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A Study of Converging Technologies towards the Development of AR/VR-based u-Healthcare Systems

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Abstract

The Augmented Reality(AR) and Virtual Reality(VR) are visualized to revolutionize the medical and healthcare industry. This paper deals with the study on the converging technologies towards the development of AR/V-based u-Healthcare systems. The various significant technologies that were converging to realize the development of the future AR/VR-based u-Healthcare system will be discussed such as wireless sensor networks(WSNs), ubiquitous computing, wireless communication technologies and mobile computing, AR/VR technologies, and Artificial Intelligence(AI) in healthcare. The comparative analysis among these converging technologies highlighting their advantages have resulted to significant contributions and implications towards the future u-Healthcare systems. This convergence leads to having the significant features for the future AR/VR-based u-Healthcare systems such as medical training, treatment administration, and disease awareness. Hence, the cognitive impairment diagnosis and treatment will be highly alleviated.

요 약

의료 및 헬스케어 산업에서 증강현실(AR)과 가상현실(VR)이 혁신을 일으키고 있다. 본 논문에서는 AR/VR 기반 u-헬스케어 시스템 개발을 위한 융합 기술들을 연구하며, 향후 AR/VR 기반 u-헬스케어 시스템 개발을 실현하기 위해 사용된 무선센서 네트워크(WSNs), 유비쿼터스 컴퓨팅, 무선통신기술 및 모바일 컴퓨팅, AR/VR 기술, 인공지능(AI) 등과 같은 다양한 중요 기술들을 논의한다. 이러한 융합 기술들 간의 비교 분석은 미래의 u-헬스케어 시스템에 많은 기여와 시사점을 가져왔다. 또한, 융합기술을 통해 향후 AR/VR 기반 u-Healthcare 시스템이 의료 교육, 치료 투여, 질병 인식과 같은 중요한 기능을 제공한다. 이로 인해, 인지 장애 진단 및 치료에 크게 기여할 것이다.

Keywords
ubiquitous computing, wireless sensor network(WSN), AR/VR technologies, cognitive impairment, u-Healthcare system, converging technologies

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Ⅰ. Introduction

The biggest challenge of the current society is the rapidly ageing population. According to the United States department of Health & Human Services(HHS), there are more than 10,000 people that turns 65 everyday, and people are living longer with healthier lives[1]. The improved healthcare services, healthy lifestyles, retirement planning, and awareness with healthcare and long-term care options have shifted the world's population from young to old.

South Korea is considered as one of the world's fastest ageing countries[2]. Koreans aged 65 or older comprised about 15.5 percent of the country's total population as of the end of 2019. This signifies a drastic increase of more than one percent from 2018 with 14.2 percent. According to Statistics Korea, the country has reached the ageing society in year 2000 [3][4]. In 2030, it is foreseen that the population of the elderly Koreans will amount to 24.3 percent and will reach 40.1 percent in the year 2060[5]. In 2067, the Korea's senior population will account up to 46.5 percent of the total population that will bring the country to become the world's most aged society. The very reason for this is that Korea's fertility rate that measures the average number of children a woman will have in her lifetime, hit a record low of 0.98 in 2018. This is in contrast with Japan's fertility rate with 1.42, Singapore's 1.14, and Hong Kong's 1.07.

In addition, recent studies have indicated that most of the elderly suffer from chronic diseases such as diabetes, cancer, Alzheimer's disease, and dementia[6]. Moreover, more than half of the elderly population were not too healthy and with cognitive impairments. Thus, with the ageing population and as chronic diseases continuously increases, healthcare becomes a significant necessity and the society becomes more health conscious that is always looking for better health management and healthier lifestyle. Nowadays, healthcare services were shifted from the traditional hospital-centered health services towards being patient-centered and oriented.

Healthcare services have evolved from the then typical e-Healthcare to mobile healthcare(m-Healthcare) and now towards ubiquitous healthcare (u-Healthcare). The u-Healthcare refers to the integration of ubiquitous computing into the healthcare industry where intelligent and autonomous healthcare services will be delivered based on context-awareness. It utilizes the sensor technologies and focus on the management of healthcare services, medical routines, real-time monitoring of the health of patients, and to support the welfare of the society.

