Commentary

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Introduction and Application of ZEP-based Metaverse Hospital (Chosun University Metaverse Hospital)

Running title: Introduction and application of a ZEP-based metaverse hospital

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CONCEPT AND DEFINITION OF THE METAVERSE

A "metaverse" is a virtual world or universe that is fully immersive, interactive, and persistent, where users can create their own digital avatars, interact with each other, and participate in various activities and experiences. It is often described as a fully realized version of the internet, where the virtual world is seamlessly integrated with the physical world and allows users to transcend the limitations of space and time. In a metaverse, users can create, own, and trade digital assets, such as virtual real estate, virtual currency, and other virtual objects [1]. They can also participate in social interactions, such as attending virtual events, playing games, and collaborating on projects [2].

Such concepts have been popularized by science fiction [3], such as Neal Stephenson's Snow Crash, which depicts a virtual reality universe called the "Metaverse," and Ernest Cline's Ready Player One, which is set in a dystopian future where people spend most of their time in a virtual world called the "OASIS." While the idea of the metaverse is young, several companies and developers are actively working on creating metaverse platforms, incorporating technologies such as virtual reality, augmented reality, and blockchain. They believe that the metaverse has the potential to transform the way people interact with each other and the world around them, and may become a significant part of our daily lives in the future.

A MIRROR WORLD METAVERSE HOSPITAL FOR ENHANCING ACCESS TO HEALTHCARE SERVICES

Our goal in this project was to establish a hospital in the metaverse by creating a virtual, digital twin of a real hospital. To do so, there are several considerations. First, it is imperative that communication takes place not only using avatars or characters, but also through the incorporation of video conference capabilities to enable seamless, face-to-face interactions. Secondly, due to the nature of hospital processes, it should be possible to hold conferences, virtual meetings, seminars, and other similar events to facilitate communication among participants. Lastly, it is crucial to ensure that many stakeholders, including patients, medical staff, and visitors, can participate in the metaverse space at the same time.

Conventionally, metaverses are categorized into four distinct types: lifelogging, augmented reality, virtual reality, and mirror world [4–6]. Two additional ways to analyze the metaverse consider
external dimensions and intimate dimensions. The external dimension covers activities that happen in the surrounding world, whereas the intimate dimension relates to personal and subjective experiences. Overall, each metaverse platform has its own unique functions and features, but they all aim to provide users with immersive and interactive virtual experiences.

The metaverse hospital described in this study was specifically designed to be easily accessible to all users and utilizes a mirror world design to resemble the real-life Chosun University Hospital (CUH; Gwangju, Korea). To create a medical metaverse hospital with high patient accessibility, it was necessary to identify a platform that could create a customized virtual space within a metaverse that allowed face-to-face communication between doctors and patients. ZEP (ZEP Co Ltd; https://zep.us/) is a metaverse platform that accommodates up to 50,000 simultaneous participants, emphasizes two-dimensional pixel art, and creates domains for each page, facilitating the construction and operation of metaverse spaces. The platform enables easy communication through video, audio, and text messages and one-click access to metaverse spaces on a web browser. As a web-based platform, ZEP is convenient to use on personal computers, and in-app functions can be easily coded based on JavaScript. Our goal was to improve connections between users and the hospital using the metaverse, creating an improved intimate dimension.

PURPOSE OF META VERSE HOSPITAL
As part of the fourth industrial revolution, the development of technologies such as artificial intelligence, big data, information communication technology (ICT), and the explosive development of the Internet led to active exchanges across borders and rapid globalization of the service industry. The medical service industry is also rapidly changing with the acceleration of globalization. Korea has exhibited the best performance for most medical indicators (avoidable mortality, treatable mortality, infant mortality, life expectancy, and preventable mortality) among Organisation for Economic Cooperation and Development (OECD) countries [7]. Due to the excellent medical standards and services in Korea, the number of “medical tourists” traveling to the country is increasing rapidly. In addition, increasing numbers of foreign medical staff are visiting Korea for medical training. However, as the COVID-19 pandemic encouraged social distancing, the medical service industry has been characterized by a
growing number of telemedicine companies worldwide.

