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Review article

Revolutionizing Healthcare: A Comprehensive Review of Metaverse Technology Integration

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ABSTRACT

Integrating the Metaverse into the healthcare system can significantly improve patient outcomes, medical education, and healthcare practices. This study examines the various uses of the Metaverse, emphasizing the essential technologies that make it possible, such as Augmented Reality (AR), Virtual Reality (VR), Extended Reality (XR), and digital twins for personalized care. The report highlights the challenges that healthcare professionals may face while suggesting future paths in the healthcare field. Topics examined include telemedicine, medical education, and the potential advancements that can be achieved with AR, VR, XR, and digital twins. Notable uses encompass virtual counseling, medical training and education, digital therapeutics, and telemedicine. While integrating the Metaverse into healthcare can significantly enhance patient care, it may pose privacy and security risks, incur high costs, require legal compliance, and affect trust in patient-technology relationships. However, future trends should address security and legal issues, balance social and virtual life, and enhance medical training and education. By using augmented reality (AR), virtual reality (VR), extended reality (XR), and digital twins, the healthcare industry can improve patient communication, research and decision-making processes, remote healthcare services, precise medical education training, and tailored patient care. These technologies present a unique opportunity to transform healthcare while addressing privacy, security, and sustainability issues. The purpose of this paper is to review the topic comprehensively, provide suggestions for future research and advancement in this domain, and provide insights into the potential of the Metaverse to revolutionize healthcare.

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1. Introduction

Since 2021, the Metaverse concept has emerged as a popular concept that has received much attention on the Internet, particularly with the advancement of digitalisation and automation [1] [2]. The metaverse effect has had an impact on healthcare. The main objective of every healthcare system is to enhance, rehabilitate, sustain, and advance healthcare services [1]. Due to COVID-19, hospital patient management has been questioned, leading healthcare providers to explore alternative care models. It is crucial to establish new healthcare service models [3]. Implementing the metaverse into healthcare is making significant progress in addressing fundamental medical issues as the digital domain advances [4]. The goal of this review is to provide a thorough examination of the potential applications, challenges, and future direction of the metaverse in healthcare.

The Metaverse is not a new concept and has been around for several decades, adapting and evolving with advancements in the internet and other related technologies. A timeline of significant events that have occurred during the evolution of the metaverse, such as the emergence of the internet and the inception of the Second Life virtual world project, as well as recent metaverse initiatives by prominent tech companies like Microsoft and Facebook (now rebranded as Meta), is illustrated in Figure 1 [5] [6].

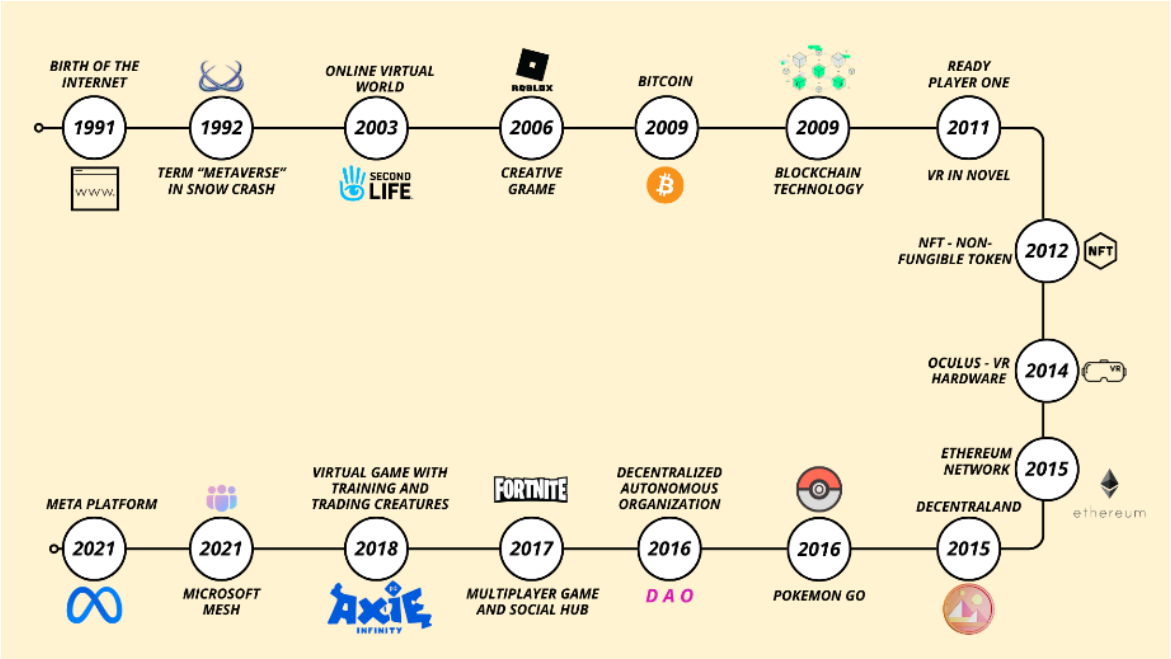

Figure 1. Timeline of the metaverse evolution for significant events from 1991 – 2021

The metaverse is a virtual world created by computers with a set of values and an economy connected to the real world. It was first mentioned in the novel Snow Crash in 1992 as a concept that combines the words "meta" and "verse" to describe a world that transcends virtuality and resembles a universe. The book describes a virtual reality world named the matrix as an example of the metaverse [5] [7] [8]. Nowadays, the term “metaverse” refers to a shared virtual 3D environment or a collection of interconnected cross-platform worlds that provide users with an entirely immersive experience through interactive and collaborative activities. Various entities as objects and user identities can be exchanged across different virtual worlds and even mirrored in the real world, in addition to virtual locations and structures with this metaverse. However, 3D gaming has caused an upsurge in the metaverse’s development in recent years. Results in both hardware and software, including built-in sensors, wireless networks, and graphic processing units (GPUs) on the hardware side and communication, computer vision, and language processing on the software side, are responsible for this growth [5] [6].