Various technologies has emerged to alleviate the delivery of services offered by healthcare systems. The emergence of context aware technologies, ubiquitous computing, ubiquitous sensor networks, mobile computing, AR and VR technologies, and AI in healthcare have significantly revolutionized the traditional healthcare systems. This results in a robust healthcare system that significantly alleviates the welfare and wellbeing of the members of the society specifically those of the elderly and suffering from chronic diseases. This paper deals with the study of such converging technologies in realizing the development of the future AR/VR-based u-Healthcare system. The utilization of these converging technologies in healthcare provided a direct impact to the near and far future of u-healthcare systems.

The rest of this paper is organized as follows: Section 2 outlines the various converging technologies in realizing the AR/VR-based u-Healthcare system; the AR/VR-based u-Healthcare system is outlined in Section 3; and the concluding remarks and future research directions were presented in Section 4.

Ⅱ. Converging Technologies

This section outlines the significant converging technologies in realizing the future AR/VR-based u-Healthcare system.

2.1 Wireless Sensor Networks (WSNs) in Healthcare

Wireless sensor network(WSN) refers to the utilization of spatially distributed autonomous and tiny devices capable of monitoring physiological and environmental conditions. In healthcare, these physiological and environmental conditions include blood pressure, temperature, pulse rates, glucose levels, and other bodily attributes[7][8]. The gathered healthcare information by the sensors were relayed to a gateway through wireless technologies such as RFID, ZigBee, or Bluetooth. Gateways will then forward these healthcare information into the processing nodes (e.g., smartphone, tablet, laptop, desktop computer, or more sophisticated server machine) by using wireless protocols that include available standards such as 2.4 GHz radios based on either IEEE 802.15.4 or IEEE 802.11(Wi-Fi) standards.

The utilization of WSN in healthcare has alleviated the monitoring of patients and providing healthcare services. The WSN for heathcare is typically classified into three groups:

• In-body networks. This is used to communicate between the sensors that were implanted inside the patient's body and a reader or receiver located outside of the patient's body. For example, implantable pacemaker, implantable cardioverter defibrillator(ICD), or smart capsules that are used to transfer bio-information, which can measure in-body health attributes, and transmits to an external device or reader.

• On-body networks. This is used to communicate between the sensors that were attached on the patient's body and the data gathering devices. For example, wrist watches to measure pulse rates, bio-shirts, and ring sensors that are attached to the patient's body to transfer the sensed health attributes for processing and analysis.

• External networks. This is used to communicate between sensor nodes, actuators, local processing nodes, and remote servers. home and mobile healthcare that communicates between sensors, devices or a location processing unit that can communicate with a remote server. This involves both wireless and mobile networks.

Fig. 1 depicts bio-sensors gathering healthcare information from an elderly and forwards the collected healthcare information to a user device that acts as the WSN gateway. Nowadays, WSNs have been replaced by ubiquitous sensor networks(USNs) that is comprised of a convergence between application technologies for sensing, networking, and computing which are context-aware and knowledge-based driven.

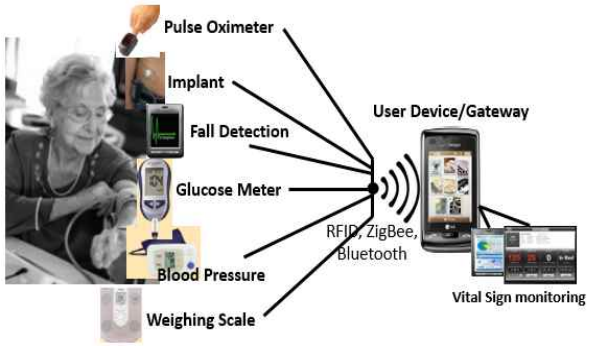

Fig. 1. WSN in healthcare

2.2 Ubiquitous Computing in Healthcare

Ubiquitous computing refers to a concept that has made computing becomes available at anytime and anywhere[9][10]. It is usually comprised of an interconnected things and inexpensive computers that supports everyday functions and chores in an automated fashion.

Ubiquitous computing has been integrated with healthcare and utilizes a large number of physiological and environmental sensors and actuators in monitoring and supporting the patient's medical and physical conditions in real-time[7][8]. The u-Healthcare system employs the Wireless Sensor Network(WSN) technology in gathering and measuring information on bodily and environmental conditions such as temperature, blood pressure, heart beat rate, pulse rate,

blood and urine chemical levels, breathing rate and volume, activity levels, and other physiological attributes that are significant in the diagnosis and treatment of the patient's health conditions.