As the demand and necessity for non-face-to-face medical services increased, new medical services incorporating information technology (IT) were required. Therefore, CUH established a metaverse platform to provide medical services via IT and promote medical tourism. First, it provides useful and enjoyable content to attract more users. Second, it improves human-computer interactions through an intuitive user experience and design interface. Third, it increases efficient provision of medical services such as a virtual map, transportation reservations, and real-time communications with hospital staff members. Finally, the platform promotes medical education users, who may include patients, students, doctors, nurses, or medical staff from abroad. Creating the CUH Metaverse took over 1 year, and a team of more than 10 people were involved in its development.

**UTILIZATION OF DIGITAL TWIN AT CUH**

**Simulation of traveling to Gwangju to give favorable impression to CUH medical tourism**

Metaverse content that simulates traveling from abroad to Incheon International Airport (Incheon, Korea), then to Gwangju Korea Train Express (KTX) station, and finally to CUH was established to bridge the psychological distance between patients and the hospital. The airport’s and KTX station’s metaverse pages provide a ticket reservation function and a clear guide for traveling to CUH. The objective of the tour guide simulation is to provide favorable impressions of CUH to patients by closely resembling the real world and creating a sense of familiarity. Foreign patients or doctors can access the metaverse at any time before, during, and after their hospital visit. Upon accessing the metaverse after virtually arriving at Incheon International Airport, they will be greeted by avatars that provide welcoming messages and information about the hospital and transportation in real time. This feature allows users to quickly address any difficulties or questions they may encounter during the transportation process. Additionally, virtual galleries, history halls, and gaming activities are provided in the metaverse to alleviate potential boredom during the journey. Information about diseases, medical procedures, medication, and other services offered by the hospital may also be found in the metaverse.

**Building a global network of metaverse hospitals**
CUH has recently launched an international medical training initiative for doctors from many nations, including Mongolia, Russia, and Saudi Arabia. The initiative, established under the supervision of the Ministry of Health and Welfare of Korea, aims to provide participants with invaluable learning experiences at CUH medical training programs. Implementation of metaverse digital twins for participating hospitals has made it easy to encourage global collaborations. The establishment of an international healthcare center in the metaverse revolutionizes the concept of patient care. The internal space of the virtual center is meticulously designed to replicate the physical environment of a hospital, complete with lifelike structures, furniture, and spaces. This virtual space creates a sense of realism and enables patients to engage in direct communication with the center's staff from anywhere at any time.

Through this innovative approach, CUH strives to bridge geographical barriers, making healthcare accessible and convenient for patients around the globe. The Middle East Clinic, an integral part of the hospital's global system, addresses the specific needs of Middle Eastern patients. Recognizing the importance of private and confidential communication, the clinic offers separate spaces in each department for one-on-one interactions. This design fosters a comfortable environment that respects cultural norms and ensures patients feel at ease while discussing their health concerns. Moreover, understanding the value of collaboration and knowledge sharing among clinicians, a dedicated space for holding meetings and seminars has been created within the metaverse. Demonstrating its commitment to religious inclusivity, the Middle East Clinic also has a virtual prayer room that recognizes and respects Islamic religious practices, which entail five daily prayers. By providing this designated space, CUH showcases its understanding and appreciation for diverse faiths, further enhancing patient comfort and satisfaction.

By developing a metaverse global hospital network and collaboration, CUH aims to enhance the knowledge of healthcare professionals, improve the hospital's reputation, and further expand its global network. Ultimately, CUH expects to overcome its geographical limitations and be in the center of the largest virtual medical complex in the world, which includes hospitals from Mongolia, Russia, Saudi Arabia, Thailand, the United Kingdom, and the United States.

Overcoming physical constraints of the real world through implementation of imaginary space
within a digital twin

Hospitals have long recognized the significance of cultural spaces in improving the overall well-being of patients and their families, offering a respite from anxiety and stress. However, the constraints of physical space often hinder the creation of diverse cultural environments within healthcare facilities. CUH found an innovative solution in the form of the metaverse. By leveraging this immersive virtual platform, CUH has reimagined the concept of hospital space, offering a range of culturally enriching experiences to enhance hospital visits for patients and visitors alike.

