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Review

Metaverse for Digital Anti-Aging Healthcare: An Overview of Potential Use Cases Based on Artificial Intelligence, Blockchain, IoT Technologies, Its Challenges, and Future Directions

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Abstract: Metaverse is the buzz technology of the moment raising attention both from academia and industry. Many stakeholders are considering an extension of their existing applications into the metaverse environment for more usability. The healthcare industry is gradually making use of the metaverse to improve quality of service and enhance living conditions. In this paper, we focus on the potential of digital anti-aging healthcare in the metaverse environment. We show how we can use metaverse environment to enhance healthcare service quality and increase the life expectancy of patients through more confident processes, such as chronic disease management, fitness, and mental health control, in the metaverse. The convergence of artificial intelligence (AI), blockchain (BC), Internet of Things (IoT), immersive technologies, and digital twin in the metaverse environment presents new scopes for the healthcare industry. By leveraging these technologies, healthcare providers can improve patient outcomes, reduce healthcare costs, and create new healthcare experiences for a better life, thus facilitating the anti-aging process. AI can be used to analyze large-scale medical data and make personalized treatment plans, while blockchain can create a secure and transparent healthcare data ecosystem. As for IoT devices, they collect real-time data from patients, which is necessary for treatment. Together, these technologies can transform the healthcare industry and improve the lives of patients worldwide. The suggestions highlighted in this paper are worthy to undergo implementation and create more benefits that will promote a digital anti-aging process for its users for a longer life experience.

Keywords: metaverse; healthcare; digital anti-aging healthcare; artificial intelligence; blockchain; immersive technology

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1. Introduction

The aging phenomenon is a natural process that cannot be avoided in humans. As time goes on, people grow and become old. Age comes with challenges, especially related to health conditions. Old people are likely to be exposed to many diseases and health complications, deriving from family background, inappropriate food intake, or low frequency of medical checkups. The aging population is fighting for better conditions all over the world, and medical experts and caregivers are using different methods to enhance the anti-aging process, thus extending the life expectancy of the patients. Recently, various methods have been suggested to maintain a healthy condition, including a healthy diet, body fitness, regular checkups, and others. Many tools, both digital and analog, have been used to ensure anti-aging mechanisms. The most common digital tools include: (1) Food-tracking apps: These apps allow users to quantify their intake of food in terms of calories, macronutrient balance, etc. Examples of such apps include MyFitnessPal, LoseIt!, and MyPlate, by Livestrong. (2) Recipe websites and apps: apps such as Allrecipes, Epicurious, and Yummly are well-known for the provision of healthy recipes that can help in making nutritious meals. (3) Nutrition education resources: These apps provide nutritional information useful for users in decision-making about their diet. Popular examples include Choose My Plate, from the Academy of Nutrition and Dietetics. (4) Wearable technologies: Most wearable devices (fitness trackers, smart watches) serve as health-monitoring tools and enhance health conditions from many angles. For instance, such devices help in tracking human physical activity, while also evaluating the amount of burned calories, fundamental information to manage the users' fitness and nutrition targets. (5) Entertainment apps: These categories assist users in maintaining good mental health. Games belong to these categories and have proven a significant role in maintaining good health, thus increasing the chances of a long life. The adoption of these digital solutions as a tool to promote the anti-aging process has been welcomed by users, but still shows some limitations and requires adapting to recent technological developments. Regarding the metaverse, the latest generation of the internet, which is a virtual environment offering more interactivity, its use in combination with new technologies (artificial intelligence, blockchain, Internet of Things) can lead to more opportunities when it comes to anti-aging-related healthcare solutions for a better life.

Since the advent of the COVID-19 pandemic, traditional healthcare services have shown drawbacks, and patients are moving toward remote healthcare services instead of traditional treatment procedures [1]. The demand for remote monitoring is increasing, and various platforms are now used to achieve customer satisfaction. Nowadays, investors are looking into the metaverse for the immersive experience it offers, which mimics real life. Many industries are looking at opportunities to invest by extending their applications into the metaverse to increase their productivity and save costs. Since clients and end users prefer to use different platforms remotely, the demand for metaverse usage is increasing day by day. In the field of healthcare, different stakeholders prefer metaverse platforms so they can provide different remote medical services to patients. For a better performance of the remote monitoring and telemedicine systems, the medical stakeholders are diving into the healthcare metaverse by using augmented and virtual reality. By using the metaverse platform, doctors can virtually examine their patients without the need for in-person visits. The metaverse is a mixture of virtual and augmented reality, and it uses other technologies such as blockchain, 3D objects' detection, natural language processing, and facial recognition [2,3]. The metaverse can also help medical experts while performing surgeries. The first surgery in the metaverse environment was performed at Johns Hopkins Hospital back in early 2020. While carrying out this operation, experts made use of AR-based headsets developed by Augmedics [4]. Medical experts can also use the metaverse platform for learning and training purposes. For instance, doctors and students can virtually learn practical procedures. The success of this practice led many medical institutions to shift from manual learning to virtual reality, mixed reality, and AI-supported systems to effectively train their employees and students [5]. In the case of the mirror world, different people sitting in different places can meet and play games together. Following this idea, doctors can suggest different games for their patients to play that are helpful to maintain their mental health. Although many companies are still at the implementation stage of their metaverse platform, it appears that it will be convenient for medical experts in the future as it allows for a full and detailed visualization of the human body, which can be used as a surgical training environment for medical practices [6,7]. This metaverse environment in which many technologies and tools can be used in combination will improve healthcare services, thus improving the user's life expectancy by facilitating the anti-aging process.

