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A survey on health monitoring systems for health smart homes

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ABSTRACT

Aging population ratios are rising significantly. Health monitoring systems (HMS) in smart environments have evolved rapidly to become a viable alternative to traditional healthcare solutions. The aim of HMS is to not only reduce costs but to also provide timely e-health services to individuals wishing to maintain their independence. In this way, elderly people can avoid, for as long as possible, any interaction with healthcare institutions (e.g. nursing homes and hospitals), which in turn reduces pressure on the health system. To fully realise this vision of seamless e-health services supporting people in need of them, a number of challenges that need further investigation still exist. To this end, we provide an overview of the current state of the art for smart health monitoring systems. We review HMS in smart environments from a general perspective and with a particular focus on systems for the elderly and dependent people. We look at the challenges for these systems from the perspective of developing the technology itself, system requirements, system design and modelling. We present a consolidated picture of the most important functions and services offered by HMS for monitoring and detecting human behaviour including its concepts, approaches, and processing techniques. Moreover, we provide an extensive, in-depth analysis and evaluation of the existing research findings in the area of e-health systems. Finally, we present challenges and open issues facing the smart HMS field and we make recommendations on how to improve future systems.

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1. Introduction

Population aging is happening faster than ever before. According the United Nations Population Fund (UNFPA) (UNFPA, 2012), the global number of people aged 60 or older will rise to 2 billion by 2050. Added to this, a report issued by the World Health Organization (WHO) stated that there was a shortage of about 7.2 million healthcare workers in 2013, and this is estimated to reach 12.9 million by 2035 (Global Health Workforce Alliance and World Health Organization, 2013). Currently, a significant proportion of the elderly population suffers from an age-related health issue such as Alzheimer's disease, dementia, diabetes, cardiovascular disease, osteoarthritis or other chronic diseases. These common diseases, coupled with the naturally occurring progressive decline in physical and cognitive skills of elderly people prevent many from living independently, in their own homes. Recent advances in communications and computing technologies, along with advances in ambient intelligent technologies, such as sensors, have resulted in a rapid emergence of smart environments. One such example is the so-called *Health Smart Home* (HSH). HSHs are smart environments where a context-aware health monitoring system is set up. They have attracted considerable interest in recent years. HSH emerged as a promising solution to the challenge of an increasing aging population. They have the potential to provide e-health services to meet the needs of this growing population. In particular, HSH systems monitor and evaluate any health condition that the elderly subject may have, as well as monitoring how they carry out their daily activities. These systems not only allow the elderly to live independently for longer but they also have the potential to make healthcare services more sustainable by reducing the pressure placed on the overall health system by the elderly and dependent individuals.

To achieve a truly health smart home, a number of challenges still exist in many aspects of the development procedure. Such challenges include the remote monitoring of the environment (data acquisition about the subject, their environment, etc.), the communication technology needed for the environment (reliability of data transmission in real-time), the existence of intelligent processing systems (analysis, making relevant decisions, etc.) and the provision of context-aware services. Consequently, to meet these challenges, further research is required to improve the design of efficient health monitoring systems for HSH.

In order for health monitoring systems (HMS) to proactively help individuals in terms of required assistance and services, it needs full access to a set of contextual information. The success of these systems lie in the ability to collect and process data to understanding a subject's surroundings, so that contextual services can be delivered to them. What we mean by contextual services in the field of healthcare is a set of continuous processes that automatically acquire a subject's information (e.g. behavioural, physiological, and environmental), and as a result of this acquisition, are able to provide and adapt the services accordingly. The context and surroundings of the elderly cannot be easily confined to a simple level of data acquisition from sensors but, instead, should be enriched by data that has been integrated and inferred from the environment, using several approaches and techniques, to enrich existing knowledge about the subject. Context-awareness facilitates a better understanding of the health conditions of the subject being monitored, by identifying behaviour patterns and making more precise inferences about the subject's situation and their environment. Numerous survey studies such as (Alam et al., 2012; Baig and Gholamhosseini, 2013; Chen et al., 2011; Peetoom et al., 2015; Rashidi and Mihailidis, 2013; Reeder et al., 2013) have been carried out in the literature. These studies have mainly focused on smart home perspectives (Alam et al., 2012), health smart homes with limited information about design issues and challenges (Baig and Gholamhosseini, 2013), wearable sensor-based systems for health monitoring (Chen et al., 2011), and health informatics and healthcare applications for the elderly from various perspectives (Peetoom et al., 2015; Rashidi and Mihailidis, 2013; Reeder et al., 2013).

In this review paper, we present a comprehensive study of context-aware computing in healthcare for the elderly. Our objective is to highlight the current technologies, as well as the

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