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RESEARCH ON THE APPLICATION OF BIG DATA IN HEALTHCARE

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Abstract

The rapid development of Artificial intelligence (AI) technology in the past decade has not only brought innovation and development opportunities to various industries, but also created many potential opportunities in the field of healthcare. Today's technology is more and more advanced. As cloud computing technology matures, big data and AI are not just novel concepts, they start to reshape and transform our lives. In the future, Taiwan will face the arrival of a long-term care society and an aging population. From healthy, sub-healthy, to the final state of disability, people's healthcare needs may vary at different stages. Technology originates from human nature, and many applications of health care technology are driven by human needs. After collecting data from Internet of Things (IoT) devices and forming "health big data", combined with artificial intelligence technology, countless possible applications and services can be provided. After introducing big data analysis, this study will further illustrate how big data is applied to three stages of healthcare: "health, sub-health, and disability".

Keywords: big data, artificial intelligence (AI) technology, healthcare industry

Introduction

Health refers to the ability of an individual or group to adapt and manage themselves when confronted with physical, psychological or social challenges. Health problems are often caused by metabolic syndrome and poor health behavior patterns. For example, the number of people suffering from diabetes and hypertension in Taiwan has been increasing year by year in recent years. According to a report (from 2017 to 2020) conducted by Taiwan's Health Promotion Administration, the proportion of adults suffering from hypertension, hyperlipidemia and hyperglycemia were 23.52%, 22.7% and 9.74% respectively (see Fig. 1). These chronic diseases may lead to disability and

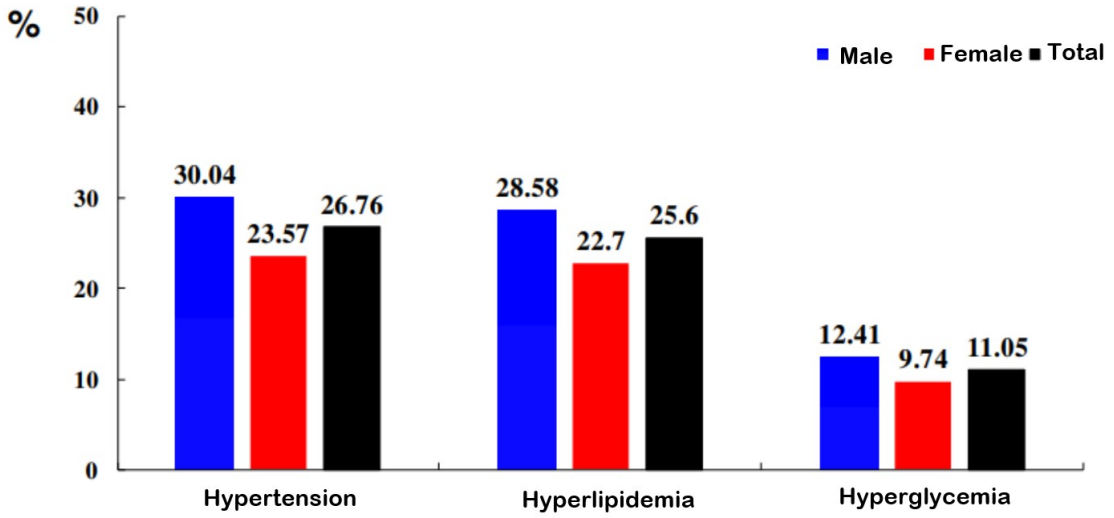

Figure 1. Three high prevalence rates among Taiwanese adults

dementia in patients in the future, thereby influencing the country's productivity and competitiveness. In 1993, Taiwan's population aged over 65 accounted for more than 7% of the total population, and Taiwan became an "aging society" as defined by the WHO. This population ratio will exceed 14% in 2018, and Taiwan then became an "aged society". Furthermore, the proportion of the elderly population in Taiwan is expected to exceed 20% by 2026, making it a "super-aged society". (National Development Council, 2020)

When an aged society comes, people should rethink how to mitigate and cope with the impact of disability. In recent years, the new concept of “sub-health” has emerged in the field of healthcare. In today's society, many people feel various physical discomforts, but no organic lesions is found during their physical examination, which makes doctors unable to treat their illness. This is called "sub-health" state; it’s not an indicator of actual disease, so it cannot be clinically diagnosed as a disease. The human body may experience various discomforts, and even suffer from chronic pains, leading to the early onset of disability (Health Promotion Administration, 2017). As the old saying goes, "Prevention is better than cure", people with sub-health symptoms should prepare for disability in advance. From healthy to sub-healthy to disabled, everyone has different healthcare needs across different stages.