In this paper, we present the following contributions:

- We show the potential of the metaverse in supporting the digital anti-aging process and increasing the life expectancy of patients.
- We introduce a technological overview of healthcare services for the metaverse, with emphasis on the eventual opportunities.

- We highlight the possible challenges of the integration of healthcare services in the metaverse enviroment.

In Section 2, we discuss related work. Then, we discuss the metaverse use case as a state-of-the-art for this paper in Section 3, and we present a technological overview of the metaverse for the healthcare industry in Section 4. Furthermore, in Section 5, we mention the challenges of the metaverse in the healthcare industry, with future directions and a conclusion to the article in Section 6.

2. Related Work

The metaverse is a virtual space that is being developed using advanced technologies, such as mixed reality (MR), virtual reality (VR), blockchain (BC), and artificial intelligence (AI), to enable users to virtually communicate, with a highly immersive experience that mimics real-life scenarios. While the metaverse is primarily being developed for social interaction and entertainment purposes, it also has the potential to impact various fields, including digital anti-aging in healthcare. One way in which the metaverse can help with anti-aging is through virtual healthcare [8]. The metaverse can provide a virtual environment where patients can interact with healthcare providers and receive medical treatment without having to leave their homes. This can be particularly useful for older adults who may have mobility or transportation issues [9–13]. Another way in which the metaverse can help with anti-aging is through the development of virtual fitness programs. These programs can provide a personalized exercise regimen based on the user's age, fitness level, and health status. The user can then participate in virtual exercise classes or workouts, all from the comfort of their own home [14]. Furthermore, the metaverse can also provide a platform for socialization and community building for older adults. This is particularly important as social isolation is a significant risk factor for various health conditions in older adults. By providing a virtual space for social interaction, the metaverse can help combat social isolation and promote overall well-being [15–18]. In summary, the metaverse has the potential to impact anti-aging by providing virtual healthcare, virtual fitness programs, socialization, and community-building opportunities for older adults. However, it is important to note that these technologies are still in development, and further research is needed to fully understand their potential impact on anti-aging. Table 1 below provides a comparative analysis of some technologies and use cases in the field of digital anti-aging in healthcare.

Table 1. Existing solutions that could be applied in the metaverse.

SL	Description of Study	Technologies	Use Case	Reference
1	User-customized smart aging system by combining AI and the metaverse	IoT, AI, and VR	Smart aging system	[19]
2	Entertainment in the metaverse as an anti-aging strategy	AR	Virtual coaching for anti-aging treatment	[20]
3	Social networks and communities as an anti-aging strategy	Metaverse social applications	Share information and resources related to anti-aging treatments	[21]
4	Skincare effectiveness and consideration	AI medical analysis	Skincare treatment	[22]
5	Fitness for anti-aging using the metaverse	VR, AR, MR, XR	Fitness rehabilitation	[23]
6	Uses of telemedicine within the metaverse for anti-aging treatment	Explainable AI, MR	Skin treatment	[24]
7	Mental health in the metaverse	Virtual reality	Mental health	[25]
8	The metaverse in cancer care	VR, AR	Cancer care	[26]
9	Therapeutic effects of metaverse rehabilitation	Avatar AR, VR	Therapeutic Rehabilitation	[27]
10	Token economies and chronic disease	BC	Chronic disease	[28]

3. Digital Anti-Aging Healthcare in the Metaverse

The metaverse could be used as a virtual environment that allows users to explore and engage with various digital anti-aging healthcare-related interventions and strategies. As an example, users could interact with virtual representations of themselves (avatars) and see how different lifestyle choices, such as exercise and nutrition, affect their appearance and overall health. The potential of the metaverse for digital anti-aging in healthcare is exciting, and it will be interesting to see how this technology develops in the coming years. In this section, we will discuss eventual use cases of digital anti-aging healthcare in the metaverse. Figure 1 shows the digital anti-aging healthcare potential use cases working within the metaverse.

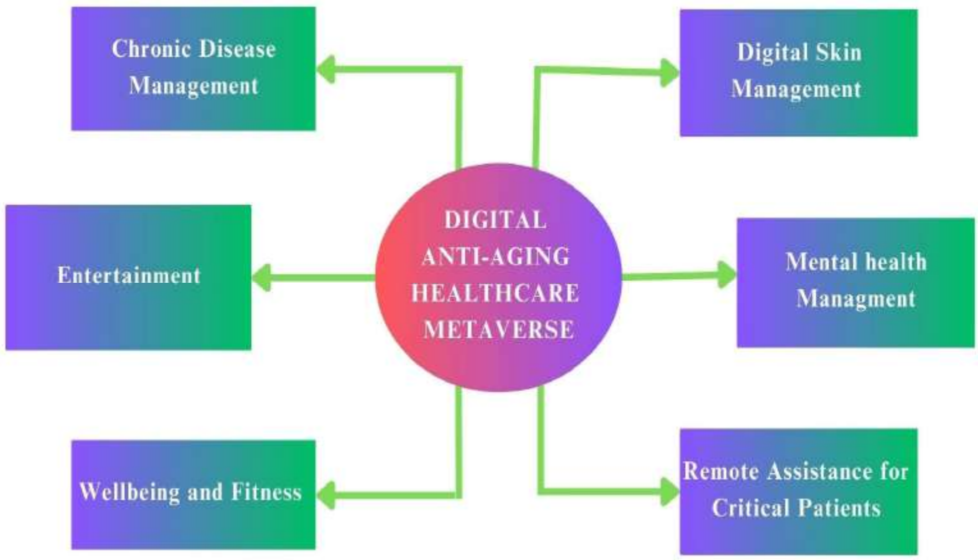

Figure 1. Digital anti-aging healthcare use cases in the metaverse.