These ubiquitous and tiny sensors can be implanted in the patient's body, worn on, or installed within the patient's living or working environment. The USN actuators on the other hand trigger medical or healthcare events and actions such as releasing of a particular amount of medicine into the patient's bloodstream, electrical stimulation of brain areas, triggering an alarm for a patient to take his/her medication, and alarming the healthcare staff or doctors with an emergency. The sensors and actuators provides the capability for the healthcare to be able to monitor in real-time the health conditions of patients and be able to design and implement intervention or diagnostic programs to improve the patients conditions and wellbeing. These devices were initially intended for remotely monitoring patients in order to provide healthcare advices and tips without physically visiting healthcare facilities which were particularly beneficial for mobility-impaired patients and many older people. Moreover, the technology becomes more of a self-monitoring and care system for most individuals and not only intended for the elderly and patients with chronic diseases.

The USN has evolved from WSN(i.e., the previous generation of sensor networks) that has converged with the ubiquitous computing technology. The USN technology has enabled the functionalities of WSN to become available at anytime and anywhere[11]. It does not focus only on sensor node networking and node system development but covers a wider spectrum in terms of user- and service perspective and deals with both lower-layer and higher-layer sensor network issues. Information in USN were acquired using context awareness through detecting, sensing, measuring, storing, processing, analyzing, and integrating physiological and environmental conditions that were collected from sensor nodes deployed geographically in the environment or embedded on anything. The USN technology deals with both the network installation view and the application services view.

For patients with cognitive impairments, more intensive support from their family members and healthcare personnel were required. Thus, u-Healthcare technologies can alleviate these services to provide real-time patient monitoring and deliver long-term healthcare programs such as taking proper diet and exercises.

In addition, u-Healthcare technologies and systems were also developed to support the activities of healthcare workers and doctors. Patient record systems were developed to support healthcare workers which are capable of automatically updating the information gathered from patients based on their current context, support for improved information flow between shift changes of healthcare workers, and robust transmission of real-time information from accident scenes to healthcare facilities. For doctors, surgery training systems were developed to support doctors' training and simulation exercises.

2.3 Wireless Communication Technologies and Mobile Computing

The evolution of wireless communications has delivered an "anytime and anywhere connectivity". The continuous enhancement of RFID and Wi-Fi standards and the emergence of 4G networks(now 5G networks) have facilitated the anytime and anywhere access to wireless and mobile communications[12]. The continuous developments in mobile and wireless computing will enable a seamless and robust real-time patient monitoring to continuously collect health -specific metrics from the deployed biomedical sensors and devices in the patients' homes and other environmental settings outside the healthcare facility. Healthcare monitoring of patients typically measures and gathers patient's physiological and environmental

attributes(through context awareness) and forwards these healthcare information for storage, analysis, and processing by healthcare professionals which will be the basis for providing diagnosis or treatment programs.

Healthcare applications and services strictly imposes end-to-end system reliability and data delivery. Seamless and robust wireless network and mobility management are required to support the real-time and in-time transmission of healthcare information. Thus, optimizations on mobility management protocols are necessary and so is the emergence of 5G networks.

2.4 Augmented Reality/Virtual Reality (AR/VR)

Augmented reality(AR) refers to a technology that augments virtual elements into the real world. These virtual elements are overlaid into the real world to provide an interactive experience enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities such as visual, auditory, haptic, somatosensory, and olfactory. On the other hand, virtual reality(VR) refers to a technology where a virtually simulated experience can be similar to or completely different from the real world. A person interacts with the virtual environment through an artificial three-dimensional(3D) environment with the aid of special devices such as goggles, headsets, gloves, etc.

Both AR and VR technologies provide significant contributions to healthcare as both responds to real-time changes such as how a patient moves or perform his/her daily activities[13]-[15]. AR and VR in healthcare can assist surgeons with a safer and more efficient surgical planning. VR can also be used to educate patients before undergoing to surgeries.

In addition, AR technologies were integrated in medical training where an AR tool can display an internal view of the body to study its anatomy. Gesture-sensitive interfaces for these applications allow users to interact immersively with the representation.