With the rapid development of information technology, smart healthcare has become a significant potential solution to upgrade the value of medical services. Medical and health services combine several information and communication technologies such as big data, Internet of Things, and artificial intelligence. Through the intelligent application of clinical big data, real-time analy-

sis and information technology, doctors can make informed decisions, reduce possible medical errors, enhance the efficiency and quality of medical services, and further improve the overall efficiency of healthcare system (Zeadally, et al., 2019). More importantly, recent advances in smart healthcare provide possible solutions to the challenges posed by an aging population. This research mainly discusses the related applications of big data and smart technology in the three stages of "health, sub-health, and disability": (1) In the health stage, focus on smart health management and technological preventive medicine. (2) In the sub-health stage, smart home care and smart companionship are included in the discussion. (3) In the disability stage, smart medical treatment and smart monitoring are the primary topics (Papa, et al., 2020).

Literature Review

"Big data" refers to data that is too large to be processed in traditional ways. Due to its ever-growing nature, the required data analysis must take atypical approaches and involve specific requirements for data collection, data preprocessing, and data analysis. Therefore, many algorithms designed for big data analysis have been developed (Mohamed, et al., 2020). The analysis results of big data have offered unprecedented breakthroughs in healthcare field and apply to many fields, including business, medicine, meteorology, security law enforcement, real-time traffic, and so on (Li, et al., 2021).

Big Data

Big data can be used to provide real-time and outstanding analysis and reflect the real situation in time, so it is widely used in various fields. In healthcare field, big data analytics can help support clinical decision-making, optimize clinical operations, and reduce medical cost, as well as drug discovery, precision medicine, and telemedicine (Lopez Segui et al. 2020). The benefit of big data analysis lies not only in the large amount of data, but also in the statistical significance of the data. It can be used for machine learning while responding to sudden surges in medical demand. For example, the application of big data has shown its advantages during the covid-19 pandemic: Provide quick and effective alerts for pandemic, track and diagnose covid-19 cases, prove the efficacy of potential cures, promote and implement preventive public health measures, etc. (Bragazzi et al. 2020). With the penetration of big data analytics and the growing amount of medical data, the collection, management, and analysis of medical data will drive the arrival of big data in healthcare (Ginsburg & Phillips 2018). The process of big data analysis (i.e. data mining) can be divided into the following 5 steps: data identification, data collection, data preprocessing, data analysis and data visualization (Alonso-Betanzos & Bolón-Canedo, 2018). See Figure 2.

(1) Data Identification

The first step of big data analysis is to identify the types of data needed for the analysis. The sources of these data can be either internal or external, and can come from data providers. Taking

Figure 2. Big data analysis process

the healthcare industry as an example, its internal resources originate from hospitals or clinics, while the external sources come from governments, laboratories, pharmaceutical companies, data collectors, and medical journals, etc. (Mehta & Pandit, 2018).

(2) Data Collection

The second step will collect data. In this phase, the unedited data is called metadata. Metadata (including data size, structure, date, creation time, etc.) is an important basis for analysis and should be stored in the database for a long time to prevent data from being damaged or lost during the analysis process (Alonso-Betanzos & Bolón-Canedo, 2018).

(3) Data Preprocessing

The data should be consistent and can be processed in a posterior analysis before proceeding to data analysis. Thus, these metadata must be preprocessed in order to fulfill the purposes including but not limited to denoising, filtering data, compiling data, and simplifying data (Alonso-Betanzos & Bolón Canedo 2018). The preprocessing process can be simply divided into two types: data cleaning and data transformation.

