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Intelligent Virtual Agents and Robotic Systems in the Era of Digital Health Care

Hyunghun Kim*

MechEcology Research Center, Seoul, Korea

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***Corresponding author**
Hyunghun Kim
MechEcology Research Center, 150, Mokdongdong-ro, Yangcheon-gu, Seoul 08014, Korea
Tel: +82-2-2643-2323
E-mail: relyonlord@gmail.com

ORCID
Hyunghun Kim
https://orcid.org/0000-0002-3013-075X

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Abstract

It is clear that artificial intelligence-based systems, intelligent virtual agents (IVAs), and robots will gradually replace human labor, not only physical activity but also mental activity. Rapidly changing demographics will accelerate technological development and result in a machine-dependent society, which humankind has never faced. The healthcare sector cannot avoid mechanization due to the low possibility of hiring appropriate professionals for a highly digitalized environment, the efficiency of IVAs and robots, and cost-effectiveness from the management's view. In this paper, the author describes the future features of the healthcare sector in which human staff, IVAs, and robots cooperate to produce optimal outcomes for patients and healthcare facilities.

Keywords: artificial intelligence; intelligent virtual agent; robot; digital healthcare

PROLOGUE

Dr. Anderson watches the falling rain, reminiscing about events from approximately fifteen years ago. Now a renowned gastroenterologist, he has significantly contributed to improving the health of local residents. As a gifted doctor, caring for his patients is not a heavy burden; however, managing his clinic presents a different set of challenges. The most troublesome issues have been recruiting and managing employees. He feels that the healthcare labor market has undergone significant changes. When he first opened his private clinic, hiring staff was not a major concern. These days, it can take months to find and employ suitable personnel. Staff wages are rising rapidly, and more recently, employees have begun abruptly quitting their jobs. Dr. Anderson is deeply concerned about the clinic's future.

Meanwhile, Professor Harris, the CEO of a university hospital, has just succeeded in passing an influential agenda during the hospital board meeting. Her hospital is set to implement artificial intelligence (AI) systems. She believes this innovation will enhance both patient satisfaction and key management indicators.

At the same time, Director Smith, a healthcare officer, is crafting a new plan to support older adults who are still employed but physically fragile. To address the shortage of human resources, he is considering the introduction of AI and robotic systems. With the help of his most trusted assistant, Thomas, the AI system of his division, he is calculating the potential impacts and details of this new system.

THE RISE OF INTELLIGENT VIRTUAL AGENTS AND ROBOTS IN THE HEALTH CARE SECTOR

The healthcare sector is a labor-intensive field (Lee et al., 2019). Healthcare workers, including doctors, nurses, and paramedics, must possess specialized skills to ensure proper outcomes (Jarva et al., 2022). Additionally, workers need to develop computer proficiency due to the widespread adoption of digitized systems (Alwan et al., 2015). Unfortunately, not all healthcare workers are adept at computer-based tasks (Alwan et al., 2015).

Furthermore, there is a growing trend toward alternative work arrangements, with many individuals preferring flexible employment options (Katz & Krueger, 2019). The rise of the platform economy and gig workers has contributed to a shift in the traditional employment landscape, as these workers engage in various tasks across different sectors (Kaine & Josserand, 2019). This transformation of the workforce structure has implications for both workers and organizations, potentially affecting the stability and nature of full-time employment in various industries (Kaine & Josserand, 2019; Katz & Krueger, 2019).

Intelligent virtual agents (IVAs), powered by AI, are now a common feature in daily life. Familiar examples include Apple's Siri, Amazon's Alexa, and Microsoft's Cortana, which provide real-time information through verbal communication (Amjad et al., 2023). Improving the patient experience through seamless interactions is an important reason for adopting IVAs in healthcare settings (Amjad et al., 2023). However, operational efficiency is also a significant factor driving IVA adoption. Healthcare providers often turn to IVAs to address resource challenges and automate routine tasks.

