

Revolutionizing Healthcare—The Integration of Virtual Worlds, AR, and Metaverse Technology

Fatma Kilic

The View Hospital, Doha, Qatar
Email: f.kilic@theviewhospital.com

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Abstract

This paper explores the transformative impact of virtual worlds, augmented reality (AR), and the metaverse in the healthcare sector. It delves into the ways these technologies are reshaping patient care, medical education, and research, while also addressing the challenges and opportunities they present. The paper highlights the potential benefits of these technologies and emphasizes the need for comprehensive regulatory frameworks and ethical guidelines to ensure responsible integration. Finally it outlines their transformative impact and discusses the challenges and opportunities they present for the future of healthcare provision.

Keywords

Virtual Worlds, Augmented Reality, Metaverse, Healthcare, Patient Care, Medical Education, Research, Transformative Technologies, Regulatory Frameworks, Ethical Guidelines

1. Introduction

In recent times, the healthcare sector has seen a significant shift as it incorporates virtual worlds, augmented reality (AR), and immersive technology. This integration has propelled the industry into a new age characterized by innovation and a focus on patient-centered care. The utilization of advanced technology has brought about significant transformations in patient care and medical education, while also expediting the progress of medical research. Consequently, this has led to remarkable breakthroughs in comprehending and treating intricate ailments. In addition, the integration of the metaverse, a vast virtual world, into the healthcare domain has brought about a fundamental change, reshaping the manner in which healthcare practitioners engage, cooperate, and provide medical services to individuals. The integration of healthcare has not only broa-

dened the scope of potential healthcare advancements, but has also introduced complex difficulties that need thoughtful analysis and effective resolutions. Through an examination of the transformative capabilities of immersive technologies and the innovative implications of integrating the metaverse into the healthcare sector, it becomes apparent that this fusion is fundamentally altering the landscape of healthcare provision, education, and research. Moreover, it holds the potential to improve healthcare in space by leveraging artificial intelligence, AR, and metaverse integration. By examining the potential of these technologies in healthcare, this paper aims to outline their transformative impact and discuss the challenges and opportunities they present for the future of healthcare provision.

2. Transforming Patient Care

The convergence of virtual worlds and AR has fundamentally transformed the domain of patient care, introducing a new epoch characterized by enhanced accuracy, heightened safety measures, and superior treatment results. The use of virtual reality (VR) simulations allows healthcare practitioners to recreate realistic medical settings, facilitating efficient training and readiness for complex treatments [1]. The aforementioned method not only facilitates an experiential approach to education but also effectively minimizes the potential hazards linked to real-time surgical procedures, hence improving patient safety and decreasing the probability of procedural mistakes. The utilization of AR apps has furthermore provided healthcare practitioners with enhanced capabilities by superimposing essential patient information onto their visual perspective, enabling immediate access to crucial data without the need to divert attention away from the patient. The integration of digital information in a seamless manner provides doctors with improved diagnostic skills, so enabling them to make correct evaluations and educated decisions. Through the use of AR technology, medical professionals are able to effectively perceive complex anatomical structures and superimpose diagnostic imaging in real-time during medical operations [2]. This has been demonstrated in **Figure 1**.

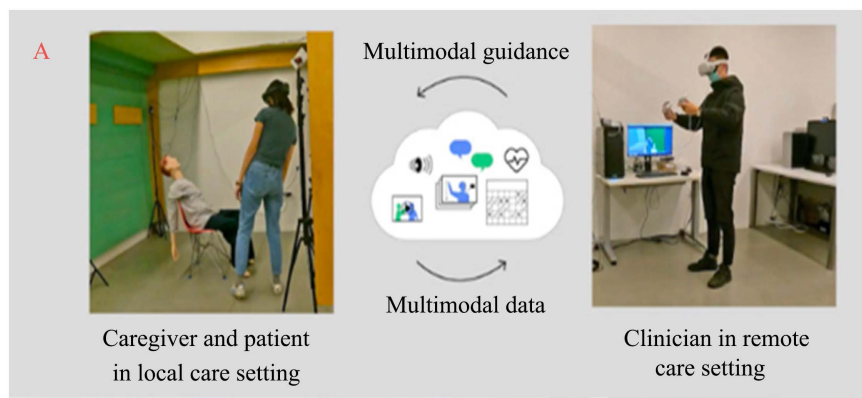


Figure 1. Showing use of AR technology.