(4) Data Analysis

Data analysis aims to identify patterns, relevance, predictions or anomalies. The ultimate goal of this step is to choose different methods suitable for different purposes. There are several methods for applying big data analysis in the healthcare field, including cluster analysis, data mining, graph analytics, machine learning, neural network, pattern recognition, spatial analysis, deep learning, and natural language processing (NLP), etc. (Cirillo & Valencia, 2019)

(5) Data Visualization

Tables, graphs, and information "boxes" can make data easily understood so business clients can take good advantage of the results obtained by the analysis and make informed decisions. At present, existing databases have functions such as adopting data analysis results, searching for diseases, genes or allele frequencies, and colleting clinical data for easy access. Users can leverage data and analytics to support clinical decision-making without establishing their own databases (Kounelis, et al., 2020).

Smart Healthcare

Smart healthcare refers to the use of equipment, sensing devices, computing and communication technology, software and hardware systems, cloud computing, and big data analysis. Generally, smart healthcare can offer personal, universal, engaging, predictive, preventive, systemic and permanent healthcare services (Volkov, et al., 2021). Based on WHO, eHealth is defined as the applica-

tion of "information and communications technologies in support of health and health-related fields, including healthcare services, health surveillance, and health education, knowledge and research." (WHO, 2020). In contrast, the definition of "digital health" is broader than that of e-health, which includes e-health, telehealth and mobile health (mHealth). Compared with digital healthcare, eHealth relies more on medical information and pays more attention to the application of information technology to health promotion, aiming at achieving economic benefits and enhancing efficiency. As the name suggests, mHealth stands for using wireless technology on mobile devices to advance public health (Khillar, 2020).

The development of smart healthcare can be traced back to 1998, and eHealth, telehealth, mHealth, and digital healthcare are essential cornerstones. Among these key elements, eHealth is the first area to receive attention, and the Internet often shows ads about healthcare products. In addition, the rise of the Internet reminded the World Health Organization of the influence of the Internet on health issues, so it began to advocate and promote the member states to establish relevant policies to integrate smart healthcare into the existing healthcare system (Hou, et al., 2021). With the rapid development of technology, eHealth and digital healthcare can provide a wider range of services, and the future smart healthcare will definitely have an increasingly profound impact on the health of all human beings. For the future smart healthcare field, related technology trends and emerging products will be the most popular in five categories: (1) telehealth, (2) artificial intelligence, (3) robotics, (4) IoT and wearable devices, and (5) blockchain (Basit, et al., 2020). Therefore, countries around the world have invested lots of resources in the hope of transforming the traditional medical and healthcare model. Here are a few use cases for smart healthcare: Significantly improve the healthcare efficiency by leveraging robots for medical supplies replacement or using automatic pill dispensers for labor reduction. Combine wearable devices and mobile applications to assist patients in health self-management or self-care training, thereby improving the quality of tele-healthcare services for patients with chronic diseases and other groups. Adopt artificial intelligence and machine learning to establish disease prediction models to implement precision medicine.

Smart healthcare is not only a demonstration of technological progress, but an ingrained concept or way of thinking that enables people to apply information, enhance communication, and improve local, regional, and global healthcare models. In addition to convenience and entertainment, smart healthcare also includes the core characteristics of efficiency and quality (Mehrotra, et al., 2021). Shaw et al. (2017) pointed out that today's smart healthcare should cover the following three interrelated and important dimensions:
(1) "mHealth" adopts digital monitoring technology to track and notify health-related information.
(2) "Interactive health" can apply digital technologies to ease the communication between healthcare workers and patients.

(3) "Data-based health management" collects and leverages health-related data to achieve effective empowerment, provides healthcare workers with sufficient information, build efficient and interconnected health caring models, and offers integrated healthcare platforms.

Empirical Analysis

Over the past few decades, the rapid advancements of big data and artificial intelligence has spawned many innovative technologies, which have been widely applied in various fields. Taking the field of healthcare as an example, innovative applications of AI-based technologies such as Pattern Recognition, Natural Language Processing, and Speech Recognition are emerging one after another. In the future, there will be more interdisciplinary research integrating big data, artificial intelligence and medical care, which will help realize personalized and precision medicine, thereby enhancing human health and well-being.