Digital anti-aging in healthcare is a very important domain in the modern healthcare industry as it is capable of promoting healthy aging, prevents chronic diseases, reduces signs of aging, boosts self-esteem, promotes lifestyle changes, and many more. The potential of the metaverse for digital anti-aging in healthcare is exciting, and it will be interesting to see how this technology develops in the coming years.

3.1. Chronic Disease Management in the Metaverse

Chronic diseases refer to a condition that requires permanent medical attention or limits daily living activities. According to [29], a disease is chronic when it has lasted for at least a year, and the causes can be tobacco use and exposure to secondhand smoke, poor nutrition, physical inactivity, and excessive alcohol consumption, to name a few. Major chronic diseases include heart-related diseases and stroke, cancer, diabetes, Alzheimer’s disease, Parkinson’s disease, arthritis, chronic obstructive pulmonary disease (COPD), and obesity. Many researchers have proposed digital solutions for patients suffering from these chronic diseases using various technologies as shown in Table 2.

Sun et al. [13] recently proposed four key stages for developing the medical metaverse, which is the path to transfer the abovementioned technological solutions into the metaverse environment. The four stages are stated as follows:

- Holographic construction.

A static geometric model for the virtual world must be built at this stage. This includes virtual hospitals, medical staff, and medical tools. The various objects appearing in the environment are classified into three categories, namely scenes, events, and people. In surgery setup, the environment enclosed with equipment is considered as the scene, patients and all medical staff constitute the people, while the dynamic data generated between people and the scene constitute the event.

- Holographic simulation.

The real-world environment is to be mimicked and implemented into the virtual world. All possible technologies must be combined and used to continuously improve the physical implementation. The immersive process is expected to be at its highest level, connecting to medical information and existing data systems. Real-time motion capture and multi-sensor devices support the process with data from the patients' and physicians' avatars.

- Fusion of virtual and real.

The aim is to make the virtual world appear as real as possible. The immersive experience is expected to be full as mixed reality (MR) breaks boundaries between the medical virtual world and the real world. The continuous improvement of digital technologies motivates the desire to obtain a fully immersive experience. XR devices are used to access the virtual space no matter the patient's or physician's location and enable communication between them. Patients' data and information will be transferred to the virtual world and used in a real-time setting.

- Virtual–real linkage.

Artificial intelligence (AI), IoT, brain–computer interfaces (BCI), and others will be utilized to create medical equipment and methods for the simulation process. The implementation process is expected to adapt to technological development and create an intersection between the real and virtual worlds for medical interventions. The four above-mentioned stages are a pathway for implementing medical solutions into the metaverse. In our case, is it a promising way to handle chronic diseases using a fusion of technologies and the real-life existing digital methods.

Table 2. Some chronic disease management techniques are transferable into the metaverse.

SN	Task	AI	IoT	BC	Reference
1	Acute exacerbation of COPD detection	✓	✓	×	[30]
2	Diabetes monitoirng assited by BC and IoT	×	✓	✓	[31]
3	Validation of wearable sensors for gait monitoring in patients	✓	✓	×	[32]
4	Retinal photograph analysis and blockchain platform to facilitate AI medical research	✓	×	✓	[33]
5	Remote patient monitoring for cardiovascular diseases	×	✓	×	[34]
6	Quality of life framework for cancer patients	×	✓	✓	[35]
7	Heart rate monitoring older people	✓	✓	×	[36]
8	Parkinson's disease diagnosis, monitoring, and management	✓	✓	✓	[37]
9	Stroke disease prediction system	✓	×	×	[38]
10	Cancer care in India	✓	✓	✓	[39]

3.2. *Entertainment in the Metaverse as an Anti-Aging Strategy*

Entertainment becomes more important as we age. As people get older, they reduce socializing and interacting with others. This attitude changes their psychological state and sometimes leads to an unhealthy mood. Interaction with others becomes very important to maintain a positive outlook and emotions. The entertainment program is recommended for the aging population and can involve many aspects. It could be puzzles, card games, having coffee, playing games, or tasks such as making jewelry. Regarding IT entertainment tools, the gaming industry is the leading entertainment program for both young and old people. The venues of the 2D and 3D games with a high level of interaction and immersion constitute a great means of entertainment that has been proven to help users feel good and have a better outlook, reducing stress. The metaverse environment, in connection with other digital technologies such as AI, BC, and IoT, making use of VR devices, facilitates the entertainment program by not only limiting the user to games (early application of the 3D environment), but by making way for a new social environment where people can meet and make many other discoveries. It will be possible in the metaverse to meet and collaborate with others, socialize, and make new friends, shop for real and virtual products, play virtual games, and attend events such as concerts, trade shows, and learning events.

3.3. Well-Being and Fitness for Anti-Aging Using the Metaverse

Well-being and fitness promote the anti-aging process. The metaverse offers opportunities in this arena through the use of VR technologies. As demonstrated above, the gaming industry plays an important role in human well-being. It has been proven that the use of VR devices helps in stimulating brain activity, especially in those suffering from dementia [40]. Dementia patients can use the metaverse to connect with other environments and are able to simulate memories and connect with friends and family. The metaverse also offers many ways for people to keep fit. Global giant Animoca Brands, OliveX, adapted the Sandbox metaverse to make a fully interoperable fitness gaming ecosystem called Gamified Fitness [41]. The game Fortnite acted as a blueprint, and fitness streaming is one of their most popular fitness games. Though some people seem not to accept the fitness metaverse as revolutionary, it appears today as one of the top radical and exciting opportunities in the fitness sector thus far.