This integration of AR technology facilitates more accurate treatments and ultimately improves patient outcomes. The use of these technologies has shown significant efficacy in enhancing the whole patient encounter. The use of these technologies has yielded therapeutic advantages in the form of virtual worlds, which provide patients immersive experiences that effectively mitigate pain, ease anxiety, and promote emotional well-being. Virtual worlds and augmented reality have the potential to enhance the delivery of healthcare by providing patients with a means of diverting their attention away from their medical issues and treatment processes [3]. This, in turn, contributes to a more comprehensive and patient-centric approach to healthcare.

The profound influence of these technologies on the provision of medical treatment highlights the considerable potential for further incorporating virtual worlds, augmented reality, and immersive technology to improve the overall caliber and effectiveness of healthcare services. Healthcare providers are actively investigating and implementing these novel technologies, with a primary emphasis on patient safety, experience, and treatment results. This concerted effort is propelling the industry towards a future characterized by the seamless integration of technology and compassionate care.

3. Revolutionizing Medical Education

The incorporation of virtual worlds, augmented reality (AR), and immersive technology has introduced a groundbreaking paradigm in medical education, fundamentally altering the methods by which aspiring healthcare professionals acquire knowledge, undergo training, and cultivate crucial clinical competencies. Virtual reality (VR) platforms have become prominent instruments in the field of medical education, providing students with an immersive and authentic learning environment as shown in **Figure 2** sourced from El Miedany and El Miedany, 2019.

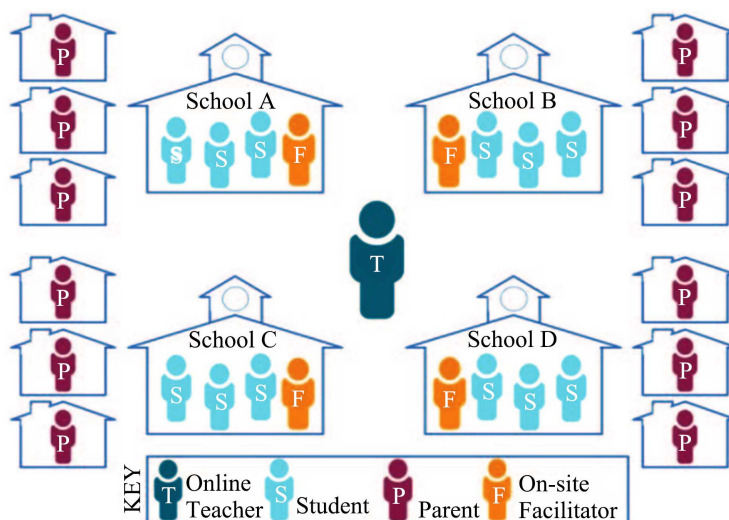


Figure 2. Showing virtual education.

These platforms enable students to participate in simulated medical operations and intricate clinical situations. Virtual reality (VR) simulations provide a secure environment for practical training, allowing trainees to cultivate essential decision-making abilities, refine their surgical methods, and augment their overall clinical proficiency.

Furthermore, the use of augmented reality apps has effectively enhanced the educational process by enabling an engaging and fluid learning encounter, enabling students to see intricate anatomical structures and physiological processes in a live and interactive manner [4]. By superimposing digital information, augmented reality (AR) enhances students' comprehension of complex medical concepts and facilitates a more holistic knowledge of clinical relationships. The use of this interactive educational method not only facilitates active participation but also fosters a more profound recognition of the intricacies of the human body and the various presentations of illnesses and disorders. The incorporation of the metaverse into medical education has beyond geographical limitations, establishing an international platform for healthcare professionals and educators to collaborate, exchange information, and engage in interactive learning [5]. The utilization of virtual conferences, workshops, and collaborative research initiatives within the metaverse has cultivated an environment that promotes ongoing education and interdisciplinary interaction. This has provided medical students with opportunities to interact with professionals, gain access to state-of-the-art research, and engage in simulated case studies that closely resemble real-life healthcare situations.

Through the use of immersive technology, medical institutions and educators are actively constructing a novel educational environment that places emphasis on experiential learning, cultivates critical thinking skills, and facilitates the development of a holistic comprehension of the intricate nature of contemporary healthcare. The ongoing development of virtual worlds, augmented reality, and the metaverse is expected to shape the future of medical education. This evolution will bring about dynamic, interactive, and globally connected learning experiences that enable the upcoming cohort of healthcare professionals to effectively address the constantly changing demands of the healthcare sector.