Health Stage

In terms of the development and application of big data in health industry, medical data are rich, diversified and can be applicable to various areas (Kao et al., 2016). This research involves electronic health records, technological preventive medicine, intelligent health devices and other fields.

(1) Electronic Health Records

After integrating various case data scattered in various departments of the hospital into the cloud, doctors can search for relevant information of any case through semantic search, thereby providing more informed data for medical diagnosis. This can provide patient-centered personalized treatment recommendations and further develop into AI-based diagnosis to address medical concerns and automatically assist patients in diagnosis. This database contains information about patients, doctors, and medical institutions under the health insurance system, and researchers have free access to the database for research purposes. The analysis process will not only use statistical methods to interpret the results, but must also interpret the relevant data along with medical methods. In the era of big data, data science will become mainstream.

(2) Technological Preventive Medicine

Regarding technological preventive medicine, healthcare institutions can analyze the detected data, including height, weight, body mass index (BMI), body fat ratio, waist circumference, heart rate, heartbeat, blood pressure, body temperature, blood sugar, etc. With a combination of visualized tools and easy-to-understand charts, users can see the whole picture at a glance. For example, you can visualize sleep quality trends over time, check how much time you spend in deep sleep each day, observe other physiological indicators, and further compare with other variables (such as occupation) to see if there is a correlation, providing a reference for doctors or medical professionals (Gu, et al., 2017). The reference data generated by smart devices can also be applied to

diet management, health diary, weight loss planning, sleep aid, and many other fields. To further illustrate, people leverage smart devices to record daily life data, as if they have a personal health secretary. With the help of AI, we can better grasp abnormal information and provide health status prediction to slow down the advent of sub-health status (Manogaran, et al., 2017).

(3) Intelligent Health Devices

Today, the Internet of Things is in the dominancy of healthcare industry. Benefiting from the big data collected via various channels, more and more diversified prediction models can be established. Technically, it is not difficult to write predictive models into hardware devices. Therefore, smart health devices with judgment will become popular, making today's smart medical equipment present a variety of types, and related use cases cover different applications such as smart chips, sleep quality monitoring, robotic exoskeletons, and surgical robots.

Moreover, the game industry has launched somatosensory games in line with the trend of the healthcare market. Somatosensory game is an emerging exercise mode, through which players can perform various common sports (such as rowing, running, heavy training, aerobics, archery, etc.). Somatosensory games leverage sensors/cameras, virtual human skeleton models and other auxiliary tools to recognize human movements, and use them in combination with virtual reality, augmented reality and mixed reality technologies to enhance gaming experience and interest (Rauschnabel, et al., 2022). Users can not only achieve sports effects during the game, but also get advice on correct sports postures to avoid injuries. After the game, the screen will display parameters such as cardiopulmonary fitness measurements, calorie burn and physical activity. In this way, people's willingness to exercise can be greatly improved, and their physique and health can also be enhanced, thereby delaying the arrival of sub-health conditions. In addition, these techniques can be applied to assist in rehabilitation.

Sub-health Stage

In the sub-health stage, the application of healthcare technology can be divided into smart home care and smart companionship. These use cases rely on information and communications technology to connect home devices to the Internet of Things (IoT) and record users' living habits and health data. Examples are as follows: (1) Smart mattress: Monitor the sleep quality of the care receiver, so that family members working outside can know when the care receiver gets up, and even greet them remotely, and detect whether there is a risk of falling through the smart bracelet (Anghel, et al., 2020). (2) Smart pill box: Provide medication reminders, so that busy modern people do not have to worry about whether their family members take medicine on time or forget to take medicine, and even prevent accidental or repeated taking of medicine (Chu & Xiao , 2020). (3) Physiological detection device: Use blood glucose machine, blood pressure machine, weight machine and other

devices to record physiological conditions in daily life. (4) Smart sensing device: By using devices and thermal sensors, no matter where you are at home, you can know the location of your family members and ensure the safety of the elderly. (5) Smart robots at home: Apart from providing companionship and controlling electronic products in the home, smart robots can also combine AI to provide multiple functions, such as weather forecasts, activity reminders, and playing music. In addition, when the user interacts with the robot, speech recognition and deep learning can be employed to collect sound data and analyze the characteristics in order to judge the user's mood and physical and mental state (Chandler, et al., 2020).