3.4. Digital Skin Management as a Digital Anti-Aging Strategy

Another aspect of anti-aging is the skin's appearance. People tend to think that anti-aging procedures are for the sole purpose of physically looking younger, believing that it is the main reason for the existence of the anti-aging treatment. Though delaying aging appearance to satisfy the desire to be more youthful is part of anti-aging process, the above sections outlined many other possibilities that encompasses anti-aging. So far, the maintenance of human skin to keep its youthful state is carried out by using skincare products, specifically anti-aging skincare products (examples include sunscreen, moisturizer, and anti-wrinkle creams, from brands like Drema E and Neutrogena) which constitute another important target for the anti-aging strategy. These products are manufactured using natural ingredients such as vitamin A, vitamin C, peptides, coenzyme Q10, tea extracts, grape seed extract, and niacinamide. Using VR/AR supported by AI, users can find the most suitable skincare product for themselves. In this case, the user will be able to visualize the product output over time and make a good decision. An example of such an application is the Skin Analysis Face App by Cosmopolitan US, which is capable of conducting a face skin analysis using a model made of many face images to determine spots, wrinkles, texture, and dark circles from a selfie.

3.5. Mental Health and the Metaverse

Mental health is among the most important healthcare sectors for humans as it has an impact on the aging process. A healthy mental condition is linked to a lower risk of a shortened lifespan. The metaverse has the potential to reshape the human mental condition using its own technology. A metaverse environment can serve as a rehabilitation center for mental disease patients. While in the metaverse environment, patients gain full immersive experiences and can follow-up with a rehabilitation training session for the betterment of their mental condition or any other health issue. The metaverse is being used in hospitals for training, and some doctors are using it for remote consultations. As more businesses investigate its potential, this technology will probably advance [42]. VR, AR, and mixed reality are the most important technologies for this type of treatment, and nowadays they are also increasingly used for the diagnosis of mental health. Some mental health disorder applications can possibly be created within the metaverse, for disease such as:

- Attention deficit hyperactivity disorder.
- Eating disorders

- Anxiety, phobias, and post-traumatic stress disorder
- Autism
- Alzheimer's disease
- Stress and pain prescription
- Psychosis, delusions, and schizophrenia

The use of games as a strategy to address mental health diseases' management using the metaverse has been adopted by a few Big Tech firms. A mental health app called Bump Galaxy in a VR environment explored this as prototyped on Minecraft. It acts as a 'game world therapy' and helps patients not only as a societal support and safety tool, but also as an assistant to patients in overcoming depression, anxiety, or trauma through the Bump Galaxy gaming environment. Visualizations with deep hypnosis will develop mental resilience and well-being in the community via this bottom-up model [43–45].

3.6. Remote Assistance for Critical Patients within the Metaverse

Assisting patients by constantly monitoring their health condition is a key factor in the digital anti-aging process. The applications for treatment and monitoring using the metaverse are applied to speed up the attainment of a healthy condition without any fear and risk. It is applied in the medical field for a wide range of diseases. The healthcare provider can define the specific objective of the required treatment and collect the patient's information. Different software and hardware are used to create 3D virtual data, which then creates a 3D virtual environment. The metaverse VR and AR of the required medical data are created and identified with the best possible procedure. This procedure is applicable to plan the treatment, and then helps to perform the actual treatment [46]. An example of a monitoring plan is shown in Figure 2. In this case, the doctor analyzes the data collected from the patient and is then able to discuss with other experts for appropriate interpretation and the correct suggestion of eventual treatment, after which feedback is recorded and sent to the patient to inform them about their current health condition.

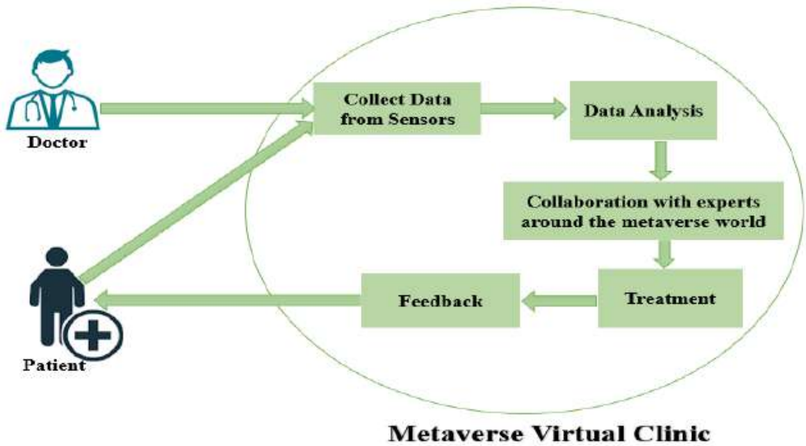

Figure 2. Patient monitoring within the metaverse.

4. Digital Anti-Aging Healthcare-Supporting Technologies in the Metaverse

The use of other technologies in the metaverse regarding healthcare provides numerous benefits, such as improving accessibility and reducing costs. Patients can receive care from anywhere, reducing the need for transportation and lowering healthcare costs. Additionally, healthcare professionals can provide more efficient and personalized care by using these technologies. An illustration of some supporting technologies in the metaverse for digital anti-aging in healthcare is depicted in Figure 3.

