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Metaverse and Health Care System

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The rapid progress in digitalization and automation have led to an accelerated growth in healthcare, generating novel models that are creating new channels for rendering treatment with reduced cost. The Metaverse is an emerging technology in the digital space which has huge potential in healthcare, enabling realistic experiences to the patients as well as the medical practitioners. The Metaverse is a confluence of multiple enabling technologies such as artificial intelligence, virtual reality, augmented reality, internet of medical devices, robotics, quantum computing, etc. through which new directions for providing quality healthcare treatment and services can be explored.

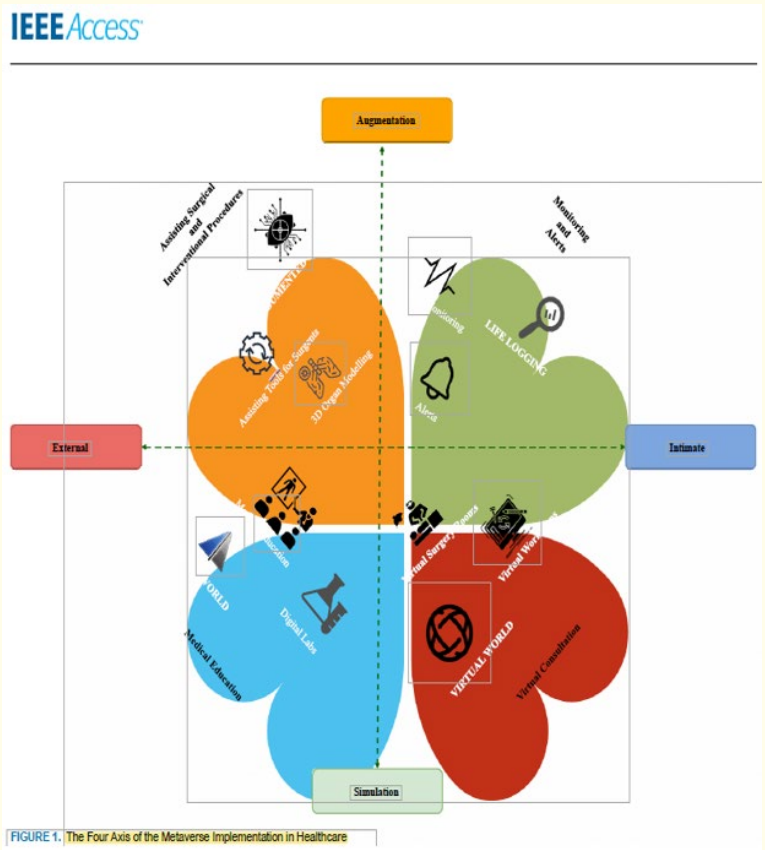


FIGURE 1. The Four Axis of the Metaverse Implementation in Healthcare

The amalgamation of these technologies ensures immersive, intimate, and personalized patient care. It also provides adaptive intelligent solutions that eliminates the barriers between healthcare providers and receivers. Healthcare is one of the most significant determinants of ensuring general, physical, social and mental well-being of the entire human population.

In the world. The primary objective of any healthcare system is to channelize its efforts towards activities that promotes, restores, maintains and improves healthcare services. The recent pandemic of COVID-19 have added enormous pressure to the global healthcare sector and related workforce, infrastructure and supply chain management. The COVID-19 has been the primary reason for accelerating rapid change across the healthcare ecosystem and have compelled the stake holders to pursue adaptation and innovation of all the technologies used in this sector. The need to deploy advanced digital tools and services has become a necessity to provide optimized This digital transformation has significantly impacted the healthcare ecosystem by improving their working capability, access to services, patient-clinician experience by using artificial intelligence, cloud computing, Augmented Reality (AR), Virtual Reality (VR) technologies]. The healthcare system in the Metaverse provides health-care service experience that is interactive, immersive and recreational customized to meet individual patient's needs. The use of these technologies provides exposure towards new ways of delivering treatment in significantly lower cost thereby enhancing patient outcomes. The Metaverse technologies can help healthcare professionals in effective planning and diagnosis of diseases. The Metaverse environment enables enhanced surgical pre-operative planning by transforming CT scans into 3D reconstructions using headsets. This also helps the surgeons to specifically view, isolate and manipulate anatomical regions to perform critical surgeries. Plastic surgery is an extremely complex procedure which requires reconstruction of human body parts. In case of plastic surgeries, the use of VR in the Metaverse could play an important role wherein the virtual avatar could accurately predict the outcome of a plausible plastic surgery.