All of these these smart devices can be integrated with mobile devices, including (1) adopting smart pill boxes to provide medical push notifications services, (2) using smart bracelets for fall detection, and (3) making emergency calls to notify family members (Aronson, 2019). These application methods enable people in the sub-health stage to enjoy the caring functions when they are confronted with early warning signals of health conditions, thereby enhancing their sense of security, avoiding physical and mental health problems caused by loneliness, and using smart devices to offer companionship, encourage the interaction among relatives, and strengthen their bonds (Jeste, et al., 2019). Smart home care technology can help record people's home living habits and health information for remote monitoring and future recommendations in collaboration with medical institutions. Smart devices can also send out alarm signals immediately when emergencies occur in order to facilitate timely rescue, and medical institutions will be able to provide comprehensive smart healthcare services when people enter their disability stage in the future.

Disability Stage

Regarding the application of healthcare technologies, the Taiwan government has established relevant regulations in recent years to meet the demands of telehealth and solve the problem of insufficient distribution of medical services in remote areas. As mentioned in Article 11 of Physicians Act enacted by Ministry of Health and Welfare (Taiwan), physician appointed by competent authorities may adopt telecommunications methods to inquire about illness, set diagnosis and issue prescriptions in response to medical needs. This practice is in line with the provisions of Article 3 of the Rules of Medical Diagnosis and Treatment by Telecommunications and encourages the development of telehealth in Taiwan. Recent advances in telehealth have enabled healthcare providers to leverage modern information and communication systems (including video conferencing, still image transmission, remote monitoring of physiological indicators, and telemedicine response). In addition, coupled with a number of lifestyle modifications that can be supported by the remote system, it is expected to break through the limitations of traditional medical care and become a strong support for healthcare in the super-aged society.

In the light of this, the disability stage requires the assistance of smart healthcare and smart monitoring systems. Currently, Taiwan is actively promoting value-added applications such as telehealth, electronic medical record integration, health databases, and health passbooks, as well as encouraging disease prevention and screening in remote rural areas, with a view to improving the quality of medical services. Moreover, medical institutions are encouraged to cooperate with information and telecommunications companies to provide medical services such as smart healthcare, telehealth, and smart monitoring. At the same time, medical institutions will develop comprehensive smart hospitals and combine advanced smart healthcare equipment to improve the overall level of medical services. In telehealth, medical devices or wearables can be employed to connect physiological data results with hospital information systems. If any special condition is detected, family members can be notified to arrange medical treatment. If special situations are detected, family members can be notified to arrange medical treatment. In combination with remote management software, the occurrence of regret and social medical costs can be reduced (Manogaran, et al., 2018).

Taiwan's smart healthcare services have gradually become popular. With the development of smart healthcare, the current medical system, people's medical habits and related medical regulations have begun to change. Therefore, it is imperative to develop healthcare services powered by smart technologies. With the help of the Internet of Things, big data, and computing technology, smart healthcare can not only be used to analyze personal lifestyles, but further search for potential health risks. At the same time, the smart healthcare system is becoming more and more humanized. The combination of software and hardware helps users cultivate health management habits from the healthy stage, and further alleviate the symptoms of sub-health and disability stages. More importantly, the development of smart healthcare can provide various possible solutions to the challenges arising from an aging population. Smart healthcare also adopts big data analysis and artificial intelligence algorithms that were difficult to perform in the past to innovate professional knowledge in the medical field so as to combine medical profession with information and communication technologies to generate practical knowledge. Big data has infinite development potential in the medical field, and this technology deserves the participation of more experts and scholars.

Conclusion

Taiwan's smart healthcare services have gradually become popular. With the development of smart healthcare, the current medical system, people's medical habits and related medical regulations have begun to change. Therefore, it is imperative to develop healthcare services powered by smart technologies. With the help of the Internet of Things, big data, and computing technology, smart healthcare can not only be used to analyze personal lifestyles, but further search for potential health risks. At the

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