Besides, Figure 2 has described the seven layers of the metaverse platform, which can be expressed as follows:

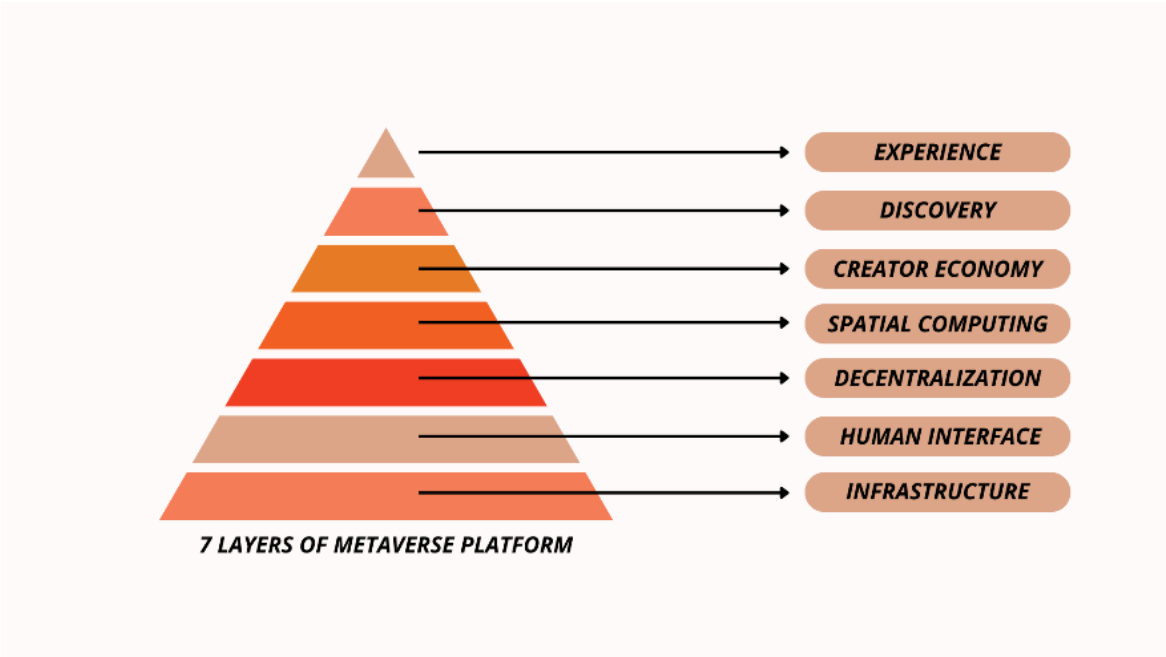

Figure 2. Seven layers of metaverse platform

- Infrastructure: 5G, 6G, Wi-Fi, cloud, data centre, central processing unit (CPU), and GPUs.
- Human interface: smart glass, smartwatch, mobile, wearables, HMDs, gestures, voice, and electrode bundle.
- Decentralization: blockchain, AI agents, edge computing, and microservices.
- Spatial computing: VR, AR, XR, geospatial mapping, 3D engines, UI/UX and Data Integration.
- Creator Economy: asset markets, E-commerce, retail stores, NFT market, design tools, and creation.
- Discovery: Advertising networks, virtual stores, social curation, ratings, avatars, and chatbots.
- Experience: Health check, Scanning, Training, Diagnosis, games, events, learning and working.

Rather than a single software platform, Jon Radoff describes the metaverse as a digital environment comprising seven layers representing different phases. These layers will work together as each range requires a function that works with the other six fields. In this scenario, the recent spread of COVID-19 has opened the path of metaverse to be introduced in the healthcare domain. The post-pandemic era has forced all stakeholders to reevaluate their approach to the healthcare ecosystem as technological advancement has become one of the key strengths in the current generation to overcome the challenging circumstances of the COVID-19 outbreak [9]. Therefore, the metaverse could be a game-changer in this scenario [6]. The potential of the metaverse is to overcome healthcare challenges by utilising practical, real-world applications that lead to the highest levels of experience duality, which includes endless, open, and shared virtual worlds [3]. This paper discusses how the metaverse can improve healthcare by enabling users to exchange content across virtual realms. Besides, this paper discusses the enabling technologies and potential healthcare applications of the metaverse, along with its challenges and future directions. The following is an overview of the different sections covered in a paper about the metaverse and its potential applications in healthcare. Section 1 covers the basics, including the concept of the metaverse, its development timeline, and the seven layers of the metaverse platform. Section 2 provides an overview of key enabling technologies of healthcare, the potential applications of the metaverse, and the challenges and future directions of the metaverse in healthcare. Section 3 highlights the reviewed paper from 2018 onwards about the potential applications of the metaverse, the challenges of implementing it, and future research directions in healthcare. Section 4 explains the methodology, Section 5 suggests future research, and Section 6 summarizes the paper.

2. Overview of Key Enabling Technologies, Potential Applications, Challenges and Future Direction of Metaverse in Healthcare

In this section, the research has been dedicated to discussing the critical enabling technologies, potential applications, challenges, and future direction of metaverse in healthcare.

A. Key Potential Technologies of Metaverse for Healthcare

This part covers the critical enabling technologies for the healthcare industry. The conversation began by exploring the possibilities of utilising Metaverse in the healthcare industry. Metaverse is a combination of technologies from different domains, each to varying stages of development. It is the internet but in 3D. Real and digital life come together in the Metaverse, and users are crucial to this system. Users can engage with simulated environments using technologies such as Augmented Reality (AR), Virtual Reality (VR), and Head-Mounted Displays (HMD) [10]. Moreover, these gadgets allow users to interact in virtual conversations and carry out tasks. The metaverse is made possible by networks that support digital, physical, and Internet of Things (IoT) interactions. Therefore, the critical potential technologies of the metaverse for healthcare, such as shown in Fig.3, are revolutionising the healthcare sector by offering innovative ways of providing healthcare services [1]. These technologies make it possible to build an immersive digital environment where patients, medical professionals, and medical students will allow them to interact with each other and with medical information in fresh and innovative ways [11]. These technologies are expected to create better access to healthcare, make accurate diagnoses, and provide personalised patient experiences and care [11]. In Figure 3, this review will address some essential vital technologies, as shown.