The health data can be visualized by the patients on the virtual dashboard helping them to communicate with clinicians, researchers, nutritionists, and other stake holders for achieve individual care and treatment. The Metaverse has the potential to revolutionize medical education and training. The use of AR provides the conducive environment to explain practical procedures rather than disseminating theoretical knowledge.

The Metaverse can provide 360 degrees visualization of the body ailments and can act as the most helpful surgical training tool fostering optimum level of cooperation and highest degree of immersion.

The global statistics of the Metaverse reveal that the global healthcare market in the Metaverse holds a value of 5.06 billion Dollars in 2021 and is expected to reach 71.97 billion Dollars by 2030 with a compound annual growth rate (CAGR) of 34.8 percent during considered period of forecast.

Sensors

The precision of personal healthcare analysis partly depends on the measurement of different physiological parameters using sensors. Recently, an innovative wearable temperature sensor technology which utilizes freestanding single reduction graphene oxide fibre was introduced and developed with many benefits, such as fast response, high stability and repeatability under mechanical deformation, and wearable comfort. Despite being readily available, medical equipment is costly and consumes a lot of power. With biomedical sensors, medical systems are flexible with machine-to-machine interactions, saving time of both patients and medical institutions, and offering treatment plans over tele diagnosis. Among various sensors, temperature, electrocardiogram (ECG), and pulse are the most important ones for health status evaluation besides blood pressure, accelerometers, and imaging sensors.

The following part will discuss some relevant sensors commonly used in healthcare and medical systems.

In general, *big data* is currently characterized by seven Vs as follows: volume (a large amount of data), variety (including structured, semi-structured, and unstructured data with different formats), velocity (high rates of data inflow and real-time processing), veracity (detailed data accumulation), value (in-depth and meaningful information), variability (offering extensionality and scalability), and valence (data interconnection).

- ***Big data collection***: Sqoop is an open-source framework for data import and export between Hadoop Distributed File System (HDFS).
- ***Big data processing***: MapReduce is a programmable model that simplifies and accelerates a massive amount of data, featured by three main functions (e.g., mapping, sorting, and reducing)
- ***Big data storage***: Hadoop performs the distributed system HDFS and the non-relational databased HBase for big data storage. HDFS, a primary component of a Hadoop cluster, provides high throughput access to application data and is suitable for high-volume data applications.

Artificial Intelligence

In the last decade, several modern technologies and tools based on distributed architectures, along with large memory and powerful computing units, have been introduced for big data processing in healthcare and medical domains:

All in healthcare is an all-encompassing term used to describe the use of ML algorithms to mimic human cognition in presenting, analysing, understanding, and learning complex healthcare and medical data. In fundamental, most of the existing AI/ML algorithms can be grouped into two categories: traditional techniques and advanced techniques, which can solve three principal problems: clustering, classification, and regression. Conventional AI/ML algorithms usually performs four data-based learning types: supervised learning (i.e., learn the relation between input and output via a mapping function using labelled data and classify/predict the outcome for an unforeseen input sample using the trained model), unsupervised learning (i.e., involve the utilization of ML algorithms for unlabelled data analysis and clustering, and can find out data groups without the need for human intervention), semi-supervised learning (i.e., trained upon the combination of clustering similar data using an unsupervised learning algorithm and using the existing labelled data to label the remaining unlabelled data), and reinforcement learning (i.e., make a sequence of decisions, in which an agent learns to attain a goal in an uncertain and complex environment). Recently, deep learning (DL) is a subset of ML with advanced architectures, e.g., recurrent neural network, long short-term memory network, and convolutional neural network, relying on multi-layered artificial neural networks, to attain ground-breaking performance in many classification and regression tasks of healthcare and medical domains.