4. Pioneering Medical Research

The integration of virtual worlds, augmented reality (AR), and immersive technology has expedited the progress of medical research, facilitating remarkable developments in comprehending, diagnosing, and treating intricate ailments. Virtual environments have emerged as valuable resources for researchers, offering them robust tools to visually represent complex biological processes and dynamic cellular interactions. This has significantly contributed to enhancing our understanding of disease pathophysiology and the development of therapeutic approaches. Researchers may expedite the drug discovery and development process by using immersive simulations of biological systems [6]. Through this approach,

they are able to evaluate intricate data sets, pinpoint crucial molecular targets, and mimic the effectiveness of prospective therapies. The incorporation of artificial intelligence (AI) and machine learning algorithms into virtual research settings has significantly transformed data analysis and predictive modeling in the field of medical research. The use of AI-powered analytics facilitates the fast processing of enormous quantities of data by researchers, enabling them to detect patterns and reveal previously undiscovered connections within intricate biological systems. Through the utilization of AI-driven insights, researchers have the ability to discover innovative biomarkers, forecast the advancement of diseases, and customize treatment plans. This facilitates the advancement of personalized therapeutic strategies that cater to the distinct requirements of each patient.

In addition, the metaverse has arisen as a vibrant center for collaborative research initiatives, enabling multidisciplinary collaborations and the sharing of information among academics and institutions on a global scale. The incorporation of the metaverse into medical research has beyond conventional constraints, facilitating the involvement of researchers in virtual collaborative endeavors, the exchange of data, and the participation in real-time conversations that foster innovation and propel the collective progress of medical knowledge [7]. The establishment of an integrated research ecosystem has facilitated the development of a collaborative and innovative culture, driven by data-driven exploration. As a result, the area of medical research has seen significant advancements, leading to the emergence of unique discoveries and transformational solutions in healthcare.

The healthcare sector is now seeing a significant shift in medical research because of the increasing adoption of immersive technology. This change is characterized by improved data visualization, expedited discovery procedures, and the creation of individualized treatment approaches. Researchers are positioned to explore novel domains in medical science by utilizing virtual environments, augmented reality, and the metaverse. This holds the potential to facilitate significant advancements and transformative breakthroughs, thereby revolutionizing patient care and enhancing global health outcomes.

5. Remote Healthcare in Space Exploration

The incorporation of virtual worlds, AR, and the metaverse has expanded its transformational impact on the realm of remote healthcare in the context of space exploration. As mankind embarks on expeditions into unexplored regions of space, the need for sophisticated healthcare interventions capable of effectively managing medical crises and delivering sustained medical support to astronauts becomes more crucial [8]. The unique difficulties arising from the isolation experienced during space flight need the implementation of inventive strategies that use immersive technology to effectively monitor the health of astronauts, provide timely treatments, and safeguard the overall well-being of space explorers throughout prolonged missions.

The use of virtual reality and augmented reality technologies has shown significant value in enabling the provision of remote healthcare services in space. These technologies provide the continuous monitoring of vital signs, physiological parameters, and the general well-being of astronauts, therefore providing mission control centers with essential data for timely medical treatments. Virtual reality simulations may be used as a valuable training tool for astronauts, enabling them to acquire the essential skills and knowledge required to effectively handle unanticipated health problems in space [9]. This includes preparing them for medical procedures and emergency scenarios that may arise during their missions. By engaging in VR simulations, astronauts can effectively equip themselves with the necessary expertise to manage such situations, hence enhancing their preparedness for potential health-related issues in the space environment.

The metaverse, due to its real-time communication capabilities and collaborative problem-solving features, provides a platform for remote consultations and medical assistance from specialized healthcare specialists located on earth. By using virtual interfaces and immersive communication technologies, astronauts have the capability to engage with medical professionals, get diagnostic assistance, and acquire therapy suggestions [10]. This facilitates the connection between healthcare requirements in space and the experience of medical practitioners on earth. The establishment of an integrated healthcare ecosystem in space serves to cultivate a feeling of assurance and assistance for astronauts, guaranteeing the entire fulfillment of their healthcare requirements, even within the far and secluded environment of space.

In addition, the incorporation of artificial intelligence (AI)-based analytics into the virtual healthcare system used in space exploration allows for the development of prediction models and data-informed decision-making¹. This integration supports the timely identification of possible health hazards and the proactive maintenance of astronauts' overall health. Through the use of artificial intelligence algorithms, the analysis of health data obtained during space missions enables healthcare practitioners to proactively predict potential medical difficulties, establish tailored healthcare plans, and optimize the allocation of medical resources. This approach ultimately guarantees the enduring well-being and safety of astronauts throughout their time in space.

The incorporation of virtual worlds, augmented reality, and the metaverse into remote healthcare is becoming more significant as the scope of space exploration expands. This development is crucial for ensuring the physical and mental health of astronauts during prolonged missions. By adopting these revolutionary technologies, space agencies and mission control centers have the potential to establish a comprehensive and adaptable healthcare system that effectively tackles the distinctive obstacles encountered during space travel. This would guarantee the successful implementation of missions and safeguard the physical and mental well-being of astronauts as they embark on humanity's quest to explore the universe.

