Telemedicine and Telemonitoring in Healthcare

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Abstract. Over the last decade, there has been an increasing demand of information technology, specifically, telemedicine and telemonitoring in healthcare. Many elderly and disabled people are unable to look after themselves. They also desire quality healthcare. If the healthcare can be provided at home instead of only hospitals, the service could be more affordable, and people would feel more comfortable. Aiming to help elderly and disabled people, technology has been developed to provide assistance in various ways. Consequently, telemedicine and telemonitoring have been deeply embedded in healthcare industry and made significant impact. This report has provided a comprehensive review covering current progress of research in telemedicine and telemonitoring and their applications to healthcare services.

1 Introduction

Information technology is integral to people's life deeply, and will be evolving and expanding continuously. People who are unable to go to the hospital to see doctors could also enjoy healthcare with medical service at home by taking advantage of the technology. With remote monitoring devices and wireless sensor networks, doctors and carers can check the status of patients at any time, anywhere. Information technology has certainly advanced healthcare systems in the way that patient data is stored and retrieved. As a result, health information services on administration including paperwork and workload of health professionals have been largely reduced [2]. To patients, health information technology has also made significantly improved the quality of healthcare services with noticeable reduction of financial cost [21]. Information technology has assisted practitioners who provide healthcare service, as well the patients who enjoy the service. It has made significant impact on the healthcare sector.

Some information technology approaches are designed to help manage healthcare problems and to assist patients who suffer from chronic diseases or any serious illness such as stroke or heart attack [10]. Krey [14] argued that information technology in healthcare is better to be managed by government institutions. Governmental control may help achieve good performance results, deal with laws and regulations, improve personnel management for regulatory needs, and develop commercial applications. One of the developed approaches in the healthcare arena is wireless sensors, which is used in health monitoring and medical

care [20]. Sensor equipments are designed to capture vital motion of patients. After being stored in a data repository, the patient data will then be transferred to medical doctors or specialists for analysis and consultation. These sensors are small and economic; the technology is intelligent [28, 30]. With support by Information Technology, healthcare systems can also be effective in emergency situations [1, 3]. Applications have been developed from advanced techniques such as Blue-tooth Area Network, Personal Area Network, Local Area Network, Home Area Network, Mobile Area Network, and Wireless Area Network, etc. Clinicians have become more comfortable using health information technology applications and made medical decisions based on patient's health data stored in information systems [21].

This report has reviewed state-of-the-art applications used in telemedicine and the systems that are designed for telemedicine, such as smart home or remote monitoring using robots, smart phones, or wireless sensors that can be placed in the patient's home. Specifically, smart homes refer to those homes installed with wireless sensors to capture patients' vital signals. The sensors are capable of connecting to data repositories in order to send the data to physicians. The objective of smart homes is to bring the healthcare techniques into the patient's home environment (or anywhere the patient is at). Various techniques in telemedicine and telemonitoring will be reviewed in the report, including wireless sensors devices that attach to the patients' body or placed in the patients' living environment; applications installed in smart phones based on intelligent agent technology; intelligent robots. The report will also discuss the improvements that Information Technology has brought to the healthcare sector. The report will discuses about telemedicine first; how telemonitoring technology is applied to healthcare will be discussed follow-by. Finally, in conclusion a summary will be given and discuss the impact of Information Technology to healthcare.

2 Telemedicine in Healthcare

It is challenging to ensure the delivery of healthcare services to everyone who needs the service, especially people who live in remote and rural regions. Many research projects are ongoing, especially in developing countries such as Iran and Malaysia, with an aim to extend healthcare systems to rural areas away from modern cities. Many private organisations and governments have assisted in developing and implementing telemedicine systems [12]. In Malaysia, due to the large scale of rural areas, various healthcare services are delivered taking advantage of the Internet. One of them is called *Mass Customized Personalised Health Information and Education* (MSPHIE), a typical telehealth system. The MSPHIE provides high quality healthcare related information using multimedia, mass communications and Internet. Another project is called *Continuing Medical Education* (CME), an education program aiming to deliver high quality medical skills and knowledge to improve professional medical performance. The Lifetime Health Plan (LHP) is also a telehealth system, which is a network application based on a patient's historical health records to provide a person-

alised healthcare plan [12]. Another healthcare service is E-Farmaci. It allows people to communicate with the nearest pharmacies, to access the databases in order to research diseases and medicines. These information is available online with instructions such as the usage and side effect. Sepas, as an electronic health system developed in Iran, aims at promoting electronic healthcare quality management with assessment of whether the health resources are provided fairly to everyone [12]. Another project in Iran is the Ensejam, which aims to foster cooperation between the Health and Medical Education and Information Communication Technology. Other electronic healthcare projects in Iran include an equipment and medical facilities data bank, a food and drug data bank, and a medical information repository [12].

