Smart Medical Services: A Discussion of State-of-The-Art Approaches

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***Abstract*—This paper presents a discussion of current developments in the field of smart medical services. Smart medical services are often cited as a promising solution to support elderly or disabled people. By providing a wide variety of services, they bear an immense potential for revolutionizing the way health services are provided in the future. In general, smart medical services can be clustered into three categories focusing on the detection and prevention of emergency situations, long-term treatment of chronic diseases, and the prevention and early-detection of illnesses. This paper provides an overview over the different types of applications and describes several research demonstrators and prototype systems for each category.**

***Index Terms*—Smart medical services, ambient assisted living, E-health, intelligent environments, ubiquitous and pervasive computing.**

I. Introduction

An ongoing demographic change is observable in most industrialized countries and often cited as one of the major challenges for the coming generations. The World Health Organization [70] expects a total of about 1.2 billion people to be over the age of 60 in 2025. Similar studies performed by the United Nations estimate nearly 2 billion people (22% of the world population) to be 60 and older by 2050 [41]. In the same time span, the number of people being 85 years or older is expected to increase at least six-fold [69].

Already today, about 15% of the European population reports difficulties in performing daily activities due to some form of disability [60] and the prevalence of chronic diseases is expected to further increase in an aging society. For the next 10 to 15 years, it is expected that the number of patients suffering form diabetes to increase by 40 % and those suffering from cardiovascular diseases by even 50% [29]. Consequently, more and more elderly people are expected to require personal care in the coming years. And the need for assistance does not only arise due to the prevalence of chronic medical conditions, but also due to the declining physical abilities of older people. Decreased mobility makes carrying out daily tasks both at home and outsides more and more difficult, if not impossible, which makes third-party's assistance unavoidable in many cases.

In this context, smart medical services a promising solution to take care of the elderly or disabled people and undoubtedly bear an immense potential to revolutionize the way health services are provided in the future. By providing a wide variety of services, including assistance to carry out daily activities, health and activity monitoring, enhancing safety and security, getting access to social, medical and emergency systems, and facilitating social contacts, smart healthcare applications are expected to bring medical, social and economical benefits to different stakeholders.

State-of-the-art systems can be clustered into three categories focusing on (1) the detection and prevention of emergency situations, (2) long-term treatment of chronic diseases, and (3) the prevention and early-detection of illnesses. The following sections provide an overview over the different types of applications and describe several research demonstrators and prototype systems for each category.

II. Detection and Prevention of Emergencies

Most existing systems for the detection and prevention of emergencies focus on falls and congestive heart failures as their main application areas. Recent statistics show that over 30% of the people over 65 years and about 50% of the people over 80 years fall at least once a year [53]. In 20% to 30% of the cases, people suffer serious injuries with sustaining effects on mobility and independence [16][45]. As many of these falls happen, when people are alone at home, several companies started to develop mobile emergency systems, which should enable users to call for help in an emergency situation. Commercial products, usually in form of mobile devices worn either at the hip or around the wrist, are available from companies as Tunstall, International Security Technology or Vitaris (for a detailed description of devices see [45]). While this seems to be a promising approach at first sight, empirical evidence shows, that patients often do not carry those devices with them or are simply not able to operate them when medical problems have occurred [65]. As a consequence, people lie on the floor for hours, sometimes even days, with lethal outcomes not being unusual. In order to overcome the short-comings of mobile emergency transmitters, several research projects developed prototypes of pressure sensitive floor elements. One of the first systems was the Active Floor developed by Addlesee et al. [1], which allows the detection of time varying spatial weight distribution. The Smart Floor, a similar system developed by Orr and Abowd [55], also allows the identification of people based on their footstep force profiles. While the previous systems distributed pressure sensitive floor tiles at specific locations, more recent projects developed large-scale installations covering an entire room and thereby enable fine-grained location detection [37].