One of the key initiatives undertaken by CUH is the establishment of a virtual gallery within the metaverse, enabling the public to indulge in art and creativity by providing a platform for local artists to showcase their works, fostering a vibrant cultural atmosphere and stimulating positive emotions. By transcending physical limitations, the hospital extends the reach of artistic expression and contributes to the well-being of patients and their families. In addition to the gallery, the hospital created a history hall within the metaverse, inviting visitors to delve into the rich past of the institution. This virtual space serves as a repository of the hospital's heritage, showcasing its milestones and achievements. Patients and their families can explore the hospital's journey, gaining a deeper understanding of its commitment to excellence and a sense of pride in being a part of its legacy. Recognizing the importance of local tourism and community engagement, CUH has also established a content hall within the Metaverse, offering valuable information about the surrounding area. This digital space serves as a hub for sharing tourist attractions, local culture, and events, enabling patients and visitors to immerse themselves in the local community within the hospital environment.

CUH is taking patient empowerment to the next level with the introduction of a dedicated specialist hall, aimed at allowing patients to choose their caregivers from among the hospital's renowned medical staff. By showcasing detailed profiles and accomplishments of these professionals, the specialist hall provides patients with the information they need to make informed decisions about their healthcare providers. This transparent approach gives patients greater control over their medical journey and fosters stronger patient-caregiver relationships based on trust. Through the specialist hall, patients can explore the diverse range of medical disciplines offered by the hospital and select caregivers who best align with their specific needs and preferences.
Through these innovative uses of the metaverse, CUH has revolutionized the hospital experience, transcending physical limitations and providing culturally diverse spaces that promote well-being and engagement. By embracing virtual technology, the hospital has overcome the constraints of physical space and created a platform for artistic expression, historical exploration, community connection, and professional growth.

**Improving service satisfaction by providing location information services**

CUH has undertaken an innovative approach to address the challenges of navigating a complex healthcare facility. As hospitals grow in size and complexity, finding specific hospital locations in the can be a daunting task, leading to increased patient stress, prolonged hospital stays, and reduced service satisfaction [8]. Traditionally, hospitals have employed solutions such as location notices, assistants, signs, and maps to aid patients in navigating their premises. However, these methods often fall short, leaving many individuals still struggling to find their way, especially during their initial visits.

To address this issue, CUH has embraced an advanced solution by implementing a real-life space within the metaverse, focusing on outpatient departments and examination rooms that witness significant movement. By accessing the CUH Metaverse, patients can now virtually explore the outpatient departments and examination rooms situated on the first and second floors of the hospital. Crucially, comprehensive location information is readily available at all stages: before, during, and after the hospital visit. This integration of actual structure and location within the metaverse aims to enhance service satisfaction by minimizing the time spent wandering and reducing hospital stay durations. This technological approach not only streamlines the patient navigation process but also contributes to an overall improvement in the hospital experience. Patients can familiarize themselves with the hospital layout and confidently navigate to their desired destinations, eliminating stress and uncertainty associated with finding specific medical departments. Through the utilization of the metaverse and the provision of accurate location information, CUH aims to significantly enhance patient satisfaction, reduce hospital stays, and optimize resource utilization.

**DISCUSSION**
The CUH Metaverse was designed to promote medical tourism. First, it provides useful and enjoyable content to attract more users. Second, it improves human-computer interactions through a more intuitive user experience and design interface. Third, it increases efficiency in medical services by providing a virtual map, transportation reservation, and real-time communication with hospital staff members. Finally, the platform promotes medical education to users, who could be patients, students, doctors, nurses, or medical staff from abroad. However, several challenges remain to be overcome. Further research is imperative, encompassing the measurement of patient satisfaction, user experience (UX) and user interaction (UI) usability tests, privacy issues in video recordings, and other legal issues associated with telemedicine. In the end, establishing a global standard for constructing metaverse hospitals would be necessary to build a more convenient and integrated platform.

The metaverse brings with it the promise of revolutionizing the practice of medicine, ushering in a new era of accessible, efficient, and effective healthcare for both patients and medical professionals. CUH's digital metaverse twin on ZEP is at the forefront of this transformation, facilitating seamless interactions among doctors, enabling international collaborations, and providing video consultations for medical tourists. CUH is breaking down geographical barriers and bridging healthcare disparities around the world. Doctors can collaborate effortlessly, exchanging knowledge and expertise, ultimately leading to improved patient care and outcomes. Additionally, the metaverse enables video consultations, allowing medical tourists to receive healthcare services without the need for physical travel.