Wireless Communication Networks

Many innovative communication technologies have been introduced in the last decade due to the explosion of IoT technologies with edge and mobile devices along with the diversity of applications and services, especially in the health- care and medical domains.

Cellular network: As so-called mobile network, a cell network is a radio network distributed over land areas called cells. Each cell is served by at least one fixed-location transceiver, a.k.a., cell site or base station. Remarkably, cellular networks can enable a huge number of portable receivers to communicate with each other and other fixed transceivers via base stations.

Wi-Fi: is a wireless networking technology that allows diverse devices, such as computers (desktops, laptop, and tablets), mobile devices (smart phones, smart watches, and wearables) and others (printers, TVs, projectors, and video cameras) to connect the Internet.

Cloud and Edge Computing

Many traditional healthcare and medical systems have faced a big problem of massive unstructured, diverse, and exponential-growing data collected from different sources, thus arising much more challenges to store and process data effectively and securely. To this end, the advanced techniques and high capacities of cloud computing allow analysing healthcare and medical big data.

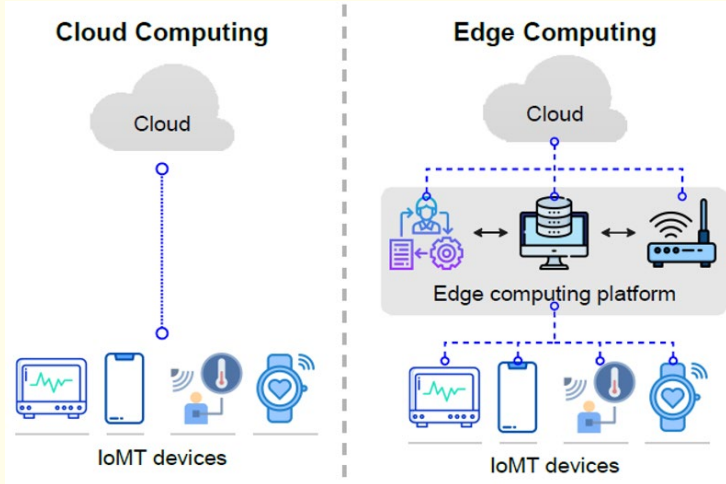


FIGURE 2. Cloud computing vs edge computing for IoMT-based healthcare and medical applications.

Immersive Technology

Immersive technology, a term that refers to the technologies for reality extension using the neuroscience of the human brain, aims to create distinct experiences by merging the physical world with a digital or simulated reality.

Besides augmented reality (AR) and virtual reality (VR) as two primary types of immersive technologies, it includes ex- tended reality (XR), mixed reality (MR), holography, telepresence, digital twins, and first-person view (FPV) drone

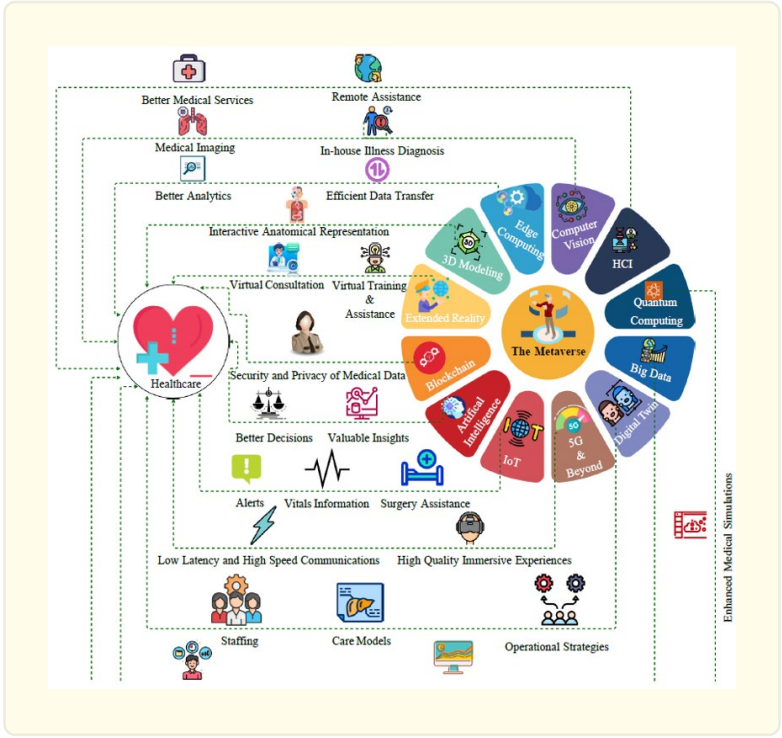
flight. The above-mentioned immersive technologies can be briefly featured as follows:

- ***VR***: a technology that allows the creation of a fully immersive digital environment, in which the physical or real-world environment is entirely suppressed.
- ***AR***: a technology that enables the superposition of digital elements into the real-world environment, i.e., the composite view of physical and digital elements can be observed.
- ***MR***: a technology that not only allows the superposition of digital elements being viewed in the real-world environment but also establishes their interaction.
- ***XR***: an umbrella term that encompasses any types of technology that alters reality (e.g., adding digital/virtual elements to the physical environment at any level, thus nearly erasing the line between the digital world and the physical world). Indeed, XR includes AR, VR, MR, and other technologies.
- ***Holography***: or hologram is a technology to product three-dimension image of an object with highest resolution of any imaging for device-free watching.
- ***Telepresence***: a novel form of robotic remote control, in which a human operator can observe, feel, interact, and collaborate an object from distance.
- ***Digital twins***: a virtual replication of real-world project, which is require for connecting the physical object for real-time data collection, processing, and response.
- ***FPV drone flight***: a technology uses unmanned aerial vehicle (UAV) with a camera for transferring high- quality videos to goggles, headsets, and mobile devices or another screen, thus allowing users to enjoy environing- mental experience in the first-person view.

- ***Haptics***: refers to a technology that uses tactile (touch) sensation to interact with the computer applications to uplift user experience.

Enabling Technologies of The Metaverse for Healthcare

This section presents a detailed discussion of the enabling technologies of the Metaverse for healthcare, which includes extended reality, blockchain, artificial intelligence, IoT, 5G and beyond, digital twin, big data, quantum computing, human-computer interaction, computer vision, edge computing, and 3D modelling. The illustration of the above- mentioned enabling technologies of the Metaverse for health- care is depicted in the next Fig.



A. Extended reality

Extended reality includes technologies such as augmented reality (AR), virtual reality (VR), and mixed reality (MR), aided by artificial intelligence, computer vision, and connected devices like mobile phones, wearables, and head- mounted displays. By incorporating voice, gestures, motion tracking, vision, and haptics, this new technology is transforming the way services are delivered, improving the quality in various sectors.

B. Blockchain

The foundation of blockchain emerged in a 2008 white paper written by Satoshi Nakamoto. A blockchain is a digital database of transactions that is duplicated and dispersed over the entire blockchain network. Each block in the chain contains several transactions, and whenever a new transaction occurs on the blockchain, a record of it is added to all participant's ledgers.

C. Artificial Intelligence

Artificial intelligence (AI), also known as machine intelligence, focuses on the development and management of technology that can autonomously learn to make decisions and carry out tasks on behalf of humans. AI is a collection of technologies that incorporates

any software or hard-ware component that facilitates machine learning, computer vision, natural language understanding (NLU), and natural language processing. AI will help strengthen the Metaverse infrastructure, enhancing the 3D immersive experience, and boosting the virtual worlds' built-in services. AI technology will also help in improving the quality of services and the Metaverse ecosystem.