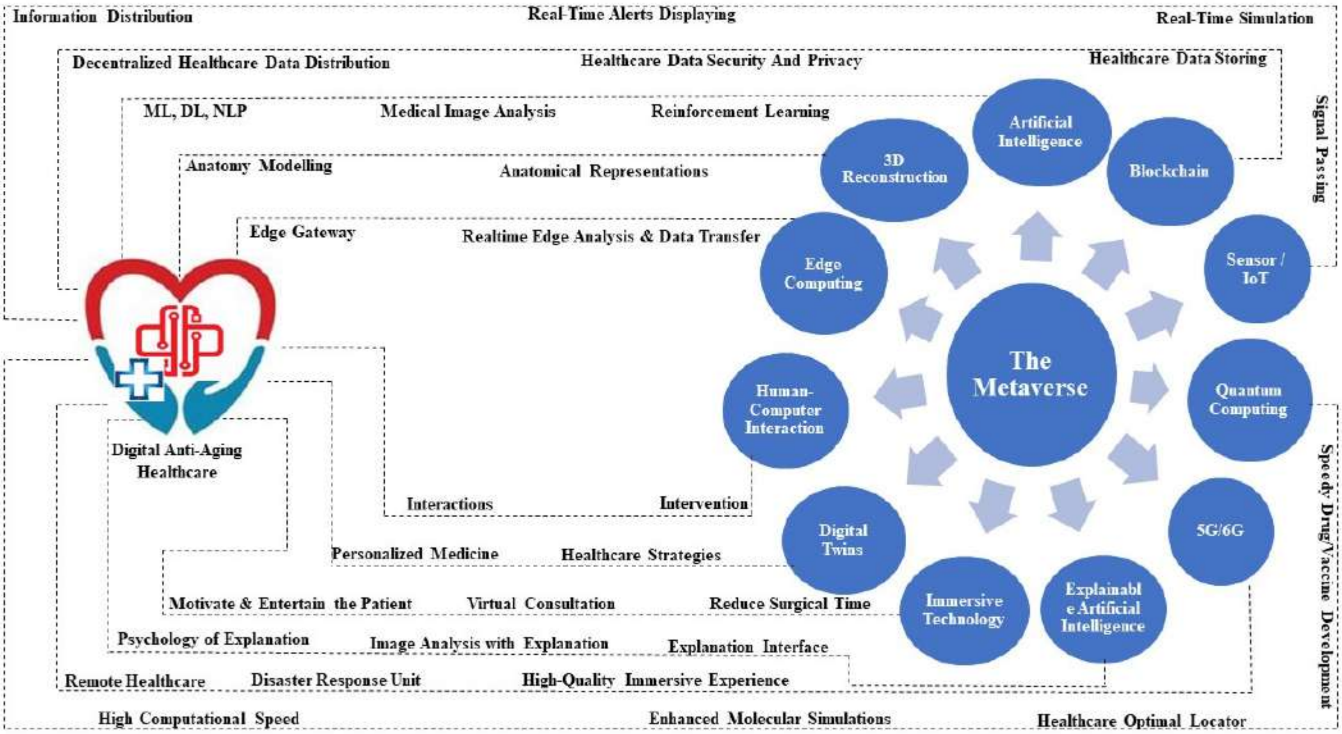

Figure 3. Supporting technologies for healthcare in the metaverse.

4.1. Artificial Intelligence

Artificial intelligence (AI) is a part of computer science that consists of developing systems that would require human intelligence to perform tasks of visual perception, speech recognition, decision-making, and many more. AI is subdivided into many subsets, for instance machine learning, deep learning, computer vision, natural language processing, etc. All the subsets of AI are useful to the metaverse's proper functioning, depending on the application areas. Natural language processing (NLP) in the metaverse can be used to provide text and speech interactive experiences [47]. In the medical domain, data can be extracted from a consultation discussion between a patient and a doctor avatar to proceed with treatment. Computer vision, machine learning (supervised/unsupervised learning, reinforcement learning), deep learning (ANN, CNN, LSTM, RNN, etc.), transfer learning, and other AI-related technologies are also combined to build and train accurate models in real life, which can be used for disease prediction in the metaverse by healthcare professionals in the treatment process [48–67].

4.2. Blockchain

Blockchain is a digital ledger of digital data transactions that allows multiple parties to securely and transparently share and store data. Blockchain technology can be used in a variety of ways to support the development and operation of the metaverse. Blockchain can be seen as a system of computing and storing data in a safer and decentralized manner. Blockchain ensures the decentralization of the metaverse due to its decentralized ledger architecture. In the metaverse, the healthcare blockchain can provide patient data management, medical supply management, a secure payment system, and many more [68–71].

4.3. Internet of Things

The Internet of Things (IoT) refers to the network of physical devices which are connected to the Internet and interchanging data. IoT has become the leading technology behind advanced telemedicine. Due to mobility restrictions, IoT has gained interest from many Big Tech companies for remote applications [72]. IoT devices can be particularly useful in supporting the development of healthcare metaverse services, enabling more personalized and efficient care delivery. Wearable IoT devices can monitor vital signs, such as heart rate, blood pressure, and oxygen saturation, and transmit these data to healthcare professionals. This can enable remote monitoring of patients, allowing healthcare professionals to detect potential issues before they become critical and provide more timely interventions [73–75].

4.4. Edge/Cloud Computing

Edge computing technologies can play a significant role in supporting the development and operation of healthcare metaverse services, enabling the secure and efficient storage and processing of large amounts of data [76]. Cloud computing can also support the deployment of machine learning and artificial intelligence (AI) algorithms for healthcare applications. These algorithms can be used to analyze vast amounts of data, providing insights into disease patterns and treatment outcomes, and supporting more accurate and personalized diagnoses and treatment plans [77].

