in display technology.

## B. NETWORKING

### 1) BANDWIDTH

Bandwidth is commonly thought of as 'speed', but it's actually refers to the maximum amount of data a connection can handle at any moment. Speed refers to the maximum rate data can be transmitted, typically measured as megabits per second (Mbps) and gigabits per second (Gbps).

Obviously, the requirements for the Metaverse are much higher than most nowadays Internet applications and games, and is expected to drastically increase as the complexity of virtual processes grows.

Currently, some platforms benefit from the fact that a number of previously-made digital assets are widely repurposed and slightly modified/customized. For example, Roblox is mostly streaming data on how to modify previously-downloaded objects. However, the virtual platform will eventually require a near-infinite number of transformations and creations. Many online gamers already struggle with bandwidth and network congestion in games that require only positional and input information. The Metaverse will further intensify these needs. The good news is that broadband connectivity and bandwidth is continuously improving worldwide. Machine learning algorithms fueled by the ever-improving computational power can also help substitute for constrained data transmission by predicting what output should be triggered while waiting for the actual input data from the user [33].

### 2) LATENCY

Latency, one of the networks' biggest challenges, refers to the time it takes for data to travel from one node to another (round trip). In most modern applications, it does not matter if it takes 100 ms or 200 ms or even three-second delay from the time a WhatsApp message is sent and a read receipt is received. Likewise, it does not matter if it takes up to 500 ms after a user clicks YouTube's skip button until the next video starts. On the other hand, when watching a subscription streaming service like Netflix or Hulu, it's more important that the show plays continuously without buffering than played right away. To that end, streaming services delay the start of a video stream on purpose so that your device can download ahead of the very instant you're watching. That way, if the network encounters a congestion or hiccup for a second or two, you'll never notice. Unfortunately, latency has bigger impact when it comes to Metaverse environments where fluidity and real-time feel are of paramount importance [34].

### 3) RELIABILITY

By reliability, we mean the consistency with which the connectivity is available. Our ability to shift to a virtual environment where business, education, and entertainment take place is highly dependent on a reliable quality of service.

This covers both overall uptime (the time when a network is up and running), as well as the consistency of other aspects of the network such as download/upload speed and latency. That said, subscription services such as Netflix streams in 1080p or even 4K quite well most of the time. However, it should be noted that such services leverage reliability solutions (such as the buffering example we mentioned in the previous section) that will not work well for gaming or Metaverse applications.

## C. DESIGN, IMPLEMENTATION, AND MAINTENANCE

To offer a more in-depth coverage of the challenges, we report the technical challenges that are faced by stakeholders when it comes to the development and implementation of the Metaverse technology. Based on the authors' experience in the field, here are the most important relevant issues:

- **Interoperability:** Compatibility among different platforms, applications, and virtual worlds is a significant technical challenge. To solve this problem, the stakeholders need to establish common standards and protocols to exchange data with happening any sudden changes, interruption or difficulty. For instance, enabling avatars from one Metaverse platform to interact with virtual objects in another platform requires addressing compatibility issues and establishing appropriate communication frameworks.
- **Scalability and Performance:** Building a Metaverse that can handle a large number of concurrent users and deliver a high-quality experience is a complex task. Stakeholders must address challenges related to scaling the infrastructure, minimizing latency, optimizing network bandwidth, and handling massive amounts of data in real-time. For example, ensuring smooth interactions and responsiveness in a densely populated virtual environment can be technically demanding.
- **Real-time Communication:** Enabling real-time communication and networking capabilities within the Metaverse is crucial for user interactions and collaboration. Stakeholders face challenges in developing efficient communication protocols, and maintaining synchronization across distributed systems. For example, enabling seamless voice chat, video conferencing, or virtual events in the Metaverse requires robust networking infrastructure and protocols.
- **Content Creation and User Experience:** Providing intuitive and user-friendly content creation tools and interfaces is vital to empower users and promote engagement. Stakeholders must develop tools that allow users to create and customize virtual objects, environments, and experiences easily. Ensuring a smooth user experience while creating and interacting with virtual content is a serious challenge. For example, designing intuitive drag-and-drop interfaces or enabling interactive scripting for user-generated content can be technically complex.