The health industry has recently begun utilizing revolutionary techniques such as XR and big data combined with AI in software and hardware to increase the efficacy of medical devices, reduce the cost of health services, enhance healthcare operations, and broaden access to medical.

D. Internet of Things

The phrase "Internet of Things" (IoT) refers to the billions of devices that are currently connected to the Internet and exchanging data. Due to the introduction of low-cost computer chips and the broad availability of wireless net- works, everything from smartphones to intergalactic operations can now be connected to the IoT. Due to the incorporation of sensors and the capacity to communicate with one another, these devices can share real-time data without the need for a human supervisor.

E. 5G & Beyond

The term "5G and beyond" refers to the fifth generation and beyond of wireless technology. It outperforms 4G LTE networks in terms of both speed and latency, and it has a higher capacity. In contrast to the maximum speed of 4G technology, which is only 1 Gbps, the maximum speed of 5G technology can exceed 20 Gbps. Additionally, delivers reduced latency, which has the potential to enhance the performance of commercial applications and other digital experiences.

F. Digital Twin

A digital twin is a virtual representation that acts as the digital counterpart of a physical object or process in real-time. The first practical definition of a digital twin was proposed by NASA in 2010 to enhance the physical-model simulation of spacecraft.

G. Big Data

Big data is defined as the "Information asset characterized by such a High Volume, Velocity and Variety to require specific Technology and Analytical Methods for its transformation into Value".

H. Quantum Computing

Quantum computing is a form of computation whose activities can exploit quantum mechanical phenomena such as superposition, interference, and entanglement.

I. Human Computer Interaction

Human-computer interaction (HCI) is a multidisciplinary topic of research that focuses on the design of computer technology and, specifically, the interaction of humans and computers. Voice, gesture, visual, and brain signal interaction have replaced textual or display-based control as the dominant paradigm in HCI. HCI, VR, AR, and the future of content creation and collaboration technologies will enable the creation of the Metaverse. The visual interactions in the Metaverse will be carried out by HCI technology which is called wearable consumer head-mounted displays (HMD). These HMDs will play a crucial role in the communication between the users and surroundings in the Metaverse.

J. Computer Vision

Computer vision is the study of how computers visualize and interpret digital images and videos. Computer vision encompasses all activities done by biological vision systems, including perceiving a visual signal, interpreting what is being seen, and extracting complicated information in a form accessible by other processes.

K. Edge Computing

Edge computing is a distributed computing paradigm that moves computation and data storage closer to the data sources. Edge computing will improve response times and conserves bandwidth.

L. 3D Modeling

3D modelling is the process of producing a mathematical coordinate-based representation of any three-dimensional surface of an item using specific 3D modelling techniques. As a result of advancements in image processing, computer- aided design, and modelling techniques, it is now feasible to create extremely realistic and trustworthy 3D models. Multiple sectors, including cinema, animation, and gaming, as well as interior design and architecture, utilize 3D modelling.

Medical diagnosis is the process of determining the medical condition of a patient based on the symptoms. Adoption of the Metaverse in healthcare significantly helps in efficient diagnosis of the medical conditions of a patient with the help of various advanced technologies such as AR and VR enabled MIoT models, extended digital twin, blockchain, 5G and so on.

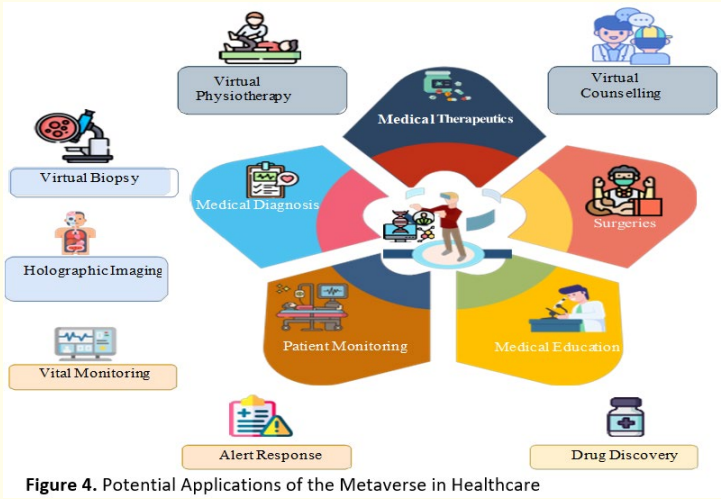


Figure 4. Potential Applications of the Metaverse in Healthcare

A. Medical Diagnosis

Medical diagnosis is the process of determining the medical condition of a patient based on the symptoms.