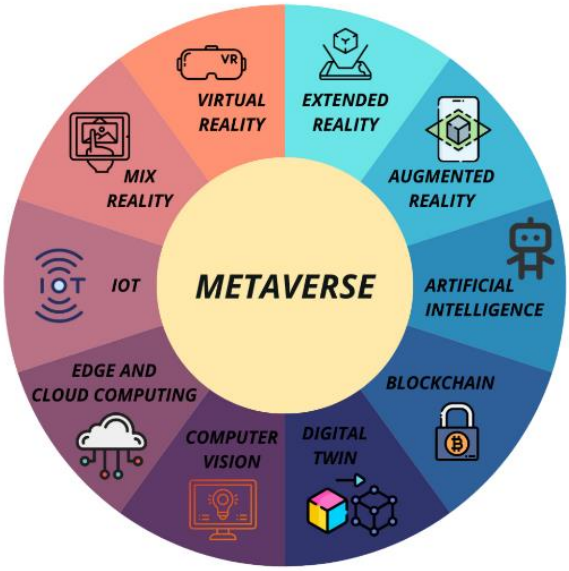

Figure 3. Metaverse key enabling technologies for healthcare.

1. Virtual Reality (VR) and Augmented Reality (AR)

   VR allows users to experience simulated experiences using a head-mounted display (HMD) or VR glasses. In contrast, AR uses overlaying digital images in the real world to enhance them with digital displays [12]. Virtual reality (VR) and augmented reality (AR) are crucial tools for creating immersive and interactive medical experiences, such as virtual training for medical personnel, VR therapy for patients, and visualizing medical data and diagnostic information in a virtual space [13]. VR and AR enable healthcare professionals and patients to imagine complex medical information and scenarios, thus enhancing learning, diagnosis, and treatment outcomes. Besides, AR allows surgeons to improve their vision of the operating field using digital imagery [14]. Therefore, VR and AR are part of the technological framework supporting the medical metaverse development and application [13].

2. Digital Twins

   In healthcare, digital twins – virtual copies of your bodies – hold immense potential. These mimics can not only guide treatment decisions but also predict your health future. Imagine testing different medications virtually or comparing your digital twin to similar patients to find the best personalised care. Plus, by constantly monitoring your health data, they can catch potential problems early and suggest preventive measures. While privacy concerns must be addressed, the promise of better, more informed healthcare through digital twins is too exciting to ignore [12] [15]. It is feasible to consider specific and practical application scenarios in domains such as healthcare performance evaluation and clinical approaches, employing digital twins as an alternative to the current methods involving mannequins and virtual patients [16].

3. Extended Reality (XR)

   In healthcare, the role of XR is quite significant regarding the various potential applications in the Metaverse [6]. Figure 4 displays that Extended Reality (XR) encompasses a range of tools that blend physical and virtual environments. XR technology includes Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) to create immersive and interactive experiences in the healthcare industry. These experiences can be utilised to improve medical education, allow for precise surgical interventions, and facilitate remote healthcare delivery [10] [17]. The healthcare industry is expected to be the primary sector for utilizing XR technology. XR tech is employed in various contexts, from educating and training medical professionals to performing surgical procedures and providing patient care [16]. The introduction of XR technologies in healthcare education aims to augment the effectiveness of learning outcomes while also providing advantages such as scalability, motivation, and cost savings [17].

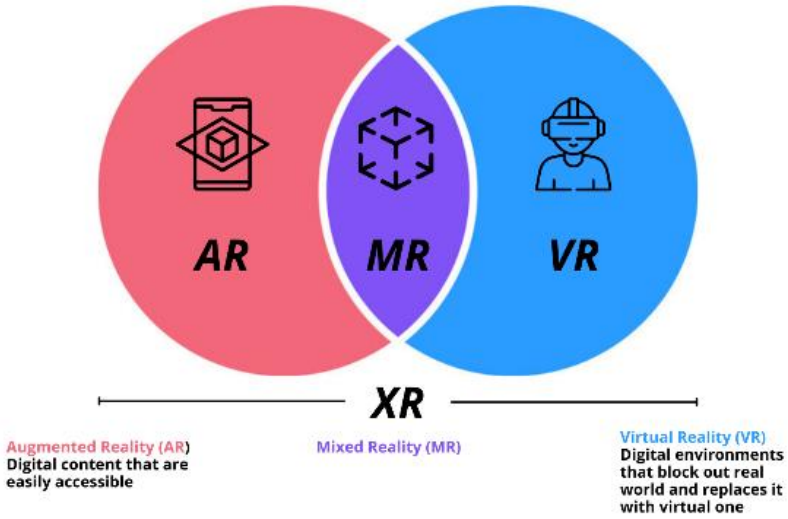

Figure 4. "XR" includes AR, MR, and VR.

B. Potential Uses of Metaverse for Healthcare

A few potential uses of Metaverse for healthcare were reviewed in this report. Based on Figure 5, there are many potential applications, but this report only focused on the selected:

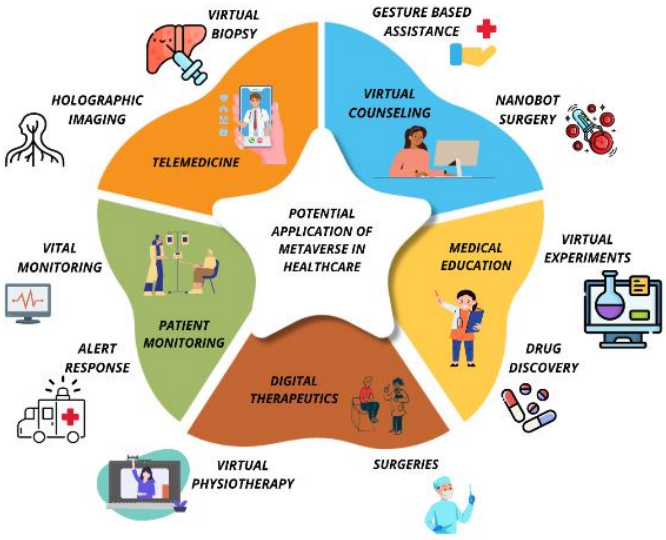

Figure 5. Potential uses of Metaverse in Healthcare

1. Digital Therapeutics

Based on clinical evidence, software applications known as digital therapeutics are utilised for the prevention, management, and treatment of physical, mental, and behavioural health issues [18]. The purpose of these treatments is to be used in clinical settings that are not considered traditional. They are frequently backed by top-notch software that uses AI, ML, and mobile apps. Digital therapeutics differ from conventional pharmaceuticals because they are software-based treatments that can be delivered through apps, wearables, or online platforms. This approach aims to empower patients and enable them to participate actively in treatment decisions [19]. Digital therapeutics are software-based treatments that use cognitive behavioural therapy to target the brain and nerves. This helps reduce the likelihood of toxicity and adverse effects. Developing digital therapeutics demands lesser financial and temporal resources for research, development, and licensing than developing new drugs. Consequently, medical costs are expected to decrease. Digital therapeutics can effectively address shortages of healthcare providers and geographical barriers to accessing physical healthcare systems. Furthermore, these therapeutics can fill important gaps in care that may exist due to the aforementioned factors [18].

The implementation of personalised digital therapeutics in the Metaverse is taking place through multiple approaches. Cognitive behavioural therapy for various mental health problems, including anxiety, fear, addiction, and stress, is being increasingly treated with virtual reality (VR). Due to its ability to create unique and manageable situations, VR is a suitable option for addressing these issues [18]. There are virtual reality programs that offer psychotherapy to people with mental health conditions, such as agoraphobia and anxiety, especially those with psychosis. Furthermore, incorporating digital therapeutics into the Metaverse will revolutionise their use and application, including medical staff training and surgical navigation tools [18].

2. Medical Education

Amidst the COVID-19 pandemic, remote work and study have become the new normal. Nevertheless, surveys on medical education and training have indicated that a significant number of medical students have experienced adverse effects on their learning and training because of the pandemic [20]. This negative effect can be attributed to the limitations imposed on trainees' exposure to medical procedures, such as surgical interventions, thus resulting in a notable disruption in their educational journey.

Medical students can benefit from an immersive experience using accessibility equipment such as virtual reality and augmented reality headsets within the metaverse. By virtually transporting students and trainers to an operating room, these devices allow them to practice and exchange expertise. The metaverse is a digital world that provides this opportunity. In addition, the progress of both learners and instructors can be tracked and documented for further evaluation, helping them to identify areas of strength and areas that require improvement. Moreover, the digital platform promotes teamwork between learners and instructors from various locations, expanding their shared knowledge and expertise [20]. Authors have utilized extended reality (XR) technology to develop a holographic museum of anatomical structures. This museum comprises various brain regions, cranial nerves, cerebral venous and cerebral artery systems, and the eye. Such technology assists in imparting knowledge on ophthalmology [21]. XR is primarily utilized in medical education and rehabilitation fields. Its purpose is to replicate the patient's condition accurately, enabling medical professionals to identify the specific surgical site required for the intended treatment [16].

3. Telemedicine

Over the past ten years, telemedicine and online health communities have witnessed a considerable increase in applications—a noteworthy contribution to advancing the medical and health sectors within the digital economy [22]. Digital health is beneficial to various stakeholders, including doctors, patients, internet companies, and pharmaceutical companies. Telemedicine is a combination of technology and healthcare services. It includes various aspects such as digital medicine, e-health, telehealth, and m-health [23]. The healthcare industry is increasingly using telemedicine and remote care technologies, such as telehealth, which offer tremendous potential to improve patient outcomes, increase accessibility to healthcare, and foster collaboration among healthcare providers. Incorporating the metaverse into medicine can further enhance these opportunities [23]. Besides, VR can enable virtual consultations, and AR can overlay real-time information on the clinician's field of view during procedures [24]. In pandemics like COVID-19, telemedicine is preferable for diagnosis and prognosis in a virtual environment [25].

4. Virtual Counselling

Virtual counselling is a method of treatment conducted through online platforms and technologies, enabling clients to engage in therapeutic conversations with mental health specialists remotely [26]. It allows individuals to obtain counselling services remotely, from the convenience of their homes or any location with internet connectivity. Virtual counselling can be done using different platforms, including video conferencing, phone calls, instant messaging, or virtual reality environments. It offers a simple and accessible alternative for persons who may experience challenges accessing traditional in-person counselling due to geographical, physical, or personal limitations. Evidence indicates that virtual counselling can be as beneficial as in-person counselling in treating many mental health issues, such as anxiety, depression, and trauma. It provides clients with a secure and private environment to address their difficulties, get assistance, and progress towards their therapeutic objectives [26].

C. Possible Challenges of Metaverse in Healthcare

1. Privacy and Security Concerns

Various virtual healthcare providers collect data from patients using multiple methods. Medical specialists utilise a metaverse virtual environment to deliver treatments more effectively for this digital content [27]. The interaction between doctors and patients occurs via virtual reality (VR), enabling the flow of information through the metaverse. However, this poses a significant risk to patients as data integrity is not guaranteed. Nonetheless, hackers or malicious individuals could obtain their data at any given moment, perhaps resulting in adverse outcomes when engaging in medical procedures via the metaverse platform [27]. Protecting sensitive patient data is crucial to prevent unauthorised entry and maintain patient confidentiality within the healthcare metaverse [24]. Failure to safeguard the data of patients and staff will result in legal responsibility, typically resulting in financial setbacks and harm to the organisation's reputation [20].