The convergence of emergency medicine and the metaverse holds immense implications for the healthcare industry. Utilizing metaverse simulations in emergency medicine training presents a controlled and secure environment for medical professionals to refine skills, potentially minimizing errors in emergency care and enhancing patient outcomes. Moreover, the metaverse improves access to emergency medical services in remote or underserved areas, leading to more efficient emergency response protocols. Finally, the metaverse provides a dashboard of empty beds among emergency rooms in participating hospitals, enabling patients and rescuers to easily locate available spaces during emergencies.

Just as the internet surpassed its initial purpose of static websites and became a foundation for various industries, the concept of the metaverse encompasses more than just a singular technology or
In digital space. The evolution of technologies like extended reality, blockchain, digital twins, and edge computing is giving rise to metaverse platforms such as Gather (Gather Presence Inc), Meta Horizon Worlds (Meta), Roblox (Roblox Corp), The Sandbox (Pixowl), Second Life (Linden Lab), and ZEP. A metaverse hospital that can be utilized across various platforms is desirable, rather than developing a metaverse digital twin hospital limited to a single platform, as metaverse platforms will continue to evolve. Ultimately, regardless of the platform used, the establishment of a healthcare metaverse requires a deep understanding of healthcare systems, robust data security measures, and strong networks with healthcare institutions. Therefore, it is anticipated that healthcare metaverse expertise will gradually increase.

CONCLUSION

The potential of the metaverse in healthcare extends far beyond CUH's pioneering efforts. From virtual reality simulations for medical training to remote patient monitoring and telemedicine, the metaverse has the power to reshape the entire healthcare landscape. By harnessing the capabilities of this immersive digital realm, the future holds the promise of enhanced accessibility, personalized care, and optimized healthcare delivery. However, as with any transformative technology, challenges and considerations lie ahead. Security, privacy, and standardization are crucial factors that must be addressed to ensure the safe and ethical implementation of the metaverse in healthcare. Ongoing research, collaborations, and regulation will be necessary to unlock the full potential of this paradigm-shifting technology.

In conclusion, the metaverse hospital exemplifies the transformative potential of merging technology and healthcare. CUH's metaverse digital twin serves as a testament to the possibilities of improved collaboration, global connectivity, and enhanced patient care. In the near future, CUH will announce the world's first fully functioning hospital in virtual reality. As the metaverse continues to evolve, the future of medicine promises a healthcare landscape that is more interconnected, accessible, and patient-centric than ever before.

AUTHOR INFORMATION
Author contributions

Conceptualization: MRK, YK; Data curation: KJK; Formal analysis: JYC; Funding acquisition: YK; Investigation: MRK, YK; Methodology: MRK, HJN; Project administration: YK; Supervision: YK; Visualization: MRK, HJN; Writing–original draft: MRK; Writing–review & editing: JYC, HJN, KJK, YK. All authors read and approved the final manuscript.

Conflicts of interest

The authors have no conflicts of interest to declare.

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Data availability

Data analyzed in this study are available from the corresponding author upon reasonable request.
REFERENCES


**FIGURE LEGENDS**

![Diagram](image)

**Fig. 1** The four types of metaverse. Based on Smart et al. [4], Milgram et al. [5], and Chengoden et al. [6].
**Fig. 2.** Virtual space experience service system for strengthening psychological accessibility in the Chosun University Hospital (Gwangju, Korea) Metaverse. (A) Airport entrance. (B) User guide. (C) Bus reservation link. (D) Train ticket reservation link. (E) Guide to using the keyboard. (F) Quiz game. (G) Gwangmyeong station. (H) Gwangju Songjeong station.
Fig. 3. Network expansion through global system diversification in the Chosun University Hospital (Gwangju, Korea) Metaverse. (A) International Healthcare Center. (B) Middle East Clinic. (C) Meeting room. (D) Seminar room. (E) Lecture room. (F) Prayer room.
Fig. 4. Overcoming physical environmental constraints by implementing space beyond reality in the Chosun University Hospital (CUH; Gwangju, Korea) Metaverse. (A) The Snail Gallery. (B–D) Content Hall. (B) Tourist Hall. (C) History Hall. (D) Introduction of medical staff. (E) MLK Hall. (F) Lobby.
Fig. 5. Improving service satisfaction by providing location information services in the Chosun University Hospital (Gwangju, Korea) Metaverse. (A) Guidelines on the use of metaverse transportation facilities. (B) Location information service.