- **Artificial Intelligence and Virtual Characters:** Creating intelligent virtual characters within the Metaverse involves technical challenges related to artificial intelligence. Stakeholders need to develop sophisticated AI algorithms that can understand and respond to user interactions, exhibit realistic behaviors, and adapt to dynamic environments. For example, implementing AI-driven virtual assistants or virtual characters with natural language processing capabilities requires advanced AI techniques and data processing capabilities.
- **Data Management and Analytics:** The Metaverse generates vast amounts of user data, including interactions, preferences, and behavior patterns. Stakeholders face challenges in managing, processing, and analyzing such data to gain insights, personalize experiences, and improve the platforms while ensuring data privacy, scalability, and effective data governance. For example, implementing robust data storage and analytics systems to understand user behavior and provide personalized recommendations requires advanced expertise in data management and analytics.

These are some important examples of the technical challenges that Metaverse stakeholders encounter. Overcoming these challenges requires collaboration, research, innovation, and continuous improvement in supporting technologies and infrastructure to build a seamless and immersive experience.

## V. SWOT ANALYSIS

This section presents the strengths, weaknesses, opportunities, and threats of the Metaverse technology:

### A. STRENGTHS

- 1) **Immersive Experience:** The Metaverse provides users with an immersive experience, allowing them to interact with each other in a 3D environment.
- 2) **Potential for Innovation:** The Metaverse has the potential to be a hub of innovation, allowing for the development of new technologies and applications.
- 3) **Global Accessibility:** The Metaverse can be accessed from anywhere in the world, making it a global platform for communication, collaboration, and entertainment.
- 4) **Economic Potential:** The Metaverse has the potential to create new economic opportunities, such as virtual real estate, virtual goods, and virtual services.

### B. WEAKNESSES

- 1) **Technical Challenges:** The Metaverse faces technical challenges related to scalability, interoperability, and latency.
- 2) **Limited User Base:** The current user base of the Metaverse is relatively small, limiting its potential impact.
- 3) **Cost:** The cost of developing and accessing the Metaverse can be prohibitively high, limiting its accessibility.

- 4) **Dependence on Technology:** The Metaverse is dependent on several other technologies, making it vulnerable to technical failures and cyber-security threats.

### C. OPPORTUNITIES

- 1) **Collaboration:** The Metaverse can facilitate collaboration between individuals and organizations across different industries and geographies.
- 2) **New Business Models:** The Metaverse can support new business models, such as virtual real estate, virtual goods, and virtual services.
- 3) **Education and Training:** The Metaverse can be used for education and training, creating new opportunities for learning and development.
- 4) **Social Impact:** The Metaverse can have a positive social impact, providing a platform for socialization, support groups, long distance relationships, and therapy.

### D. THREATS

- 1) **Privacy and Security:** The Metaverse is vulnerable to privacy and security threats, such as identity theft, data breaches, and cyber-attacks.
- 2) **Addiction and Social Isolation:** The Metaverse has the potential to create addiction and social isolation, especially if users become disconnected from the physical world.
- 3) **Legal and Regulatory Issues:** The Metaverse may face legal and regulatory challenges related to intellectual property, virtual assets, and taxation.
- 4) **Competition:** The Metaverse faces competition from other virtual worlds and social networks, which might compromise compatibility.

The Metaverse technology has significant strengths, including its immersive experience, innovation in new use cases, global accessibility, and economic growth potential. However, it also faces weaknesses, such as technical challenges, limited user base, cost, and dependence on technology. The Metaverse presents opportunities for collaboration, new business models, education and training, and social impact. However, it also faces threats, such as privacy and security, addiction and social isolation, legal and regulatory issues, and competition. A balanced approach is needed to maximize the strengths and opportunities of the Metaverse while addressing its weaknesses and threats.

## VI. FUTURE DIRECTIONS

In this section, we present the future directions of the Metaverse technology:

*Designing and Implementing the Metaverse Infrastructure:* Future research should focus on developing scalable, interoperable, and secure metaverse infrastructure that can support a wide range of applications and use cases, and enable seamless integration with existing technologies and systems [35].

*Exploring the Intersection of AI and the Metaverse:* As AI technology advances, it is expected to play an increasingly important role in the Metaverse. Future research should explore the intersection of AI and the Metaverse, and investigate how AI can be used to enhance user experiences, create more realistic virtual environments, and support new applications and use cases [36].

*Understanding the User Experience in the Metaverse:* The user experience is a critical factor in the success of the Metaverse, and future research should focus on understanding how users interact with and experience virtual environments, and how these experiences can be optimized for positive outcomes, such as engagement, satisfaction, and well-being [37].