2. High Costs

The Metaverse is presently in its early stages of development, and like any other nascent technology, it is anticipated to encounter multiple technological obstacles [20]. The metaverse is not an independent entity but a complex system that depends on various modern technologies such as Medical IoT, artificial intelligence, blockchain technology, distributed hardware and software, and HMDs to maintain its continuous and up-to-date functionality. Unequal access for regular users is expected due to the high cost of accessibility equipment, which is likely to create a significant barrier [20]. For instance, while IoT devices for personal use may be affordable, companies offering these solutions must analyse the costs of meeting the requirements to use their resources effectively and attain the maximum possible return on investment (ROI) [28]. Due to the integration of several advanced technologies and their complete systems, the cost often limits the broad application of the metaverse environment [13].

3. Legal Compliance

There are no established rules or standards in the metaverse regarding healthcare. The rapid advancement of metaverse technology is surpassing the pace of legislation, which raises concerns about security and privacy. Enforcing data protection protocols such as GDPR and HIPAA is crucial in the metaverse due to the anticipated large number of users [20]. The Metaverse lacks clear regulations or guidelines in any field, granting unrestricted autonomy to all participants. As such, they must establish and outline appropriate protocols to combat illicit activities in a digital setting [27]. Healthcare metaverse solutions are challenging to implement due to regulatory requirements [24].

4. Trust Issues between stakeholders

The healthcare sector in the metaverse is still in its early stages, leading to a lack of confidence in relying on avatars and holographic AI systems. People trust traditional medical professionals more since these new technologies have yet to establish a proven track record of providing reliable healthcare services [12]. To build trust between patients and the metaverse, there is a need to improve the quality of healthcare services, treatments, and diagnostic capabilities within the metaverse. This can be achieved by investing in skilled medical professionals, advanced technologies, and strict protocols [12].

D. Future Directions of Metaverse in Healthcare

1. Security and Privacy Metaverse

Commercial metaverse systems use security patches to improve their system security. However, this strategy leads to a continuous cycle of vulnerabilities being exposed and patched [8]. For example, innovative solutions such as "clone cloud" and "private copy" can help protect against malicious exploitation and data leaks [23]. When designing Metaverse-based healthcare solutions that involve sensory, communication, and behavioural aspects, it is important to prioritize privacy measures. Exploring this area further can reveal the Metaverse's transformative potential in healthcare [23].

2. Law of Metaverse

As the use of metaverse becomes more widespread, it is essential to recognise that virtual crimes will be a reality. Just like social media, the metaverse will have its share of cyber criminals.

However, blocking accounts with rules and regulations will not be enough to deal with offenders. Proper laws need to be established to provide fair justice [3]. There have been reports of virtual crimes on social media, suggesting the presence of lawbreakers in the Metaverse. Therefore, to maintain fairness, the closure of an account cannot be solely based on rules and regulations; it must be governed by proper legislation. As the Metaverse exists independently of the physical world, governments and agencies must identify the responsible authority for creating a secure digital environment across international borders and protecting people worldwide [10].

3. Balancing Social and Virtual Life

The metaverse, a virtual reality world, is gaining popularity in healthcare. It allows people to communicate with each other, access healthcare services and even undergo medical procedures. However, excessive use of the metaverse may adversely affect people's mental and physical health [20]. Over-engagement in this virtual environment may lead individuals to lose touch with the real world. There are worries regarding the possible problems that could emerge due to the overuse of the metaverse in the healthcare sector. Therefore, it is crucial to conduct extensive research to find a balance between virtual and real-life experiences. This research should explore the potential positive and negative effects of the metaverse on people's health, including its impact on social interactions, emotional well-being, and physical activity [20].

4. Medical Training and Education Enhancement

With advancing medical technology, the healthcare industry is looking for innovative ways to improve medical training and education. The healthcare Metaverse is a digital world that combines AR and VR technologies with medical training and simulation. This rapidly expanding technology is one of the most promising avenues for improving the quality of medical training and education [29]. VR and AR offer safe and immersive medical training. Advanced simulations replicate real-world scenarios with feedback, models, and interactive equipment. This enhances medical training and improves patient outcomes [29].

3. Literature Overview

This literature overview summarises at least 15 recent papers on Metaverse's potential uses, difficulties, and future trends.

Table 1. Survey of Potential Uses, Difficulties and Future Trends of Metaverse.

Article	Table 1		
	Potential Uses	Challenges/Difficulties	Future Trends
[30]	The article explores the potential applications of telehealth, augmented reality (AR), and virtual reality (VR) in cardiology to enhance patient care.	Privacy and security challenges are highlighted in the article. The risks of privacy invasion and the consequences of integrating the latest technologies and methods in the virtual world are also mentioned.	The article discusses the Metaverse's future in healthcare, emphasising security measures and Metaverse-based education.
[16]	The Metaverse could transform healthcare using digital humans and collaborating with intellectual property entities. This could create interactive healthcare experiences, improving patient care and medical education.	Implementing the Metaverse for healthcare poses several challenges, including conflicting opportunities, technological requirements, and strategic planning concerns. Failure to consider these factors may lead to costly consequences and unsatisfied customer needs.	Metaverse for healthcare can improve network infrastructure, develop new business models, integrate advanced technologies, promote global collaboration, and prepare regulations for borderless interactions. Utilising digital humans and IP collaborations can enhance the healthcare Metaverse experience, demonstrating the potential for Metaverse to revolutionise healthcare.
[22]	The Metaverse has great potential in healthcare, offering advanced training for medical professionals through virtual and augmented reality, as well as improving surgical	The Metaverse has potential in healthcare, but there are challenges to address. These include security concerns, limited accessibility, and high costs. Solving these issues is crucial for successful integration.	To ensure the successful implementation of Metaverse in healthcare, new infrastructure, standards, and procedures need to be established to address the unique challenges that come with it. Key innovations such as gamified healthcare, safeguarding patient