Moreover, healthcare services are increasingly relying on IVAs and IVA-integrated systems to enhance safety and efficiency across various care settings. This paper will explore IVAs and IVA-linked systems, which have the potential to mitigate workforce challenges and improve healthcare delivery.

VIRTUAL CALLERS

At the beginning of patient interactions, IVAs manage schedules and update patient data through telephone or chatbot communication, functioning much like human receptionists. For optimal performance, IVAs must be capable of natural language communication, both verbal and text-based. Additionally, their actions must be seamlessly integrated with patients' electronic medical records (EMRs). The primary functions of IVAs as virtual callers are outlined below.

Appointment Management

IVAs can schedule, reschedule, and cancel appointments, adapting to patients' frequently changing circumstances. They record the reasons for changes and manage specific appointment details.

Information Provision for Medical Procedures

IVAs provide detailed instructions for medical examinations, procedures, or operations. For instance, they can schedule an upper gastrointestinal endoscopy and inform patients not to eat for 12 hours beforehand. Similarly, they guide patients on colonoscopy preparation. After interacting with patients, IVAs can send text messages confirming appointments and providing preparation instructions.

Active Patient Follow-Up

IVAs actively manage scheduling-related tasks. They can contact patients several days before appointments to provide reminders. After invasive procedures or operations, they call patients for follow-up questions about their condition and record the responses in the EMRs.

Profile Updates

Following communication with patients, IVAs automatically update patient profiles, including details like address, phone number, or changes in insurance information.

Frequently Asked Questions (FAQ) Navigation and Assistance

IVAs can answer patients' FAQs regarding business hours, specialties, medical devices, pricing, clinic locations, and more. As each clinic has unique policies and processes, if IVAs encounter questions they cannot resolve or situations they cannot handle, they will immediately transfer the conversation to human staff.

Telemedicine Support

IVAs significantly enhance telemedicine by handling essential communication before a doctor's diagnosis or treatment. They create brief reports for doctors based on patient interactions. After telemedicine sessions, IVAs follow up on patients' conditions and relay the results to doctors as requested. Additionally, IVAs can receive and analyze biometric data from advanced home medical devices, presenting the results to doctors for further evaluation.

The unique advantage of IVAs lies in their ability to provide uninterrupted, full-time service. They require no rest, holidays, or vacations, allowing patients to make appointments or request information anytime. When human staff members arrive at work, IVAs report their completed tasks. Furthermore, IVAs can interact with multiple patients simultaneously, demonstrating exceptional multitasking capabilities.

VIRTUAL MANAGERS

IVAs will efficiently handle inventory management without significant difficulty. Hospitals require a vast array of supplies to care for patients (Moons et al., 2019), and IVAs will monitor stock levels and notify human managers for approval to order specific items, especially perishable products, to maintain optimal inventory levels Upon approval from a human manager, IVAs will place orders with suppliers, potentially communicating directly with the supplier's IVA. By analyzing past data, IVAs can predict when stock will deplete and continually refine their calculations with daily updates. To ensure an uninterrupted supply, IVAs seek human approval before stocks run critically low.

In addition to managing the hospital's central inventory, IVAs will also calculate and monitor inventory for individual wards, laboratories, operating rooms, and outpatient clinics. Each area has specialized needs, and a shortage of diagnostic or therapeutic items in critical situations can have serious consequences. IVAs predict which items are at risk of running out at specific times and locations, reducing the likelihood of shortages during urgent situations, particularly for hands-on nurses.

Among the many types of medicine, specific agents are subject to strict regulatory control. Their purchase and usage must be meticulously recorded and reported daily (Videau et al., 2019). Traditionally, designated staff handle this process to avoid errors (Videau et al., 2019). IVAs will automate and document the management of psychotropic agents, scheduling reports at a specific time each day for review by human managers. Once approved, IVAs securely store the records using blockchain technology.

