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Emerging information technologies for enhanced healthcare

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ABSTRACT

The appropriate collection and consumption of electronic health information about an individual patient or population is the bedrock of modern healthcare, where electronic medical records (EMR) serve as the main carrier. This paper first introduces the main goal of this special issue and gives a brief guideline. Then, the present situation of the adoption of EMRs is reviewed. After that, the emerging information technologies are presented which have a great impact on the healthcare provision. These include health sensing for medical data collection, medical data analysis and utilization for accurate detection and prediction. Next, cloud computing is discussed, as it may provide scalable and cost-effective delivery of healthcare services. Accordingly, the current state of academic research is documented on emerging information technologies for new paradigms of healthcare service. At last, conclusions are made.

1. Introduction

Healthcare covers complex processes of the diagnosis, treatment, and prevention of disease, injury, and other physical and mental impairments in humans. The patients' consumption of products and services provided by hospitals and other institutions forms the healthcare industry. The healthcare industry is especially fastest-growing part of the economy of many countries in modern society, not only the more economically developed countries like those in Western Europe and North America, but also in areas of high growth, such as China and India.

The proper collection, management and utilization of health information play a critical role in detecting medical problems [5] and identifying innovative solutions and allocating resources [1] to treat patients. Information technologies are widely employed to improve the quality of healthcare services [4]. In the evolution of those improvements emerging technologies are not only used anymore for the general management of health systems, such as those in used in hospitals and clinics, but they are also focused on development and implementation of other solutions, such as those for rehabilitation purposes and for prevention, e.g. using serious gaming. Moreover, technologies are not solely used anymore for therapeutic purposes, but analysis using big data and cloud computing can reveal trends and can be used predictive medicine. Additionally, the enormous increase of the number and capabilities of sensors and smart sensor systems vastly increases the possibilities of generation and usage of data. Existing methodologies for the detection and analysis of medical conditions can and will have to be revised and extended. In healthcare times are truly changing due to emerging information technologies.

The enhancements that emerging information technologies offer are not only really necessary, but could not have come at a better time also. The cost relating to the demographic changes of an ageing population in industrialized nations is expected to place a significant burden on healthcare systems and economies [99,100]. In the near future the number of retired people (with an increased life expectancy [103]) will approach the number of working people worldwide [104] and the shrinking workforce will probably not be able to sustain the current level of support to elderly.

This paper first surveys the emerging state-of-the-art information technologies for enhanced healthcare and tries to provide insight on how the developments in IT impact on healthcare

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practices. Finally, authors provide a reflection on this challenging field, in a broader context.

2. Emerging medical information technologies

Technology offers possibilities, but also poses challenges. Science is obliged to support this evolutionary process.

2.1. Trends

There are a number of significant technologies and emerging models that are making a big splash on the healthcare information technologies and applications [4–7]. The following trends can be observed:

- *Health sensing:* There's been a sharp incline in the quantity and variety of consumer devices and medical sensors that capture some aspect of physiological, cognitive and physical human health. The implementation of these technologies empowers the end-users (e.g. chronic patients) by providing means to monitor and record the status continually and, if the need arises, seek remote assistance.
- *Big data analysis in Healthcare:* With the increasing digitization of healthcare, a large amount of healthcare data has been accumulated and the size is increasing in an unprecedented rate. Discovering the deep knowledge and values from the big healthcare data is the key to deliver the best evidence-based, patient-centric, and accountable care.
- *Cloud computing in Healthcare:* With healthcare providers looking at solutions to lower the operating costs, emerging technologies such as cloud computing can provide an ideal platform to achieve highly efficient use of computing resources, simplify management, and improve services in a safe and secure manner. Cloud computing can support the analysis of the big data mentioned above. There is no doubt that the adoption of these innovative technologies in medical fields can create significant opportunities. Nevertheless, many challenges still need to be addressed in order to achieve truly enhanced healthcare services.