6. Challenges and Opportunities

The incorporation of virtual worlds, augmented reality, and the metaverse inside the healthcare sector exhibits significant promise, but it also introduces a range of intricate obstacles that need thoughtful examination and smart resolutions. One of the primary concerns revolves around the issue of data security and patient privacy. The extensive use of these technologies requires the implementation of strong safeguards to secure confidential medical data and adhere to strict data protection standards. In addition, the use of these technologies necessitates significant expenditures in infrastructure, training, and technical support, hence presenting budgetary limitations and operational complexities for healthcare organizations, especially those with little resources. The absence of established legislation and ethical principles pertaining to the use of virtual and augmented reality technology within healthcare contexts poses a substantial barrier to their widespread implementation [11]. The lack of well-defined regulatory frameworks might impede the incorporation of new technologies into conventional healthcare procedures, resulting in issues pertaining to liability, safety, and effectiveness. Furthermore, a significant challenge lies in the task of guaranteeing fair and equal availability of these groundbreaking technologies in various healthcare environments and geographical areas. This challenge arises due to disparities in technological infrastructure and resources, which can hinder the widespread implementation of these advancements. This issue is particularly prevalent in underserved communities and developing regions.

Notwithstanding these obstacles, the incorporation of virtual worlds, augmented reality, and the metaverse within the healthcare sector offers a wide range of prospects for collaborative efforts, inventive advancements, and multidisciplinary collaborations. Through the cultivation of collaborative efforts among healthcare professionals, technology developers, and regulatory authorities, the industry can harness the combined expertise of these stakeholders to formulate comprehensive frameworks that effectively tackle concerns regarding data security, establish universally accepted guidelines, and advocate for ethical practices in the responsible integration of these groundbreaking technologies. In addition, the establishment of strategic collaborations between the public and private sectors can serve as a means to foster the creation of scalable and economically viable solutions that improve the accessibility and affordability of virtual healthcare services. This, in turn, helps to bridge the divide between technological progress and the provision of patient-centered care. In addition, the incorporation of the metaverse into the healthcare sector has unparalleled prospects for the establishment of virtual communities, support networks, and platforms for patient education [10]. These resources enable patients to engage actively in their healthcare journey. Through the use of the immersive and interactive characteristics of the metaverse, healthcare professionals have the ability to include patients in virtual support groups, educational seminars, and individualized wellness programs. This facilitates the development of a culture that promotes patient em-

powerment, education, and proactive management of healthcare. These programs serve the dual purpose of fostering patient participation and promoting adherence to treatment regimens, while also playing a significant role in the advancement of comprehensive, patient-centered care models that emphasize the well-being of individuals and their long-term health outcomes.

Within the realm of remote healthcare for space exploration, there exist distinctive challenges and prospects as well. The establishment of robust technological infrastructure that can endure the harsh conditions of space, the development of comprehensive healthcare protocols for autonomous medical interventions, and the assurance of secure data transmission are critical challenges. Nevertheless, the establishment of collaborative research and development initiatives has the potential to facilitate the development of customized medical technologies, thereby empowering astronauts through enhanced training and cultivating a sense of autonomy. The incorporation of immersive technologies presents the possibility for astronauts to proactively manage their health and receive timely and comprehensive medical attention, thereby guaranteeing the triumph and long-term viability of forthcoming space expeditions.

In the context of healthcare, the incorporation of virtual worlds, augmented reality, and the metaverse into clinical practice presents a multifaceted endeavor. It is crucial to acknowledge the inherent difficulties and concurrently capitalize on the potential for collaborative efforts and advancements in this domain. The healthcare sector can realize the complete potential of transformative technologies by tackling these challenges through strategic collaborations, comprehensive regulatory frameworks, and initiatives that ensure fair access. This will ultimately lead to a future where patient care, education, and research seamlessly converge within a dynamic and interconnected healthcare ecosystem.

7. The Groundbreaking Paradigm Shift

The incorporation of the metaverse into the healthcare sector signifies a groundbreaking transformation that surpasses traditional limitations and redefines the core principles of patient care, medical education, and research. The healthcare industry is now undergoing a significant transformation towards a more linked, patient-centric, and collaborative approach to healthcare delivery. This transition is facilitated by the development of an expanded virtual universe that effectively incorporates virtual worlds, augmented reality, and immersive technology [12]. The integration of the metaverse facilitates the development of a vibrant healthcare ecosystem in which patients, healthcare professionals, researchers, and educators come together in a virtual reality that surpasses geographical constraints and physical obstacles. The interconnectivity of this environment allows for instantaneous communication, the exchange of information, and the collaborative resolution of problems. This empowers healthcare practitioners to use their combined experience, share exemplary methods, and collaboratively propel the progress of medical knowledge and patient care.