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Another promising application domain is the monitoring of patients with congestive heart failures (CHF). Recent studies estimate the number of patients suffering from heart insufficiency to be approximately 1.8 million in Germany [22] and around 10 million in Europe [31] and these numbers are constantly rising. In Germany only, the number of CHF patients is expected to increase by 200-300.000 people per year. Remote monitoring of significant bio-signals is often cited as a promising approach for optimizing medication and identifying critical or unstable patients. Within the last decade several projects started to develop smart monitoring applications with the goal of increase the safety and well-being of patients with chronic heart insufficiencies (see, e.g., [36], [62], [74] or [75]).

III. Long-Term Treatment of Chronic Diseases

Long-term treatment of chronic conditions using smart medical devices does not only increase the quality of life for patients, it is also expected to bring significant economical benefits compared to traditional care concepts. Hence, it is not surprising, that a broad variety of smart homecare services have been developed for various kinds of chronic diseases. The majority of research prototypes is concentrating on assistive services for patients with diabetes, pulmonary diseases, memory loss or physical impairments.

For example, Riva et al. [61] developed one of the first remote monitoring devices for managing insulin-dependent diabetes. By providing a set of automated services for data collection, transmission, analysis, and decision support, the internet-based system supported most routine activities of physicians and diabetes patients [18]. A similar web-based system for delivering daily care to diabetic patients was developed by Baker et al. [3].

Morlion et al. [49] developed a remote monitoring system for directly transmitting spirometry data from the patients' home to a hospital. An evaluation of the system demonstrated that home monitoring of pulmonary function in lung transplant recipients is feasible and accurate [18].

As stated earlier, most western countries are experiencing a considerable increase in the number of people suffering from dementia and this number is expected to rise further in the coming decades [19]. A variety of IT projects (e.g., [50] or [57]) have been addressing this problem over the last years and provide different solutions for personalized memory support.

Assistive devices for supporting people with physical impairments, like wheelchairs or walking-aids, are used by patients for many generations. But it was only within the last couple of years that researchers from both industry and academia started to enhance these mechanical devices with computer and sensor technology. For example, the Intelligent WheelChair developed by Kuno et al. [40] captures intentional and near unintentional user behaviors (e.g., face direction) in order to control the direction of travel. ROLLAND is another computer-controlled wheelchair, which uses rotating laser scanners to detect obstacles in its environments and automatically navigates around them (see [39] or [47]). Similar systems were developed by Kim et al. [35], Bourhis et al. [4], Lankenau and Röfer [42] or Yanco [73]. For supporting people who are still able to walk on their own, Krieg-Brückner et al. [38] developed an walking aid called IntelligentWalker, which is equipped with an electronic motor and laser scanners for proving computer-supported walking assistance.

IV. Prevention and Early-Detection of Illnesses

Providing intelligent services for the prevention and early-detection of illnesses requires up-to-date information about the patients' physiological states and activities. Smart monitoring systems usually focus on one of the two domains: capturing of activity data within home environments or monitoring of vital parameters.

Home monitoring systems using video are often perceived as being rather intrusive as there is a high chance of violating individual privacy at home. Hence, a variety of projects explored alternative approaches for activity monitoring in home environments. For example, Fogarty et al. [24] use a system of low-cost-sensors for capturing data about water consumption and employ the extracted usage patterns to infer activities in the home. Chen et al. [8][9] developed an automated activity monitoring system based on acoustics, which recognizes and classifies different activities occurring within a bathroom based on sound. Using strain sensors under the floor, Rowan and Mynatt [63] are able to detect persons based on their weight, allowing them to capture their movement around the home. Wilson [71] developed a method for automatic low-cost monitoring based on binary sensors for tracking and activity recognition within defined environments. Based on sensor data about movement, appliances usage, and presence Ogawa et al. [54] were able to extract reliable information determining behavior patterns of users in a home environment. Another low-cost solution was presented by Nambu et al. [52], who identified and analyzed behavioral user patterns based on television usage. Other sensor-based systems for monitoring activities of daily life include approaches by Consolvo et al. [12], Mynatt et al. [50], Philipose et al. [58] or Rowan and Mynatt [63].