In the realm of telemedicine, IVAs play a critical role in data management. They record biometric data from patients in the EMRs upon request, regardless of regular business hours. This real-time connectivity is invaluable for diagnosing diseases characterized by paroxysmal symptoms, such as arrhythmia, orthostatic hypotension, vasovagal syncope, and absence seizures. The continuous support of IVA-linked systems will enhance telemedicine practices and accelerate the adoption of telemedicine devices.

VIRTUAL OR ROBOT RECEPTIONISTS

In the initial phase of mechanization, the role of IVAs is limited to verbal communication via phone or text message exchange through SNS. However, IVAs could interact directly with patients at a front desk using highly advanced visual and audio sensors along with a speaker. For instance, an Israeli hotel has already deployed a robotic host (The Times of Israel, 2022). IVAs can also operate through a screen, hologram, or robotic system to avoid unsettling patients. If IVAs rely solely on sensors and a speaker, many patients might feel uncomfortable.

The primary function of a hospital receptionist is welcoming patients and collecting payments. IVAs can perform this function by utilizing electronic payment systems. Patients can theoretically complete payments through a card terminal or electronic banking system guided by IVAs. While unmanned kiosk systems for medical fee payments already exist in some hospitals, these systems often provide an impersonal experience similar to that of ATMs. An IVA-linked system, on the other hand, can enhance the patient experience by offering more human-like communication without requiring human labor.

If robotic receptionists are equipped with physical arms, they can handle cash, dispense change, distribute leaflets, and scan patient materials. These functionalities would be beneficial if the cost of an armed robot becomes lower than that of employing human staff.

CENTRAL INFORMATION SYSTEMS-LINKED GUIDE ROBOTS AND THEIR APPLICATIONS

Guide robot systems are already in use, but hospital guide robots require more sophisticated functionality (Ma et al., 2021). A GPS-guided robot can lead patients step-by-step to specific locations within a hospital, ensuring they do not get lost while navigating unfamiliar areas (Ma et al., 2021). For patients needing to visit multiple locations, the robot retrieves information from the central information system, extracted from the EMRs when the patient scans their identification card. It then calculates the shortest possible route to complete the visits efficiently.

To achieve this, the robot must be connected to an information center capable of real-time situation analysis, considering factors such as the total number of patients in the hospital, waiting lists in specific laboratories or clinics, average examination times, and estimated travel durations between locations. Additionally, a robot-synchronized elevator system is essential. Through wireless communication, the robot can call an elevator and select the appropriate floor to assist patients in navigating the hospital.

Even small clinics can benefit from guide robots controlled by IVAs. These robots can direct patients to locker rooms, clinical laboratories, restrooms, and more. IVAs understand the preparation steps required for specific examinations and issue instructions to robots accordingly. For example, in preparation for an endoscopic examination, the doctor inputs orders into the system, such as sedative endoscopy. The IVA identifies the required preparations: changing clothes, performing electrocardiography, drinking dimethylpolysiloxane, and moving to the endoscopy room. The robot guides the patient to the locker room and explains how to wear the endoscopic suit, instructs the patient to drink an anti-foaming agent, and escorts the patient to the endoscopy room. Equipped with a speaker and a pointer, the robot can efficiently guide patients. If equipped with physical arms, it can assist further, such as helping patients dress or handle materials.

In larger hospitals, inpatients often need to visit laboratories or operating rooms. Guide robots can escort patients who are mobile, while robot wheelchairs or stretchers assist those who cannot move independently). The process involves a station nurse summoning a robot wheelchair or stretcher to the patient's location, transferring the patient onto the robot device, and transporting the patient to the required destination. After the procedure or examination, the robot returns the patient to their original location.

For hospital transport robots to be feasible, two factors are critical: the robots' size must be comparable to conventional tools, and their use must be more cost-effective than human labor, such as medical orderlies. These robots can efficiently handle tasks like transporting food, laundry, and other items from one defined point to another within the hospital, potentially improving workflows and hospital effectiveness.