*Building a Sustainable and Ethical Metaverse:* As the metaverse grows in popularity and complexity, it is important to ensure that it is built and used in a sustainable and ethical way. Future research should explore the environmental and ethical implications of Metaverse technology, and investigate how it can be designed and used to promote positive social and environmental outcomes [38].

*The Metaverse and Digital Transformation:* The Metaverse has the potential to transform the way we work, learn, communicate, and interact with each other. Future research should explore the implications of Metaverse technology for digital transformation, and investigate how it can be used to create new opportunities for innovation, growth, and progress [39].

## VII. RECOMMENDATIONS

In this section, the authors present the most important recommendations for developing and enhancing the Metaverse systems.

*Invest in Distributed Ledger Technology:* Distributed Ledger Technology (DLT), such as blockchain, can provide a secure and transparent infrastructure for the Metaverse. This can enhance user privacy and security, while also enabling new forms of commerce and value exchange. According to a recent IEEE article, DLT can be used to provide secure identity verification and authentication, while also enabling trustless value exchange and smart contract execution in the Metaverse [40].

*Focus on Interoperability:* Interoperability is key to creating a seamless and connected Metaverse. It is important to develop standards and protocols that enable different platforms to communicate and share data. According to a recent IEEE article, interoperability is essential for the Metaverse to achieve its full potential, and we need to develop open standards and protocols that enable seamless data exchange and collaboration across different platforms [41].

*Leverage Artificial Intelligence:* Artificial Intelligence (AI) can enhance the user experience in the Metaverse by providing personalized recommendations and interactions. It can also enable new forms of creativity and expression, such as generative art and music. According to a recent IEEE

**TABLE 1. Latest metaverse applications.**

Applications	Examples	References
Art	Creating and displaying digital art in immersive virtual galleries	[44]
Fitness	Participating in virtual fitness classes and tracking progress in a gamified environment	[45]
Food	Simulating culinary experiences and experimenting with new recipes in a virtual kitchen	[46]
Music	Collaborating with other musicians and performing in virtual concerts	[47]
Sports	Participating in virtual sports leagues and spectating virtual sporting events	[48]
Space exploration	Simulating space exploration and training for missions in a virtual environment	[49]
Disaster response	Training for disaster response scenarios in a virtual environment	[50]
Archaeology	Simulating and exploring archaeological sites in a virtual environment	[51]
Fashion technology	Designing and testing fashion products in a virtual environment	[52]
Environmental monitoring	Monitoring and studying the environment in a virtual environment	[53]
Transportation	Simulating and testing transportation systems in a virtual environment	[54]
Virtual therapy and wellness	Virtual reality therapy sessions	[55]
Virtual activism and advocacy	Virtual reality protest simulations	[56]
Virtual cultural experiences	Virtual reality museum tours	[57]
Virtual social impact	Virtual reality community-building platform	[58]

article, AI will play a critical role in shaping the Metaverse, enabling new forms of interaction and creativity that were previously impossible [42].

*Prioritize Security and Privacy:* Security and privacy are critical concerns in the Metaverse, where users may interact with sensitive data and personal information. It is important to develop robust security and privacy frameworks that protect user data and prevent unauthorized access. According to a recent IEEE article, security and privacy are crucial for the success of the Metaverse, and we need to develop comprehensive frameworks that address the unique challenges posed by this new environment [43].

## VIII. LATEST METAVERSE APPLICATIONS

In this section, the authors summarize the most recent Metaverse applications reported in the literature. These applications are supported by examples along with corresponding references:

## IX. CONCLUSION

Humanity is on the verge of entering a new age. It is expected that virtual and augmented reality will become more and more incorporated into our daily lives. Currently, the notion of the Metaverse virtual worlds has expanded well beyond the field of immersive gaming, and it is increasingly finding its way into fields such as entertainment, communications, business, education, and other creative industries.

Meanwhile, building a virtual world presents a number of concerns and obstacles that have yet to be answered, even as it reveals a great deal of potential. There must be no attempt to replace the actual world but rather to make it better in every manner conceivable via the use of the Metaverse. The developers have the primary responsibility in this regard.

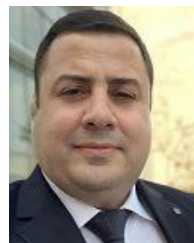
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