2.5 Artificial Intelligence in Healthcare

The utilization of artificial intelligence(AI) technologies and machine-learning algorithms to mimic human cognition in the analysis, interpretation, and comprehension of complicated medical, mental, and healthcare data has been rapidly emerging. AI provides a healthcare system with the capability of making sound decisions and conclusions through computer algorithms based on the processed input data(i.e., collected healthcare data based on context). Through machine learning and deep learning algorithms, AI can also enhance the healthcare's ability in gathering healthcare data, process it, and provide a well-defined conclusion or output to be presented to the healthcare professionals and the patients. AI algorithms must be trained using extensive amounts of healthcare input data to become more sophisticated and effective in giving predictions.

AI in healthcare provides a capability to analyze the relationships between prevention or treatment techniques and patient outcomes[16]. AI programs are applied to healthcare services such as diagnosis processes, development of proper treatment procedures, drug development, personalized medicine, patient monitoring and care, and wellbeing management.

AI in healthcare has revolutionized the healthcare systems and has provided significant improvements such as medical imaging, automated clinical decision-making, diagnosis, prognosis, and more[17].

2.6 Comparative Analysis among the Converging Technologies

The comparative analysis on the significant converging technologies highlighting their respective advantages and contributions to the future AR/VR-based u-Healthcare systems is depicted in Table 1.

Table 1. Comparative analysis among the converging technologies

Converging technology	Description	Advantages	Implication to u-healthcare
Wireless Sensor Networks(WSNs)	* Utilization of spatially distributed sensors capable of monitoring healthcare data	* Enables remote healthcare data gathering and pre-processing	* Supports real-time and continuous healthcare monitoring of patients
Ubiquitous Computing	* Made computing becomes available at anytime and anywhere	* Enables monitoring and supporting the patient's medical and physical conditions in real-time	* Supports real-time and continuous healthcare monitoring of patients which becomes available anytime and anywhere
Wireless communication Technologies and Mobile computing	* Enables anytime and anywhere connectivity	* Enable a seamless and robust real-time patient monitoring * Support the real-time and in-time transmission of healthcare information	* Support robust mobility and continuous connectivity for healthcare systems
Augmented Reality / Virtual Reality(AR/VR)	* AR augments virtual elements into the real world * VR refers to a virtually simulated experience similar to the real world	* Responds to real-time changes * Provides assistance to surgeons * Capable of educating patients before undergoing to surgeries	* Supports diagnosis and medical treatment specifically for patients with chronic diseases and cognitive impairments
Artificial Intelligence(AI)	* Mimic human cognition in the analysis, interpretation, and comprehension of complicated medical, mental, and healthcare data	* Enables making sound decisions and conclusions based on the processed input data * Enhances healthcare data gathering and processing * Enable the provision of a well-defined conclusion or output * Enables sound analysis on the relationships between prevention or treatment techniques and patient outcomes	* Supports the analysis of healthcare data for better and sound diagnoses and treatment

III. AR/VR-based u-Healthcare System

The emergence of AR and VR technologies have enabled an effective utilization of immersive virtual environments in medical training to provide support for healthcare professionals and doctors and in delivering diagnostic and treatment programs for patients(i.e., the elderly and people suffering from chronic diseases). AR and VR technologies can provide realistic simulation on the tasks or exercises included in cognitive training and programs[18][19]. In such cognitive training and programs, the patients are enabled to perform immersive sensory tasks in hearing, touch, vision, smell, olfactory, and kinematics[20]. AR and VR technologies were also utilized for the virtual training of healthcare professionals(e.g., surgeons) in performing complicated surgeries, operating room simulations, and chronic pain management.

The features that the converging technologies bring to AR/VR-based u-Healthcare system may include medical training feature, treatment administration feature, and disease awareness feature.

3.1 Medical Training Feature

The integration of AR and VR reality technologies in healthcare has provided a virtual experience that takes a person inside a human body in order to view and access body areas and parts that in real world would be impossible to reach. Traditional medical

training were focused on the examination of cadavers which provide a lot of disadvantages as compared with the examination of a live patient body. With AR and VR, healthcare professionals can view and access every detail of any patient body part through 360 degree computer-generated imagery(CGI) reconstruction and can manipulate and create a variety of training scenarios that mimic common and actual surgical operations. The CGI models of the patient body parts were combined with VR environment to provide an immersive and interactive surgical training experience for surgeons and healthcare professionals.