4.5. 5G/6G Network

The 5G and 6G networks refer to high-speed, low-latency, and high-capacity connectivity, which is vital for receiving immersive and responsive experiences. Connectivity plays a crucial part in making the metaverse a fully immersive environment. The Chief Architect at Ericsson, Silicon Valley, Mischa Dohler talks about why 5G is playing a central role in the emerging metaverse [78]. The 5G/6G networks offer rate, range, reliability, latency, and so much more, which are vital in the healthcare setting, especially in the metaverse. Such connectivity will ensure online consultation through patients' and doctors' avatars, facilitate training of medical doctors using the metaverse, allow to conduct assisted metaverse telesurgery, and many others [79]. In order to ensure the highest communication flow in the metaverse, the features and requirements mentioned in Table 3 have been addressed by the 5G/6G technology.

Table 3. Metaverse networks need and features.

Features and Needs	5G and 6G Ecosystem Potential Solutions
Global access to every multiverse that makes the metaverse	• Roaming capabilities to ease global access • Consistent coverage and capacity
Lightweight and accessible XR devices for the metaverse experience	• Access to edge computing with high throughputs and low latency • Low latency and dependable connectivity allow devices to utilize edge streaming and render more tasks at the edge
Edge-Cloud and Cloud capabilities	• Enhanced render level of detail • Offload processing to save battery life
Consistent interfaces	• Metaverse standards • XR standards, haptic, and holographic • Telco standards
Fast accesible packages for developers	• Access 5G as a "network platform" for developer using API • APIs into available developer platforms and business logic

4.6. Immersive Technology

Technology that entirely transports the user to a metaverse environment that blends the physical environment with virtual content is referred to as immersive technology. Recent-era immersive technologies are used in the medical and healthcare domain. With the aid of VR, AR, and XR technologies, medical practitioners can enhance their skills and successfully apply the knowledge they have gained from simulations to the operating room [80]. This technology is making interactive visualization in the XR environment, enabling VR patients to access drug-free treatment without physical contact [81]. Using VR, AR, and XR, doctors are creating 3D models of their smart operation theaters for taking live suggestions from other institutions and other country's expert surgeons, and for showing operational procedures to their relatives [82]. In a virtual metaverse environment, the doctor's avatar discusses with the patient's avatar and gives them proper solutions for the healthcare problem. In addition, doctors administer therapeutic treatments to patients using metaverse virtual environments by using VR. As an example, a lung cancer surgical training in the smart operating room was realized through the metaverse during an online conference provided by the Seoul National University Bundang Hospital's medical staff [83]. In Figure 4, some healthcare immersive technologies are presented.

Figure 4. Immersive technologies for healthcare in the metaverse.

4.7. Digital Twins

Digital twin (DT) is a virtual model of a physical entity. DT technology helps in creating DT for patients, and medical devices. The vital tenets of personalized medicine and the pharmaceutical industry is that treatments should be tailored to the patient, and this technology provides novel and definite solutions for accurate analysis and adherence to patient-appropriate action approaches [84]. To produce visual representations, gather, store, analyze, and provide insightful data, DT integrates four technologies, namely IoT, extended reality (XR), artificial intelligence (AI), and the Cloud [85]. With these applications, the digital twin is improving healthcare, for the support of diagnoses and treatment decisions in the medical industry. In detecting symptoms at the initial stages, doctors use wearable sensors to help diagnose the patient in the digital twin system. Similar to humans, DT is a virtual model for the physical object of medical devices' design and optimization, and DT can test new prospective medications to determine the most effective and ideal prescription by building a digital cohort of real patients with various phenotypes. By modeling an invasive clinical practice, digital twins can anticipate the result before the therapy is chosen [86–88].

4.8. Human–Computer Interaction

Human–computer interaction (HCI) is concerned about human interaction with a given system. It includes the plan, design, implementation, and modification of interactive computing systems. HCI makes it easier for the medical and healthcare industry to exchange with humans in all divisions of the healthcare industry. In recent era, HCI has been used in the ICU, CCU for analyzing equipment in the operation theater. HCI makes the decision with the help of artificial intelligence, healthcare data management, electronic health records, dashboards, patient portals, and maintains the healthcare data lifecycle. HCI also allows different types of online communication between doctors, patients, authorities, and patients' relatives [89].

4.9. Quantum Computing

Quantum computing (QC) is field of metaverse computing that uses the principles of quantum mechanics to perform certain types of calculations in the metaverse environment that are difficult for classical computers. Numerous computer-intensive applications in the healthcare industry are particularly well-suited to QC. A common cancer treatment is radiotherapy. It uses radiation to kill malignant cells or stop their growth. A radiation strategy must be developed to lessen the harm of the radiation dose to healthy tissues and organs. It takes several simulations to find the best approach to attain the ideal radiation strategy. Hence, with quantum computing, the range of possibilities that are considered between each simulation is broad. As a result, it enables healthcare experts to run several simulations at once and create the best plan. Additionally, QC works for drug research and interactions, healthcare data, and genomics, and it improves medical image solutions. Devices for quantum imaging assist in producing extremely precise images that make it possible to see individual molecules. Machine learning and quantum computing assist professionals such as doctors in interpreting the findings [90].

4.10. Three-Dimensional Reconstruction

In recent eras, three-dimensional reconstruction (3DR) has become one of the significant computer vision technologies for the healthcare sector; more accurately, 3DR is the twin of the medical domain [91]. The 3DR works with medical images such as different types of cancer images, MRI, CT, and medical surgeries. The 3DR uses medical image segmentation for better medical imaging accuracy to allow proper treatment. The use of 3DR software for preoperative assessment and surgical planning may improve surgical success rates and reduce operative risks. On the other hand, VR visualizes patients' health conditions. For medical teaching, utilizing VR technology in medical education can successfully convey instructional content, provide a realistic learning environment, enhance the efficacy of teachers' expertise and skills, and make it simpler for teachers to communicate their lesson plans and content [92].