Another potential application of guide robots is in distribution. Guide robots, including robot wheelchairs and stretchers, can mount cart units to function as distribution robots. Nighttime is a reasonable period for their regular operation. To fully mechanize distribution, hospital warehouses may need remodeling to accommodate robot-based systems.

Guide robots can also assist in patient rounds. By minimizing walking distances, robots guide doctors to each patient's location efficiently. IVA-linked guide robots provide updates on patients' conditions and laboratory findings before and during rounds. They can also record conversations between doctors and patients, ensuring accuracy and traceability. Furthermore, robot-linked systems can update medical orders instantaneously based on a doctor's directions during rounds and notify the responsible nurse of changes. Operating within a cloud computing environment, this system reduces errors and ensures no critical medical tasks are neglected.

INTELLIGENT VIRTUAL AGENT (IVA)-CONTROLLED MEDICAL DEVICES AND MECHANIZED SYSTEMS

In the future, IVAs will control medical devices in various ways. They can select and set the mode of a machine for a specific patient. For example, first, a doctor orders a thyroid sonography. Second, the patient goes to the ultrasound room with their patient identification card. Third, the patient touches the card to the terminal linked to the ultrasonic machine. Fourth, the IVA understands the situation and sets the ultrasonic mode for thyroid scanning.

A more advanced mechanized system can be envisioned, such as a four-robot-armed backpack resembling the shape of Dr. Octopus from Spider-Man and robotic arms hanging from the ceiling of the operating room. An IVA needs to mediate the communication between a doctor and a machine. This advanced system can enable a single doctor to perform various operations without assistance and will be beneficial in emergency situations. Operating a single-doctor system will be more efficient if a brain-computer interface is available.

ROBOT CAREGIVERS

Caring for patients and the elderly represents a significant social burden, with a substantial portion of the cost attributed to hiring human caregivers (Flandorfer, 2012). This challenge is compounded by dramatic demographic changes, including low birth rates and increased life expectancy (Sharkey & Sharkey, 2012). Introducing robot caregivers offers a promising solution (Góngora Alonso et al., 2019). Advances in robot technology will eventually lead to the development of professional robot caregivers; it is only a matter of time (Bedaf et al., 2015). The cost of these robots will become manageable through mass production and large-scale purchasing.

Initially, robot caregivers will assist human caregivers in their roles. A centralized information network will gather extensive data from each robot, continually updating their algorithms. This iterative process will ensure rapid upgrades across all robot caregivers, ultimately transforming them into highly skilled professionals. Each robot will adapt to the unique needs of its assigned patient, becoming a reliable and trustworthy partner. If AI gains the capability to empathize with patients, robot caregivers will provide stable, supportive environments that surpass those offered by human caregivers, who are prone to emotional instability and external stressors.

The reliability of robot caregivers is particularly significant in addressing issues such as caregiver abuse, a recurring concern in the current system. Unlike humans, robots would not engage in abusive behavior unless compromised through hacking. As such, the security of caregiver robot systems becomes a critical priority, as patients are uniquely vulnerable both physically and psychologically.

Robot caregivers will maintain constant communication with an IVA at the hospital or healthcare center, updating routine schedules and documenting unusual events or emergencies. The IVA will record these reports and respond promptly to manage urgent situations, notifying healthcare facility staff as needed. In this capacity, robot caregivers will become an indispensable component of home treatment, ensuring patients receive consistent and reliable care.

AIR AMBULANCES

Urban Air Mobility has become a reality, and one of its most promising applications is the air ambulance (Cohen et al., 2021), Combining autopilot technology with an IVA-based network system, air ambulances can transport patients to the nearest suitable hospital with minimal delay, significantly reducing the time between the onset of a medical emergency and receiving treatment.