Other approaches in this category include wearable non-invasive diagnostic tools, which are capable of analyzing human sweat, tears, stress, strain, or pH increases [18]. For example, Anliker et al. [2] developed a medical monitoring and alert system in form of a wrist device, which continuously monitors physiological parameters such as ECG, heart rate, blood pressure, and skin temperature. A number of similar ECG monitoring systems have been developed by Lorincz et al. [44], Fensli et al. [21], Shih et al. [67], Lo et al. [43], and Proulx et al. [59].

Once patient data are collected and a baseline established, anomalies and sudden deviations in the behavioral patterns can be analyzed [14]. A number of authors, including Cook et al. [13], Luhr [46] or Moncrieff [48], have developed algorithms for identifying behavioral trends and abnormal activities in home environments. Prototypes of early-detection systems have been developed for different illnesses and application domains. For example, Intille et al. [34] developed a wearable monitoring system for detecting congestive heart failures. The system uses context-sensitive questioning to ask patients simple questions about their current health condition and provides the feedback to a remote diagnosis system. The Home Asthma Telemonitoring system was developed for detecting allergies and preventing asthma attacks through timely interventions [22]. The system supports patients in their daily care activities through personalized interventions and immediately alerts health providers if patients require medical assistance [18].

Another application field is the monitoring of patients with Multiples Scleroses (MS). Predicting the course of the disease is very hard, as signs and symptoms vary from patients to patient [11] [26]. While there is no known cure for MS yet, it is possible to slow down its progression and alleviate the symptoms [72]. By monitoring the movement patterns of patients, it is possible to diagnose MS in an early stage and provide personalized therapeutical and medical assistance [64]. Besides the detection of physical decline, movement patterns can also be used to identify cognitive impairments [14][17]. For example, Chan et al. [7] use an array of low-cost motion sensors for identifying abnormal behavior patterns for patients with Alzheimer's disease. In a similar approach, Carter and Rosen [6] use information about the efficient completion of kitchen tasks in order to assess the cognitive ability of individuals.

Long-term studies (see, e.g., [20]) show that positive changes in patients' lifestyles, like regular physical activities or healthier diets, can significantly increase their life expectancy and quality of life [30]. Hence, a number of authors, like Cowan and Turner-Smith [15], argue technology should be used for encouraging a healthy lifestyle rather than compensating for the results of an unhealthy one.

In this context, Persuasive Technologies could play a mayor role. Generally, Pervasive Technologies aim at motivating behavior changes by providing well-timed information to users at points of decision, behavior, or consequence [25]. Studies in other fields (see, e.g., [5], [27], [28] or [66]) have shown that context-sensitive information presentation can positively influence human behavior. Although there are some limitations to this approach, exploiting emerging consumer electronic devices to motivate healthy behavior as people age by presenting "just-in-time" information seems to be promising way to go [34]. First systems using persuasive technologies in the medical sector exist for a couple of years. For example, Intille et al. [32] developed a prototype system for encouraging incremental, dietary behavior change.

But long-term homecare will only be successful if patients are actively involved in the process. While homecare technologies can monitor a wide range of behavioural and biomedical parameters, an important aspect of patient self-management is medication adherence. In order to support patients, several projects developed personalized and context-sensitive systems for medication monitoring (see, e.g., [10], [56] or [68]).

V. Conclusion

Over the last 10 to 15 years, research in the field of technology-supported personal care gained considerable momentum. This paper provided an overview over ongoing research activities in this field and presented applications and prototypes focusing on different aspects of medical services. While the illustrated systems successfully demonstrate the technical capabilities of computer- supported healthcare solutions further research is necessary in order to turn existing prototypes into usable products. This requires balancing the technical requirements and financial constraints with the needs and wants of potential end users. Especially the analysis of user needs represents a big challenge, as potential users of smart medical services will be very different from the typical computer users of the last decades. In order to successfully address these challenges new holistic evaluation and design concepts as well as truly interdisciplinary development approaches will become necessary.

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