B. Patient Monitoring

The convergence of telepresence, digital twinning and blockchain will reap amazing benefits of the Metaverse in healthcare, especially in terms of patient monitoring.

C. Medical Education

The Metaverse is a remarkable milestone in the field of medical education.

D. Surgeries

The Metaverse is becoming an important technology in the medical industry, especially in surgery. Surgeons are currently using tools

that range from VR headsets to haptic gloves to mimic surgical procedures, boosting prepared- ness and efficiency in the operating room.

E. Medical Therapeutics & Theranostics

Medical therapeutics can be regarded as the branch of medicine that deals specifically with the treatment of diseases. Digital therapeutics (DTx) deliver evidence-based therapeutic interventions and can be considered as a class of digital medicine. Digital Therapeutics Alliance defines digital therapeutics as products that "deliver evidence-based therapeutic interventions to patients that are driven by high quality software programs to prevent, manage, or treat a medical disorder or disease".

Enabling Technology	Contributions	Challenges	Future Directions
Blockchain, XAI, Teleoperation, 6G	A framework for blockchain and XAI assisted telesurgery is proposed. 6G TI channel is also used.	Real metaverse set up is required for testing the framework	Different XAI models can be compared and the optimal technique can be chosen
Extended reality, Mixed Reality	Eye MG Holo: An immersive 4D pedagogical tool for learning about various ophthalmologic structures is proposed.	Cost effectiveness: Approximately 3500 USD for a HoloLens 2	Can be used for surgical simulation training
Extended reality, Virtual Reality, Augmented Reality	A training in lung cancer surgery using metaverse is explained. The smart operating room was set up in Seoul National University Bundang Hospital, South Korea.	Advanced imaging and other high-end equipments are required for accomplishing the task	Can be extensively used for surgical training and other health related applications
Augmented Reality, Virtual Reality	Cardioverse is introduced for the diagnosis and prevention of cardiovascular diseases	Legal Regulations, security and privacy, user rights	Moral and credibility aspects need to be considered
Machine Learning	A hybrid Structural Equation Modelling- Machine Learning approach is proposed to predict the intention of specific users to employ metaverse in healthcare education. Application of metaverse in UAE is taken into consideration	Only personal innovativeness and user satisfaction is taken into account. Perceived Ease of Use and Perceived Usefulness only were considered	Focus to be given on other medical aspects as well
Virtual Reality	Immersion, collaboration and interaction could be greatly improved with the intervention of the Metaverse in onlile pedagogy	Only small group size was considered for evaluation	To understand the detrimental effect of adoption of metaverse in medical education
Augmented Reality, Virtual Reality	To provide counselling services to post-operative patients	Set up needs to be changed for addressing a large group of patients	Can be adopted for ICU
Wearable devices, IoT	A technique for providing social skills training for children affected with Autism Spectrum Disorder is proposed	Obtaining consent from guardians	Children of all categories can be considered for the study
Artificial Intelligence, Virtual Reality, Robotics	Adoption of the Metaverse in spine care with respect to education, diagnosis, consultation, surgery and research	Affordable advanced care facilities	Other advanced technologies can be incorporated

Ongoing and Upcoming Projects

A. Healthify.
B. Dehealth.
C. Bump galaxy.
D. Accuvein.
E. Hintvr.
F. Healthblocks.

Challenges & Open Issues

- Data privacy concerns.
- Information Security Concerns.
- Interoperability Issues.
- High Cost of Technology.
- The Personal Touch is Lost.
- Legal and Regulatory Challenges.

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