Air ambulances are particularly suited for urban environments, offering efficient patient transportation while bypassing ground-level traffic congestion (Cohen et al., 2021). With sufficient advancements in battery technology, they could also operate in more remote areas, further expanding their utility (Straubinger et al., 2020). The feasibility of air ambulances is enhanced by their ability to utilize existing helipads, minimizing the need for significant additional infrastructure investment.

A fully synchronized system involving robot caregivers, home biometric devices, hospital IVAs, and air ambulances will dramatically improve patient survival rates in urgent situations. This integrated approach ensures seamless communication and coordination across all components of the healthcare network, enabling faster, more effective responses to medical emergencies.

ELECTRONIC MEDICAL RECORDS (EMRS) AND SECURITY

A comprehensive program must record all activities of IVAs in detail, ensuring transparency and accountability. The EMRs should include the outcomes of IVA-linked system activities in real time, providing an accurate and up-to-date account of patient-related processes. Additionally, IVAs and human staff must communicate seamlessly about ongoing tasks, whether through text messages or verbal communication, to ensure coordinated efforts and reduce errors.

Given the sensitive nature of patient information, EMR-based activities require stringent security measures (Jalali & Kaiser, 2018; Kruse et al., 2017). The introduction of IVAs to clinics significantly heightens the need for robust data protection protocols). This includes safeguarding against unauthorized access, ensuring data encryption, and implementing strict access controls to maintain confidentiality (Kruse et al., 2017). As IVAs become integral to healthcare systems, addressing these security challenges will be critical to protecting patient privacy and maintaining trust in the system.

EDGES OF MECHANIZATION FROM THE MANAGEMENT PERSPECTIVE

The mechanization of the healthcare sector offers substantial advantages from a management perspective, as outlined below:

First, Stability of Assets

IVAs and robot systems are inherently stable assets for hospitals and clinics. Unlike human staff, an IVA will not resign as long as the contract with its provider is maintained. Over time, an IVA trains itself by handling numerous cases, contributing to greater business stability.

Second, Continuous Operation

IVAs can operate 24/7, responding to patient requests even when human staff are unavailable. This continuous availability enhances patient satisfaction and drives business growth.

Third, Consistent Patient Interactions

IVAs and their linked systems maintain consistent politeness in patient interactions, avoiding the negative emotional experiences that can occasionally arise with human staff.

Fourth, Adaptability to Changes

While human staff require regular training to stay updated on new guidelines and protocols, IVAs inherently adapt to changes, making them the most competent team members from this perspective.

Fifth, Enhanced Accuracy and Reliability

IVAs do not repeat the same mistakes, unlike humans, ensuring a higher level of accuracy and reliability.

Sixth, Elimination of Labor Disputes

Mechanization eliminates the risk of labor disputes, further enhancing operational stability.

Finally, Cost Reduction

Employing IVAs is expected to reduce total labor costs.

While the initial investment in mechanizing the healthcare sector may be substantial, similar to the setup of a smart factory, innovations in AI and robotics will gradually lower costs. Over time, these investments will lead to improved business outcomes by reducing expenses associated with AI and robot units.

EPILOGUE

The world is entering a new phase: the partnership between humans and machines. IVAs and robots are set to become indispensable components of future healthcare systems. The introduction of IVAs and IVA-linked robotic systems represents an inevitable historical progression across various industries.

While many aspects of healthcare will continue to rely on the human workforce, AI systems, under the guidance of professional human supervisors, will need to encounter and learn from a multitude of real-world scenarios before they can fully fulfill their roles as proficient professionals. Nevertheless, IVAs and robotic systems will increasingly take on more responsibilities, operate with greater efficiency, and significantly enhance the stability, safety, and accuracy of healthcare systems.

"Science fiction is held in low regard as a branch of literature, and perhaps it deserves this critical contempt. But if we view it as a kind of sociology of the future, rather than as literature, science fiction has immense value as a mind-stretching force for the creation of the habit of anticipation."

– Alvin Toffler, Future Shock –

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