5. Metaverse Digital Anti-Aging Healthcare Challenges

A strategy for digital anti-aging healthcare in the metaverse must meet a couple of challenges during its implementation and operation stages. Though the adoption of the healthcare solutions in the metaverse environment will help improve patients' conditions and maintain a healthy aging process, especially when assisted by the above-listed supporting technologies, it still suffers from some challenges [93].

5.1. Privacy and Security Concerns

There is a high demand and necessity for medical data, including those collected through the digital anti-aging healthcare in the metaverse environment. Data security is threatened by cybercriminals, who are always in search of means to access illegal digital platforms to steal data, regardless of the security protocol adopted by the rightful owners. Healthcare data are big data of a high-standard, and the data are a target for cybercriminals, so utilizing the metaverse for healthcare data exchange creates a new branch of challenges that must be addressed. Furthermore, confidentiality is an issue with larger amounts of patient data. Whether patients feel comfortable communicating and interacting in the metaverse, full confidence depends on evidence of data confidentiality as [94] demonstrated by presenting some encouraging results. As with various digital platforms, data security can be compromised. Metaverse hospitals must be armed with increased security systems to keep patients' data out of danger so they remain accessible only to approved healthcare personnel working in the metaverse hospital. The Health Insurance Portability and Accountability Act (HIPAA) sets tangible rules that must be adjusted concerning how much information is shared in the metaverse. Different countries have different data rules, and doctors are only licensed to exercise in specific geographical areas, which limits their power to work in a metaverse with universal patients [95]. We believe that healthcare, in combination with the metaverse, truly has the dynamic to make the world an attractive place and create value in an innovative way. In Figure 5, we demonstrate the privacy and security concerns of the metaverse, underlining how an attacker (threat) is trying to break through the metaverse user devices and the metaverse platform.

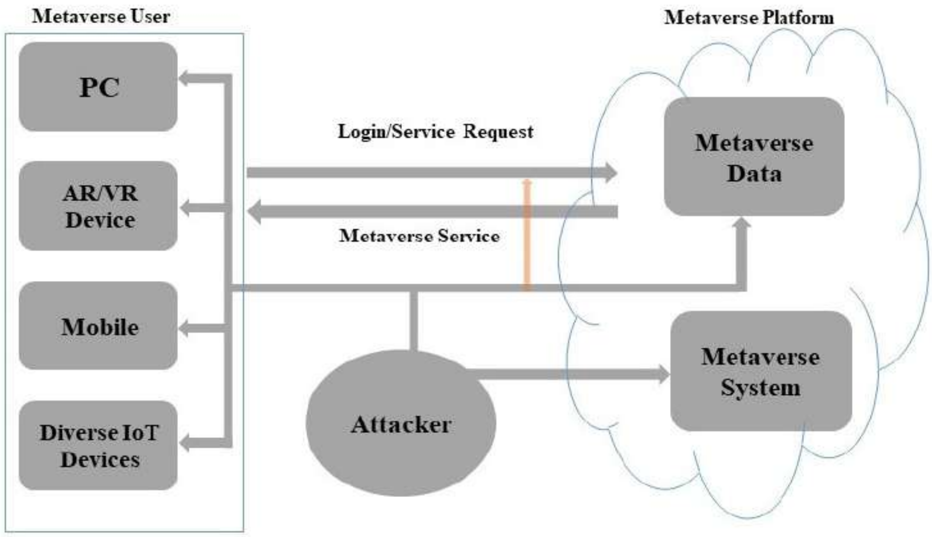

Figure 5. Privacy and security concerns in the metaverse.

5.2. Information Security Concerns

Giant healthcare companies will gather sensitive information about patients, with or without concerns, while providing healthcare in a variety of ways. The metaverse would be able to move toward an excellent virtual experience, allowing doctors to remotely treat patients with several health conditions with the aid of different electronic devices, generating a significant amount of digital data. This is made possible by virtual technologies and personal communication. The patient's health condition is passed along through the communication channel, and the doctor's reactions are also transferred over the same channel. To protect sensitive patient information from outsiders, encrypted data are generated from robust algorithms and the blockchain [96].

5.3. Standardization and Interoperability

The modern healthcare paradigm heavily depends on interoperability, which is also one of the most difficult tasks to carry out as far as innovative technologies are concerned. Which gadgets are simple to port across various platforms and networks may be significantly and unpredictably impacted by the addition of the metaverse. The metaverse adoption will be sluggish and might even have some unfavorable outcomes, which is a reason why the rapid establishment of data and communication standards is a necessity. By establishing technological standards and protocols, big IT firms will probably steer the metaverse architecture [97]. The possibility exists that certain tech firms will try to influence the developing metaverse standards to advance their own commercial interests. Some emphasis is placed on the value of technological tools, protocols, and services that enable interoperability in the development of the metaverse ecosystem, but they caution against developer lock-in, consumer choice restrictions, and the suppression of rival advances.

5.4. Increasing the Metaverse's Userbase

How can Meta and other IT companies persuade individuals to join them in metaverse healthcare? The commercial pace of every contemporary technology must be developed by its users. Thus, the metaverse's dependability and use are questioned in several ways. For instance, would older people with less technological expertise be able to access the metaverse and receive the treatment? Or do meetings carried out in the metaverse appear to offer the same benefits as in-person visits? [98].