It is widely accepted that the high quality healthcare services lie in the effectiveness and efficiency of health problem detection, innovative solution identification, and medical resource allocation, which in turn depend heavily on the proper collection, management and utilization of health information. The aim of this survey is to document state-of-the-art researches and implementations of the emerging information technologies on creating new means to access and use health information and consequently improving the quality, safety, and efficiency of the health care.

Since electronic health records serve as the main carrier of the health information, Section 2.2 gives a brief review on the adoption of EMR (Electronic Medical Record) systems in different countries. The emerging technologies on health sensing, big data analysis, and cloud computing, show tremendous promise on enhanced health information collection, utilization, and management. In Sections 2.3 and 2.4 the current state of academic research and industry implementation on technologies for enhanced healthcare are presented, especially in health sensing and in big data analysis, and Section 2.5 analyses the use of cloud computing as underlying healthcare computing infrastructure. Finally, Section 2.6 summarizes new paradigms of healthcare services enabled by these technologies and makes recommendation for future research.

2.2. Electronic medical record

According to Health Information and Management System Society (HIMSS) Analytics [2] and ISO/TS 18308 standards [3], the medical records of a patient may refer to Electronic Medical Record, Electronic Health Record and Personal Health Record (PHR).

- *Electronic Medical Record* (EMR) is created and controlled by a healthcare institution, e.g. a hospital. It is the legal record of what happened to the patient across inpatient and outpatient environments in the institution.
- *Electronic Health Record* (EHR) is generated and maintained within an institution or community. It is a record in digital format and it is theoretically capable that it is shared across multiple institutions within a community, region, or state. EMR can serve as a data source for the EHR. Once the EMR data are shared with other institution, they become EHR.
- *Personal Health Record* (PHR) is typically a health record that is initiated and maintained by an individual. It provides a complete and accurate summary of the health and medical history of an individual by gathering data from many sources, including EMRs and EHRs.

Since EMRs are the sources of EHRs and EPRs, the adoption of EMRs serves as the foundation for the acceptance of the later two medical data formats. Without loss of generality, this paper mainly focusses on EMRs, the discussion of which can be generalized to EHRs and EPRs.

With the notion that EMRs are the main carrier of electronic health information and the bedrock of modern healthcare, EMR systems are widely deployed for the exchange of medical information among various healthcare related parties [8]. Using United States as the example, the survey in 2009 [9] has shown that only 9.1% of U.S. hospitals had deployed a basic or comprehensive EMR system. While by the end of 2011, according to the National Ambulatory Medical Care Electronic Health Record Survey, the percentage of primary care providers who have practiced EHRs doubled from 20% to 40% between 2009 and 2011. In 2010, the goal was set that by 2014, 80% of physicians should be using EHRs, however recent surveys show that 82% of physicians indicated that they are currently using an EMR system or plan to do so [8]. These numbers are significant because the first step towards widespread adoption of standards-based health IT is simply getting the systems in place and converting the data into an electronic format.

By using EMR as the carrier of medical information, emerging information technologies provide great potential for facilitating research and improving quality in medical practice [6]. This chapter focuses on three most prominent areas, i.e., health data collection, health data analysis and utilization, and healthcare computing infrastructure and subsequently analyses the impact of all of this on healthcare practice.

2.3. Health sensing

The fast development of embedded computing and sensing technologies has opened up new opportunities for pervasive and unobtrusive health data collection [10]. In general, the health sensing technologies [96–98] promise to achieve the real-time monitoring and recording of the patients' health status with high precision, which provide great potential to reduce the cost and inconvenience of patients' visits to the physician. They are considered as a cornerstone technology for the early abnormity detection and intervention and effective management of patients [11].

Based on the provided functionalities, there are mainly two primary types sensors for health data collection [10,96] physiological and motion sensors. The former are used to detect and record the physiological indices or physical states of patients for diagnosis or