	techniques and enabling remote medical services. Blockchain technology can ensure secure data transmission, while virtual collaboration among medical specialists can support global teaching, diagnostics, and remedies.		privacy, and addressing the barriers to virtual reality adoption are crucial. It is also important to anticipate a paradigm shift in healthcare once Metaverse becomes more widely accepted.
[5]	The Metaverse holds tremendous potential for healthcare. It can facilitate better medical diagnosis, real-time communication between doctors and patients, virtual medical education, and immersive healthcare environments. Furthermore, it enables the sharing of medical data and the development of AI-powered diagnostic models, which can significantly enhance healthcare services.	The implementation of Metaverse in healthcare faces challenges such as data privacy, high-quality VR hardware & software, regulatory compliance, investment & expertise for AI/VR integration, and accessibility for patients & healthcare professionals.	The future of the Metaverse in healthcare includes advanced AI and VR technologies, blockchain for secure data sharing, virtual healthcare services for more patients, virtual clinical trials for cost-effective drug development, and personalised healthcare experiences for individual patients.
[23]	This article discusses the potential use of Metaverse technology in various healthcare fields, including orthopaedics, emergency response learning, fetal medicine and gynaecology, neurology, and oncology.	Managing data streams, user profiling, and potential unfair AI outcomes pose security and privacy challenges. Additionally, concerns about tracking user locations are present.	The Metaverse's complexity presents security challenges, including tracking user locations and data misuse.
[8]	This article does not discuss potential healthcare applications of Metaverse but focuses on its fundamentals, security, and privacy.	While the article does not mention a healthcare Metaverse, implementing one poses security and privacy challenges. These include managing data streams, user profiling, and the potential for unfair AI outcomes. Additionally, there are concerns about tracking user locations and illegal use of personal data. The Metaverse's complexity also presents challenges for security.	The article discusses the future of the Metaverse, with a focus on security, interoperability, scalability, and new gaming, education, and social networking applications. It also highlights the need for further research in distributed systems, AI, and blockchain to support its growth.
[3]	This article examines the potential of Metaverse technology in various areas of healthcare, including telemedicine, clinical care, education, mental health, physical fitness, veterinary medicine, and pharmaceuticals.	Metaverse in healthcare faces technical challenges, security risks, privacy concerns, and regulatory compliance issues.	The use of Metaverse technology in healthcare can enable virtual consultations, remote monitoring, and personalized treatment plans. Overall, it has the potential to revolutionize the healthcare industry making it more patient-centric, efficient, and cost-effective.

[13]	The Metaverse has vast potential applications in healthcare. It can enhance medical education, aid in accurate diagnosis, and improve the quality of physical and mental interventions, including surgical planning and physical therapy. By providing immersive experiences and remote interactions, the Metaverse has the potential to transform healthcare and significantly enhance medical outcomes.	Metaverse implementation in healthcare faces challenges such as data privacy, technology costs, and balancing reality with virtualization.	The Metaverse has great potential to transform healthcare. It can enhance medical diagnosis, broaden access to healthcare services, improve medical education and therapy, ensure secure data management, and offer personalized medicine. It is essential to establish ethical and regulatory frameworks that address issues such as data privacy, security, and responsible usage of technology.
[1]	The Metaverse could transform healthcare by enabling remote patient monitoring, realistic medical simulations for education, personalized care, and reducing surgery invasiveness, healing time, and issuing medical alerts.	Healthcare in the Metaverse is facing various challenges including the risks of data breaches, high implementation costs, ethical concerns, and challenges in gaining agreement from healthcare organisations. These hurdles must be overcome to realize the potential of the Metaverse in healthcare fully.	The article explores how Metaverse can be used in healthcare, including medical diagnosis, patient monitoring, and training. It also discusses integrating blockchain, digital twins, and telemedicine technologies and creating an energy-efficient consensus protocol. However, there are still challenges to overcome before Metaverse can be fully integrated into healthcare.
[12]	The potential uses of the Metaverse in healthcare are explored in the article, including health monitoring, virtual consultations with medical professionals, virtual surgeries, and virtual hospital environments for healthcare services.	Challenges for Metaverse in healthcare include complex app development, data privacy, high cost, and regulatory/legal issues.	The future of Metaverse in healthcare includes research and development, collaboration, education and scaling up the technology.
[20]	The article outlines potential healthcare applications of the Metaverse including telemedicine, medical education, marketing, supply chain, facilities, and wellness.	Implementing the Metaverse in healthcare presents challenges such as technological limitations, interoperability issues, privacy and security concerns, socio-ethical implications, law enforcement and regulations, and lack of standardization.	The healthcare industry expects that the Metaverse will result in cost reductions, equal accessibility for all, a balance between virtual and real life, and the establishment of regulations, standards, and ethical codes.
[25]	The potential of Metaverse technology in healthcare is explored in the article, with a focus on its use in medical education, rehabilitation, and remote patient management. The article demonstrates how immersive experiences created by Metaverse wearables can enhance healthcare outcomes.	Implementing Metaverse in healthcare faces challenges related to the privacy and security of personalized data, minimizing feedback delay, and practical obstacles that need to be addressed. These challenges must be overcome for the safe and effective use of Metaverse wearables in healthcare.	Healthcare's metaverse aims to improve collaboration, enhance immersive experiences through haptic feedback and visual perception, and develop wearable devices for intelligent analysis and efficient sensing data processing.