5.5. Limited Internet Access, Especially in Rural Areas

The use of these technologies in rural areas may be complicated by the increasing bandwidth needs of immersive practices in 3D environments. In the current introduction of AI in ophthalmology [99], where dormancy has been documented to create preemptive disruptions to applications in busy clinical situations, sporadic or rare internet connectivity is a gradual concern [100]. The 5G telecoms industry is developing solutions to improve connectivity, and recent research is building the groundwork for an approachable deployment roadmap [101]. To allow for compatible signal transmission, the 5G networks, however, call for several tiny cells to be placed closer together as base stations [102]. Due to this, implementing 5G in rural areas may also be difficult due to the high demand for infrastructure [103].

5.6. Lack of Knowledge of the Metaverse Domain in Technology

A shortage of knowledge of any innovative technology is a significant roadblock to the adoption of a solution [104]. A particular solution can take on many different forms, such as making it difficult to understand the user interface, which could lead to mistakes or incorrect interpretations of the output from a particular device [105]. Concerns about privacy and false perceptions of corporate overreach may also arise from the commercialization of behavioral or health data. Early qualitative research examining stakeholders' propensity to adopt these solutions and their capacity to put these technologies to practical use can help overcome these substantial implementation challenges [106]. Fortunately, preliminary research has started to examine this for immersive technology applications in ophthalmology, with many patients in one such study even indicating a readiness to pay for access to pertinent resolutions.

5.7. Expensive Equipment

The creation of cutting-edge AR- and VR-based technologies to enhance the general surgical environment on a universal scale has expanded with the rise of companies focusing on the metaverse. Tech wearable devices, including sensors, glasses, gloves, and other hardware mechanisms that can precisely recognize the state of the patients, are needed to effectively transform the current healthcare system within the metaverse [107]. Matching technologically advanced equipment, the cost of infrastructure will be quite high for healthcare contributors because the metaverse demands strong end-to-end connectivity for an effective strategy. Adopting the metaverse in the healthcare sector requires replacing outdated wearable devices with appropriate software and hardware infrastructure, which is a very expensive process at first [108].

5.8. Difficulties in Law and Regulation

As the healthcare industry is integrating with the metaverse, it has considerably developed, with interns now caring for patients and instructing medical professionals using cutting-edge tools and equipment. The metaverse has evolved from technology into a new business model thanks to current market developments. As the metaverse's use cases expand, emerging medical technologies that involve a variety of parties, including healthcare providers, insurers, and pharmaceutical corporations, to effectively treat patients' ailments, may raise legal and regulatory concerns [109]. The metaverse lacks appropriate standards and procedures, so adopting it could cause trust issues, confusion among different entities within the field of intellectual property rights, etc. To take appropriate action or to stop illegal activities in the virtual world, however, relevant policies must be created within the legal framework.

6. Metaverse Anti-Aging and Healthcare Future Directions

Firstly, we wanted to investigate the link between the metaverse and illness prevention and treatment. According to a bibliometric examination of VR and AR, the metaverse may be used for diagnostics and operations, as well as rehabilitation for pain, neurodegenerative illnesses, stroke, depression, and cancer, with positive outcomes [110]. For cancer disease, artificial intelligence technology may be used to prevent cancer as well as diagnose and treat patients [111]. Anti-aging healthcare technology has helped in expanding people's life expectancy. Taking a deeper look at our DNA is a terrific method to detect diseases or medical weaknesses and take preventative actions in good time. Genetic testing can help discover information on the ideal individual diet, potential medical issues, and the likelihood of allergies or pharmaceutical reactions [112]. Since virtual reality and augmented reality technologies provide an immersive experience, these may be considered the metaverse 1.0. Nevertheless, some big tech firms are already utilizing these technologies. Embodied laboratories provide immersive caregiver training, XR health provides rehabilitation, and rend ever and Silver Adventures provide meaningful virtual experiences to improve the well-being of elderly people. Furthermore, the metaverse may provide more lifelike means of communicating with others who are geographically far from us. This is when things start to get interesting. There are several ways in which this might assist elderly people. To begin with, better, more lifelike communication will significantly enhance telehealth. Our legacy is another area that may be considerably improved. Leaving anything for others to remember us by long after we have no bodily presence on this planet is still difficult these days. Many people are seeking ways to record their life tales for future generations. The metaverse will reap incredible benefits in healthcare through the confluence of telepresence, DT, and BC, particularly in terms of patient observation. Telepresence, known as telemedicine, is the remote provision of medical services [26]. The metaverse is projected to be a helpful instrument for surgeons performing complex surgeries and for improving patient care. Surgeons now perform procedures using cutting-edge technologies such as robots after collecting the patient's vital signs, pictures, medical records, and more. The new tools that interact with the metaverse can provide real-time test data to help patients perform better. The metaverse will gradually be employed at first since clinical trials are required to determine whether it is a viable tool for surgery. We anticipate that the metaverse will garner more attention as its use develops, much like robot-assisted surgery.

7. Conclusions

Integrating healthcare services in the metaverse environment has numerous potential benefits. The main goal of this study was to highlight how digital anti-aging in healthcare can be effective while integrating the metaverse environment. The integration of artificial intelligence (AI), blockchain (BC), and Internet of Things (IoT) technologies can be used in combination to enable a more personalized, efficient, and secure care delivery, reducing costs, and increasing the patient's life expectancy. Looking ahead, continued investment in research and development is needed to overcome possible challenges and realize the full potential of metaverse technologies in the context of digital anti-aging and healthcare. With the right investment and collaboration, metaverse technologies have the potential to revolutionize the way we deliver and receive care, improving the quality of life and well-being of individuals around the world. The effective adoption of the standard and the implementation of our mentioned key use cases remains the way forward to practically see our expectations.

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