Telemedicine is a multidisciplinary exploration that uses advanced technology in the area of artificial intelligent, telecommunication and data analytic. Telemedicine and telemonitoring technology is not only used to help in emergency situations, but also with patients who have chronic diseases. When patients are unwell to travel but do need medical services, telemedicine provides great advantages to them. Some patients, especially the elderly, feel more comfortable to stay at home rather than hospital. Telemonitoring can then provide health services to them [23]. The telemedicine and telemonitoring systems can be used in rural areas where there is not much health care facilities. The systems work by capturing the patient's vital signs and sent the data to medical centre using a 3G/CDMA communication network in real-time. In addition, the multi-parameter monitor and transponder can be connected with the computer off-line at home. Data can then be sent to the medical centre via the Internet [23]. . Telemedicine and telemonitoring have many advantages including financial benefits because patients do not have to pay for the cost of transportation and hospitalization [11, 26].

Telemedicine is one of the fastest developing technologies applied to healthcare industry. It has charged a lot of attention from research community over the past years and been involved with many advanced technologies including data processing and artificial intelligence [18]. Telemedicine was first designed as a healthcare system to help aged people who suffer from physical disabilities and chronic diseases. Researches have shown that aged people felt more comfortable staying in home environment even if they required long-term healthcare [32]. Telemonitoring has provided an efficient and effective solution to problems faced in the healthcare field, such as crowded hospitals or clinics in developing countries. Telemedicine can include smart-home monitoring whereby special homes have sensor devices installed on the walls and in particular areas of the patient's living environment [17]. These sensors could attached to the floor to measure the motion and speed made by the aged patient and help prevent her/him from falling. Another type of sensor is a radio- frequency identification (RFID) that helps people in alzheimer or dementia. With special applications, smart phones can also be used to assist in capturing unusual sounds, for example, crying for help [17], or the users' movement from one place to another to detect wandering

of aged people at early stage [7, 24]. Li et al. [17] have pointed out important role played by telemedicine in healthcare industry:

- Smart systems that are designed to prevent risks associated with specific diseases (e.g. chronic illnesses).
- Develop and improve technologies that monitor and assist elderly and disabled people.
- Focus on how to manage emergency situations.

Telemedicine require many properties to support their applications and systems. The first property is the Internet network. Most of the healthcare systems are based on sent-and-receiving data between physicians and patients. Some of the home monitoring systems cannot run without Internet access [25]. For reliable, efficient data transmission, healthcare systems require strong, fast internet access. Sensor technology in healthcare systems also requires a Wireless Sensor Network (WSN) [11]. Many applications in the healthcare domain depend on Wireless Sensor Networks (WSN) [23]. This feature is a part of telemedicine and telemonitoring, and cannot be used without access to a network. Telemedicine and telemonitoring are commonly seen in developed countries and big cities. However, the people who live in developing countries and towns or remote areas cannot take advantage of this important feature. The reason for that is the network has not extended into these areas [33]. Mobile networks are also very important to telemedicine and telemonitoring. In a mobile network healthcare system, a sensor monitor device is attached to the patient's body and sends vital data to a smart phone. All such information about the patient's status will then be sent from the phone to the physician via the mobile network [26]. Such healthcare monitoring systems must also employ high level of security and privacy protection, as well as excellent capabilities for storing and retrieving data in a repository [11]. Network communication such as WSN and mobile network are essential to telemedicine and telemonitoring.

Robots are commonly used in modern healthcare systems in the past decades. Robots can provide the following features of patients' healthcare: the patient interview, physical assessment and diagnosis, treatment assessment, maintenance activities, consultation, education and training [27]. Robots have also played an important role in the hospitals and clinics and help reduce mistakes made by physicians, especially in highly insensitive operations such as thoracic, abdominal, pelvic and neurological surgeries [6]. The chances of success are increased in robotic surgeries, as they are free of surgeon's hand-shaking, concentration being affected by outside circumstances, or performance being affected by tension or stress [6]. Robot-assisted applications is also an ongoing research for using robots in healthcare, aiming at improving and maintaining the health of elderly people. Robot-assisted applications are working in two ways; (i) monitoring patients through image and sound sensors attached to the robot; (ii) understanding patients' social situations adopting face authentication technology [15]. Clearly, the security and privacy protection for the information gathered is extremely important in robot-assisted applications [15]. As pointed out by Briere et al. [4], robots in healthcare systems usually consist of four basic components: the movement,

sensing and navigation, teleoperation and remote running, and video meetings. The movement component helps the robot to move between places; the sensing and navigation component helps the robot move without collision with the furniture and other objects; the video meeting component is for communication between the patient and the physicians [4]. The use of robots requires a trained operator for remote control, which could require only minimum training, a good news [4]. For teleoperation and remote running systems, the operator has a special computer installed to handle the robot. The computer requires two screens. One for the medical information system when the operator is dealing with a patient who enters the clinical information. The other screen is a control interface used to give the operator the ability to control the robot [4]. Robot technology plays an important role in modern healthcare systems.