[4]	This article discusses the utilization of Metaverse virtual surgery technology to develop a novel medical system that surpasses current knowledge. It also proposes the creation of a virtual consultation room in Metaverse, which will allow doctors to communicate via 3D holography. This is a potential breakthrough in telemedicine, which could improve healthcare accessibility.	The article discusses challenges in implementing Metaverse technology in healthcare, including popularizing it at the grassroots level, avoiding complete replacement of traditional teaching and clinical practice, and the need for further technological breakthroughs.	The article discusses the potential of Metaverse virtual medicine technology, especially for China's medical diagnosis system. The future development should focus on making it affordable, accessible to the grassroots population, and promoting the real with the virtual. Metaverse virtual medical technology will benefit the grassroots people in China and contribute to the construction of a healthy China and coping with the aging population.
[18]	The article discusses potential healthcare applications of the Metaverse, including telemedicine, medical education and training, surgical simulations, conferences, awareness and research programs, and therapy for mental health disorders.	When implementing the Metaverse in healthcare, it is important to ensure data security and privacy, address technological infrastructure requirements, integrate with existing healthcare systems, and ensure regulatory compliance. Furthermore, challenges may arise in terms of accessibility and equity in healthcare delivery through the Metaverse.	The future of healthcare is anticipated to be greatly impacted by the Metaverse, which could potentially offer tailored digital therapeutics and improve medical education and training via immersive experiences. Additionally, it has the potential to enhance surgical simulations and broaden the scope of mental health therapy applications. The Metaverse is also expected to revolutionize telemedicine and transform healthcare delivery, making it more accessible and efficient for all.
[31]	Metaverse can have several applications in healthcare, such as social interactions among avatars for mental health benefits, a virtual office to reduce stress and enhance work performance, and real-time health impact estimates for optimized designs based on stakeholder feedback and social, cultural, health, socioeconomic, and inclusivity considerations.	The article highlights the health risks associated with excessive sitting and physical inactivity in Metaverse users. Users may experience headaches, eye strain, vertigo, and nausea, which can discourage healthy behaviours. Moreover, isolating oneself in the Metaverse may lead to mental health consequences such as social isolation, depression, and antisocial behaviours.	The article puts forth a suggestion for upcoming research to investigate the consequences of a built environment that promotes health in a Metaverse on the actual health outcomes of people. It also recommends formulating safe usage guidelines for employing a Metaverse in the healthcare industry and exploring its capacity to encourage physical activity and healthy behaviours.
[21]	The article mentions potential applications in healthcare, education, and research, including prevention and treatment of illnesses, anatomical education, and surgical simulations.	The article talks about difficulties in using the Metaverse in healthcare. These include a lack of research, technical issues, ethical and legal concerns, accessibility, and the cost of developing healthcare programs in the Metaverse. The text is written in easy-to-understand language, with short sentences and only necessary information. The	Some of the suggested future directions for the use of Metaverse in healthcare include conducting more research studies and increasing investment, developing connectivity standards for interoperability and security, addressing ethical and legal challenges, ensuring accessibility and inclusivity, and planning cost-effective solutions for healthcare applications.

		vocabulary used is simple and familiar. The main point is clear and there is a logical flow to the text.	
[6]	The article discusses how the Metaverse can be used in healthcare. It suggests that the Metaverse can help in surgical education by providing immersive training. Additionally, it highlights that the Metaverse can be used to enhance therapeutic options through prescription-based solutions and that virtual reality (VR) could be useful in plastic surgery and radiology. The article also points out that the Metaverse can help improve patient engagement and monitoring by using gamification, immersive content, and digital twins.	Implementing the Metaverse in healthcare comes with various challenges. These challenges include technical and hardware limitations, as well as security and privacy issues. One main concern is ensuring the identity of avatars within the Metaverse. Spending too much time in the Metaverse can lead to multiple health problems. Another challenge is ensuring the safety and security of digital currency and payments while trading within the Metaverse.	The Metaverse has a bright future in healthcare, which can result in better patient outcomes, improved access to care, and innovative therapeutic solutions. This relies on the integration of emerging technologies such as AI, blockchain, and IoT, which can help advance medical research. However, it is important to address privacy and ethical concerns related to data security, patient consent, and the responsible use of virtual healthcare technologies to ensure the successful development and implementation of these advancements.

4. Methodology

A methodical approach is being taken to explore the intersection between Metaverse and healthcare systematically. The process commences with a focused literature search across prominent databases such as PubMed, IEEE Xplore, ScienceDirect, Google Scholar, and Connected Papers. The search employs carefully crafted terms such as "VR," "AR," "healthcare applications," and "telemedicine" to cast a wide net on relevant literature. Criteria for inclusion and exclusion are meticulously defined, encompassing considerations of relevance, publication date, and language. In the article selection phase, a two-tier screening process is employed. The initial results are sifted through based on titles and abstracts to pinpoint potentially pertinent articles. Subsequently, a rigorous full-text review is conducted to ensure alignment with predefined inclusion criteria and to ascertain the provision of substantial insights into Metaverse applications in healthcare.

The data extraction process follows a systematic approach wherein pertinent information is gleaned from selected articles. Key findings, methodologies employed, types of Metaverse technologies discussed, challenges identified, and proposed future directions are methodically recorded using a standardised extraction form. Quality assessment becomes paramount, involving a critical evaluation of study methodologies, encompassing aspects such as study design, sample size, and overall research rigour. Vigilance is exercised to recognise and address potential biases present in the selected literature, including but not limited to publication bias or instances of industry-funded research. The extracted data is thoughtfully organised into categories or themes related to Metaverse applications in healthcare, challenges encountered, and potential future trajectories. A comparative analysis is undertaken to discern patterns, similarities, and disparities across studies. The ensuing discussion section delves into interpreting results within the contemporary landscape of Metaverse technologies in healthcare. The strengths and limitations of the reviewed studies are dissected, and any existing gaps in the literature are underscored.

To conclude, the review summarises the main findings, which will lead to a discussion about what these findings mean for the healthcare and Metaverse technology industries. Moreover, this paper provides recommendations for future research directions, summarising the systematic approach used to offer a comprehensive overview of the current state, challenges, and potential future trends of Metaverse applications in the healthcare sector.

5. Recommendations

Integrating Metaverse technology in healthcare is a massive shift in the medical landscape. This requires a comprehensive framework that goes beyond just technology considerations. It emphasises the need for healthcare expertise, technological innovation, ethical standards, and policy formulations. Navigating the

complex terrain of Metaverse applications in healthcare requires a holistic and collaborative approach. It is time for a nuanced exploration of essential recommendations, each contributing substantively to the establishment of a resilient, secure, and universally accessible integration of Metaverse technology into the fabric of healthcare delivery.