Furthermore, the integration of the metaverse has resulted in the democratization of healthcare services, enabling individuals to take an active role in their healthcare journey. This integration allows for the access of personalized treatment plans and the engagement in virtual support communities, which contribute to a sense of belonging and emotional well-being. Through the utilization of the metaverse's immersive functionalities, healthcare providers have the ability to provide individualized care that prioritizes the patient and extends beyond conventional clinical environments [13]. This approach places significant emphasis on holistic well-being, preventive measures, and patient education, all of which are essential elements within a comprehensive healthcare framework.

In addition, the incorporation of the metaverse has brought about a significant transformation in the field of medical education. This transformation surpasses the confines of conventional classroom-based instruction and instead establishes a worldwide platform that facilitates interactive and immersive learning [12]. Medical students and professionals have the opportunity to actively participate in global academic discourse, collaborate on research endeavors, and partake in immersive educational activities through virtual conferences. These virtual platforms enable individuals to interact with peers and esteemed professionals from various parts of the world. Moreover, participants can engage in simulated medical procedures, thereby acquiring practical knowledge in handling intricate healthcare situations within a secure virtual setting. The integration of the metaverse has a profound effect on medical research, as it facilitates virtual collaboration, data sharing, and AI-driven analytics, leading to a revolutionary transformation in the discovery and development of breakthrough medical treatments. The metaverse facilitates a collaborative research environment that surpasses geographical limitations, thereby expediting the progress of medical advancements, cultivating interdisciplinary collaborations, and promoting the creation of personalized treatment approaches that cater to the unique needs of individual patients.

In light of the healthcare sector's increasing adoption of the metaverse as a crucial element in its provision of services, educational endeavors, and research infrastructure, it is crucial to place emphasis on the advancement of comprehensive regulatory frameworks, ethical principles, and data security measures. These measures are essential for protecting patient confidentiality and ensuring the responsible incorporation of these transformative technologies. By adopting this paradigm shift and leveraging the transformative capabilities of the metaverse, the healthcare sector is positioned to redefine the trajectory of patient care, medical education, and research [14]. This will ultimately cultivate a healthcare ecosystem that is more inclusive, interconnected, and centered on the needs of patients. The overarching goal is to prioritize comprehensive well-being and ensure equitable availability of high-quality healthcare services for all individuals.

8. Conclusions

The incorporation of virtual worlds, augmented reality, and the metaverse inside

the healthcare sector signifies a paradigm shift that is reconfiguring the core aspects of patient care, medical education, and research. The integration of immersive technologies has resulted in improvements in the accuracy, safety, and effectiveness of patient care. Additionally, it has brought about significant changes in medical education by creating an engaging and interactive learning environment that surpasses geographical limitations. This has facilitated global collaboration and the exchange of knowledge among medical professionals. Moreover, the integration of the metaverse into the healthcare sector has introduced a revolutionary change in thinking, promoting a sense of interconnectivity, cooperation, and patient empowerment within a virtual healthcare environment.

The evident transformational potential of these technologies necessitates a comprehensive examination of the accompanying problems and complexity. These include but are not limited to concerns over data security, constraints in infrastructure, and the need for the establishment of uniform rules and ethical principles. Through the cultivation of multidisciplinary collaborations, the healthcare sector may effectively address these difficulties and capitalize on the prospects arising from the seamless amalgamation of virtual environments, augmented reality, and the metaverse [12]. This can be achieved by adopting cutting-edge technology and placing a strong emphasis on patient-centered care. In light of the ongoing evolution of the healthcare sector, it is crucial to place emphasis on the advancement of comprehensive regulatory frameworks, ethical guidelines, and data security protocols. These measures are essential in guaranteeing the responsible and secure incorporation of transformative technologies into clinical practice, education, and research. By promoting a cooperative and patient-centered methodology in the provision of healthcare, the sector can lay the groundwork for a forthcoming era in which technology, empathy, and ingenuity harmoniously converge. This will ultimately shape a healthcare environment that places utmost importance on comprehensive well-being, patient empowerment, and fair availability of high-quality healthcare services for individuals across the globe. The process of advancing towards a healthcare environment that is more linked, focused on patients, and technologically sophisticated is now in progress. This development is establishing the groundwork for a future where the limitations of healthcare options are redefined, and there is unlimited opportunity for revolutionary innovation.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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