Companies such as Medical Realities[21] and Osso VR[22] offers sophisticated surgical training and assessment platform that provides full simulations in delivering next-generation of immersive medical training and education. Fig. 2 depicts Osso VR's technology being utilized in Newcastle Surgical Training Centre.

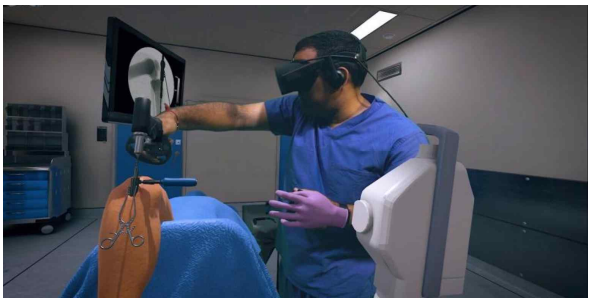

Fig. 2. Osso VR's technology being used in newcastle surgical training center[23]

3.2 Treatment Administration Feature

The treatment administration feature for AR/VR-based u-Healthcare system can include various services that could guarantee an efficient and proper administration of diagnostic and treatment programs to patients and thus, warrant for faster recovery of patients and alleviate their wellbeing.

AR and VR technologies in healthcare can provide patient education through allowing them to view the inside of their human body. This enables them to properly understand their treatment and coordinate properly with healthcare professionals in planning in advance their surgical operations and increase their healthcare service satisfaction.

AR and VR technologies assists in robotic surgery that is performed by a robotic device being controlled by a human surgeon. This feature results in fewer risks of complications while performing the surgical operation and the procedure can be performed faster. The robotic device has greater accuracy, that means, it allows for smaller incisions, reduced blood loss, thus, results in faster patient recovery.

AR and VR technologies in healthcare also alleviates the capabilities of mental health and psychological therapies. Robust simulations can be created for patients to overcome their psychological difficulties through virtual experiences. For example, whenever patients with psychological difficulties such as going up on tall buildings or coming to crowded places, there will be no need for a therapist to handle the therapy physically. Mental health and psychological therapies will be administered through virtual experiences. This can also be administered to conjure the harrowing events behind post-traumatic stress disorder(PTSD). In addition, AR and VR technologies can be used to suppress memory loss and provide support for autistic children in performing their daily activities.

AR and VR technologies in healthcare has also been proven to be effective for pain management and physical therapies[24]. Physical therapists may administer virtual rehabilitations with exercise routines which can be accessed and performed by patients while they are confined in their homes. AR/VR-based tasks and scenarios within a controlled virtual environment can be very effective in making the recovery time more faster. Moreover, an interactive and immersive virtual experience can be a distraction and may reduce pain levels for patients that have undergone surgical operations. The virtual experience

can provide more fun and keeps the patient immersed to allow them to focus on recovery even if it can take a longer period.

3.3 Disease Awareness Feature

AR and VR technologies can provide the healthcare system with a feature that presents diseases and wellbeing awareness to the society. For example, the daily struggles that patients suffering from Alzheimers disease or Parkinsons disease can be simulated in a virtual experience to raise awareness among healthcare professionals and other users. The persons that uses the virtual simulation may experience awkward and embarrassing moments when then come in contact with other people or in performing the given tasks.

Thus, with proper disease awareness, healthcare professionals and doctors can carefully plan a long-term healthcare program and treatment as well as cater the daily care needs of patients for a particular disease. For other people, experiencing the virtual simulation of diseases can make them decide in advance their long-term healthcare options, healthy lifestyle, and wellbeing[25].

IV. Conclusion

This paper has presented the various converging technologies that revolutionize the realization of the future u-Healthcare systems. These various converging technologies include WSNs, ubiquitous computing, wireless communication technologies and mobile computing, AR and VR technologies, and AI in healthcare. The integration of these converging technologies has led to the realization of a robust, efficient, reliable, and emergent u-Healthcare system. An efficient utilization of these converging technologies simplifies the monitoring, diagnosis, and treatment of patients and guarantee a high quality, reliable, and emergent medical and healthcare services. The convergence has led to the significant features for the future AR/VR-based u-Healthcare systems such as medical training, treatment administration, and disease awareness providing significant contribution to cognitive impairment diagnosis and treatment.

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