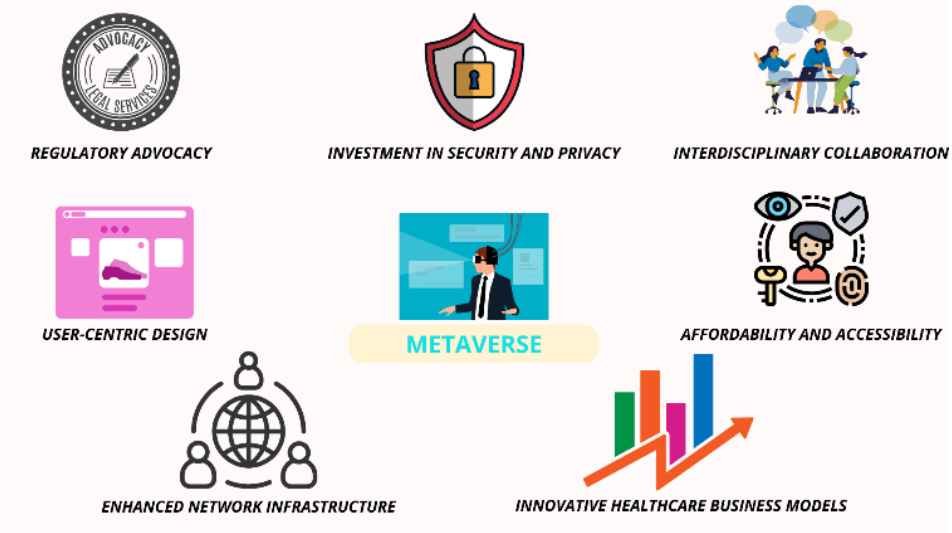

Figure 6. Recommendation innovation strategy for Metaverse

Figure 6 illustrates a recommended or comprehensive innovation strategy, visually depicting the concept proposed within the innovation process. Establishing interdisciplinary collaboration is crucial for success, creating platforms for regular interaction and knowledge exchange among healthcare professionals, technologists, ethicists, and policymakers. This ensures that diverse perspectives contribute to the development and implementation of Metaverse applications. Joint initiatives like hackathons or innovation forums allow teams to collectively address complex challenges, leading to more comprehensive and effective solutions.

To establish a strong base for Metaverse applications in healthcare, it is essential to invest in reliable security measures. This requires continuous research and technological advancements to stay ahead of potential threats. Exploring and integrating privacy-enhancing technologies, cryptography, and decentralised systems into the Metaverse infrastructure is recommended. To cultivate a culture of responsible and secure technology use, educational programs should be designed to raise awareness about data privacy and security among healthcare professionals and end-users. When developing metaverse applications for healthcare, prioritising investing in reliable security measures is crucial. This means constantly researching and advancing technology to stay ahead of potential threats.

A recommended approach is to explore and integrate privacy-enhancing technologies, cryptography, and decentralised systems to ensure the highest level of privacy and security. Data privacy and security awareness should be prioritised when designing educational programs for healthcare technology users. When developing metaverse applications for healthcare, investing in reliability is crucial. It is essential to prioritise investment in reliable security measures to protect sensitive information in healthcare technology. This requires continuous research and development of cutting-edge technology to stay ahead of potential threats. One approach is to explore and integrate privacy-enhancing technologies, cryptography, and decentralised systems to ensure the highest level of privacy and security. When designing educational programs for healthcare technology users, prioritising data privacy and security awareness is crucial. In developing metaverse applications for healthcare, it is important to invest in reliability to ensure that critical information is protected.

Incorporating a user-centric design approach is crucial for the successful adoption of Metaverse applications in healthcare. This approach goes beyond gathering feedback and requires a deep understanding of user needs and preferences. We can ensure that Metaverse applications align with real-world workflows by conducting ethnographic studies, usability testing, and continuous feedback loops with healthcare professionals and patients. To create interfaces that are intuitive, adaptable, and supportive of diverse healthcare contexts, it is crucial to integrate user experience experts into the development teams.

Improving network infrastructure is crucial for the seamless operation of Metaverse technology in healthcare. In addition to high-speed services, it involves investing in cutting-edge technologies such as 5G, edge computing, and reliable connectivity solutions. Collaborating with telecommunication companies and infrastructure providers ensures that the Metaverse in healthcare operates smoothly, minimises latency, and provides a responsive user experience. The integration of 5G technology opens avenues for real-time data transfer, thereby enhancing the overall efficiency of Metaverse applications.

Creating innovative business models that match technological advancements and have sustainable revenue streams is crucial in the healthcare sector. To achieve this, a comprehensive assessment of Metaverse business

opportunities is necessary, which includes analysing market dynamics, user needs, and long-term feasibility. Establishing incubators or accelerators concentrating on Metaverse startups in healthcare can help build an environment that promotes developing and testing new business models. With proper strategic planning, the industry can establish a sustainable and scalable Metaverse ecosystem in healthcare.

6. Conclusion

The rapid advancement of digitalization and automation has given rise to the development of Metaverse technology, which has proven to be an asset in various industries, especially in healthcare. Its development has positively impacted healthcare by integrating AI, VR, AR, robotics, and quantum computing technologies. Metaverse technology enables realistic experiences for both patients and medical professionals. It has led to the discovery of various technologies, such as the development of sensors in IoT-based medical systems that help with temperature monitoring, pulse measurement, electrocardiography (ECG), pulse oximetry, blood pressure monitoring, and blood glucose monitoring. The application of big data for data management and analysis provides an efficient and smooth data workflow, while artificial intelligence and machine learning in healthcare have revolutionized diagnostics and therapy. Additionally, implementing various types of wireless communication networks has helped resolve many issues. Technology developments such as extended reality, blockchain, digital twin, and quantum computing are also being explored. Metaverse technology can be further implemented in several diagnostic and therapeutic applications, medical training, and meetings. However, the high cost of technology, privacy, and security concerns pose significant challenges. Therefore, clear visions and directions must be planned to ensure the smooth management and process of the healthcare industry workflow that can satisfy patients' and workers' needs.

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We express our sincere gratitude and appreciation for the valuable insights gained during the Computer Network course, particularly in enhancing our understanding of the Metaverse within the healthcare industry. The experiences provided have broadened our knowledge of how technology contributes to the evolution of the Metaverse and offered new perspectives and innovative solutions for healthcare applications. Therefore, we extend our heartfelt thanks to the instructor for their dedication to creating a learning environment that has expanded our perspectives.

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