3 Telemonitoring in Healthcare

Telemonitoring systems connect two sites; home and the healthcare providers. The two parties communicate via a network infrastructure. On the home site, the structure of home telemonitoring could be divided into a physical and a conceptual layer. Due to different devices installed and protocols employed on the home site, the captured patient data may have not been well pre-processed, such as cleaning to prune noise data, or appropriately categorised for easy to understanding and analysis. Semantic technology such as ontology learning and mining may be employed by conceptual layer to help understand the conceptual meaning of data captured by physical layer, before telemonitoring systems transfer the patient data to the healthcare provider site [16]. On the healthcare provider site, data mining techniques have also been widely adopted to facilitate medical data analysis in three tasks: extracting relevant data from raw data; processing data for analysis; analysing data depending on the specific algorithm or a particular model [29]. Data mining techniques also help healthcare providers to deal with various data sources and formats.

Home-based healthcare systems work with two important components; the system itself and network construction. The systems have the following important goals for home-based healthcare [23]:

- Provides an electronic healthcare record for the patient conditions in the past and in the present time.
- Issues and alarm if there is anything wrong with the patient's vital signs or if one of his/her family member's see something is wrong.
- Sends a report, to include general information about the patient's health status, by SMS.
- Presents the patient's health status such as temperature and other vital signs to the medical experts to analyse and they can offer advice.
- Offers support service in emergency situations (first-aid).

Wireless sensors have been employed by many home-based healthcare systems to collect patient data in order to assist physician making decisions. They could also

issue an alarm when critical situation happens [22]. Context-aware Real-time Assistant (CARA) has a similar goal. It attempts to improve healthcare by using wireless remote monitoring techniques [31]. The CARA requires a number of components to work together: a wireless monitoring device, a home monitoring system, a remote clinical monitoring system and a healthcare reasoning system. Radio frequency identification (RFID) is one of the applications that assist healthcare. with recognizing people with identification badges. The RFID format includes readers that recognize the person with an identification badge [9]. Pervasive multi-sensor data fusion is another application that uses the wireless sensor to capture patient status for smart home healthcare monitoring [19]. Though the Internet, these systems send patients' data to physicians adopting the Simple Object Access Protocol (SOAP) web services using either *http* or *ftp* protocol. In addition, behavioural telemonitoring techniques capture any unusual behaviour that the patient is presenting. The monitoring process is achieved by passive infra-red sensors that are placed in the patient's living environment. [5].

Monitoring tasks can be achieved based on videos or sounds without devices being attached to the patient's body [18]. Voice activity detection driven acoustic event classification is a typical sample for patient monitoring in smart homes [8]. The system is developed to capture the patient's voice, analyse it for patient's medical condition, and make recommendations to physicians. The system works by using a Voice Activity Detection (VAD) scheme, which is designed with three levels. Patient signals are taken by the minimum level and analysed by the medium level. The final level is designed for emergency [8]. Differently, Smart-TV Based Integrated e-Health Monitoring System with Agent Technology has four influential parts: the patient area network (PAN); mobile medical support team area network (MMSTAN), distributed database; and physicians or the specialists [26]. The PAN has three components: a sensor installed on the patient's living environment, a device for exchanging data with another environmental sensor device. As a result, a MMSTAN team requires nurses, paramedics, technical staff and remote physicians [26]. A data repository is used to store the medical history of each patient as well as the consultation results given by physicians. The data repository is distributively accessed. Patients are able to access the system by using access account in classification. The design decreases the traffic in data transmission and maximises the reliability of the system. Usually, the specialist and medical consultants are stationary and need to communicate with patients remotely in order to provide constant recommendations and advice [26]. Thus, the distributed accessibility is specifically important when considering instant searches made by physicians in mobile medical support team (MMST) [26].

Patients' health record is everything in healthcare systems - they would make no sense if without consideration of patient data. The patients' health records are usually stored in a centralised repository, and distributively accessed from different healthcare facilities in order to maintain physicians' accessibility to the patient's historical health situations. Such a constant, easy accessibility helps physicians to make quality decisions. Undoubtedly, the patient's private information needs be secured in confidentiality against any improper use [13]. Many

techniques have been developed for data security and patient privacy protection. One important technique is MASPortal, which uses the Lightweight Directory Access Protocol (LDAP) for directory service and Grid Security Infrastructure (GSI) as the authentication mechanism and provides a multi-layer infrastructure for ratification and to control access to the data repository [13]. To secure the patient privacy, the Encryption and Authentication (SEA) protocol has been developed. SEA uses an elliptic curve cryptography algorithm to encrypt the data in databases when transmitting data via mobiles in a wireless network and provides a high level of privacy protection [7]. Healthcare providers need to highly prioritise the privacy protection for patient information.

4 Summary

This survey reports the recent research on the use of information technology in the healthcare field, specifically, telemedicine and telemonitoring. Information Technology has greatly improved the performance of healthcare with strong consideration of patients' interest, including comfort, safety, and privacy. Information Technology is applied to healthcare systems in various ways. The applications could be installed on smart phones or mobile devices and connected with wireless sensors placed in the patients' home environment. Intelligent robots are also used to assist surgeries and healthcare. Information and Communication Technology has made significant contributions to healthcare industry.

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