Healthcare Data Analysis in the Internet of Things Era

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INTRODUCTION

Health care advances are taking place rapidly all over the world. The newest medical discoveries and higher quality of medical practice have guided to serious improvements in human health and well-being. Life expectancy has been considerably increasing, leading to an aging population with different needs and desires. Moreover, world population has been rising exponentially, challenging the effectiveness of healthcare systems. New tests, procedures, and medicines have made medical care increasingly expensive, forcing the restraint of costs even while overall effectiveness improves (Vasanth & Sbert, 2012). Nowadays, prevention and early detection of disease signs as well as quality of life are becoming the points of focus more than ever before. Furthermore, personalized medicine is deemed particularly important and promises better disease treatment for each individual. Patients are becoming better-informed, want to know more about their health and their treatment, and demand to be involved in decision-making regarding their health.

All the aforementioned trends and changes have revealed the necessity to adopt a different model of health care. The modern healthcare delivery system should be more patient-centric, rather than career-centric, in order to deal effectively with the new challenges. Such a healthcare system should be organized in a layered structure (Pang, 2013) as shown in Figure 1. For example, the lower layer should comprise the single person and the higher one the hospital. Between these two terminal layers one can find the home and community layers. The lowest layer (person) is characterized by the lowest labor intensity and operational cost, as well as the highest frequency of usage for chronic disease and lowest frequency of usage for acute disease. In contrast, the highest layer (hospital) has the highest labor intensity and operational cost, as well as the highest frequency of usage for acute disease and lowest for chronic disease.

The delivery model of health care is now standing at the starting point of its way to transform from the traditional hospital-centric to the modern home-centric/person-centric approach. The Internet of Things with its pervasive, personalized, and ubiquitous character can guide health care through this way. Many relevant concepts have been introduced to describe the future healthcare model powered by emerging information and communication technologies. Various terms, such as connected health, health Internet of Things (Health-IoT), pervasive healthcare (pHelath), ubiquitous healthcare (uHealth), mobile healthcare (mHealth), electrical healthcare (eHealth), telehealth, telemedicine, etc., have been utilized in order to express the plethora of these new concepts (Pang, 2013; Pawar et al., 2012; Rose et al., 2015). All these new concepts include, more or less, the fundamental aspects of the home-centric/person-centric healthcare model.

This article presents the concept of the Internet of Things as applied in health care discussing the benefits and opportunities as well as the posed obstacles and challenges. The article focuses on the basic strategies for analyzing healthcare data generated by the Internet of Things enabled devices and describes the current status, the major challenges, and the future trends of this revolutionary field.

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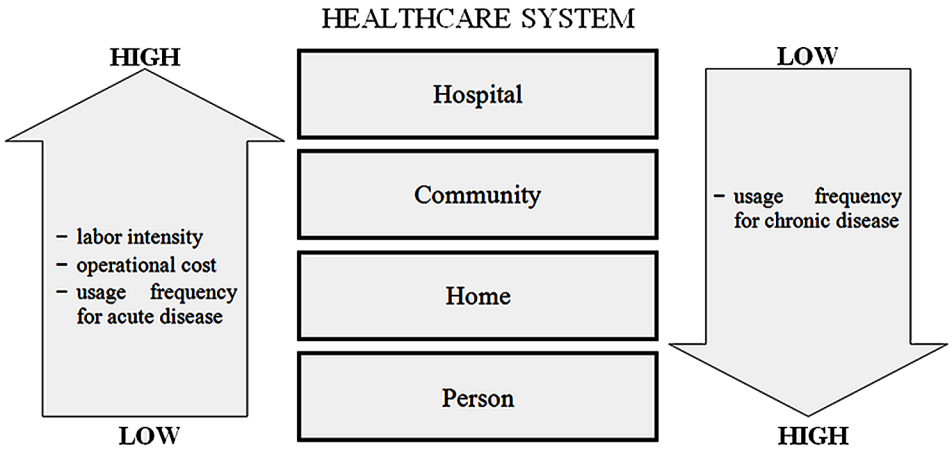
Figure 1. The layered structure of a modern healthcare system



BACKGROUND

According to the definition provided by the telecommunication standardization sector of the International Telecommunication Union (ITU-T Recommendations, 2012), the Internet of Things (IoT) is "a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies". With regard to the IoT, the term "thing" is defined as "an object of the physical world (physical thing) or the information world (virtual thing), which is capable of being identified and integrated into communication networks". Exploiting various capabilities, concerning identification, data capture, processing, communication, etc., the IoT uses any "thing" to offer any service to any application domain. At the same time IoT has to abide by the requirements for security and privacy (ITU-T Recommendations, 2012).

Undoubtedly the IoT is the future of technology, with societal implications as well, that can make everyday life more efficient. The IoT can be recognized as the second digital revolution (The Government Office for Science, 2014), given that the first one was the World Wide Web, which connected people around the world establishing a global community. The IoT is built on the basis of the World Wide Web extending its benefits and opportunities, but poses new big challenges. It is expected to greatly integrate leading technologies, such as technologies related to advanced machine-to-machine communication, autonomic networking, data mining and decision-making, security and privacy protection, as well as cloud computing, with technologies for advanced sensing and actuation. As shown in Figure 2, the IoT adds the dimension "any thing communication" to information and communication technologies (ICTs), which already provide "any time" and "any place" communication.

Among the plethora of application domains that can benefit by the utilization of the IoT, health care is one of the most important. Figure 3 presents the most popular IoT applications according to the study of IoT Analytics for Q3/2016. The popularity ranking of the IoT applications was based on 640 actual enterprise IoT projects not including any consumer IoT projects such as wearable devices, smart home or hobby projects.

Vilamovska et al. (2009) have classified IoT applications, in particular RFID applications, in healthcare across two axes:

- **IoT Enabling Functions:** These are four key and mutually exclusive functions concerning assets, staff and patients.
  - Tracking.