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Review

Smart homes — Current features and future perspectives

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ABSTRACT

In an ageing world, maintaining good health and independence for as long as possible is essential. Instead of hospitalization or institutionalization, the elderly and disabled can be assisted in their own environment 24 h a day with numerous 'smart' devices. The concept of the smart home is a promising and cost-effective way of improving home care for the elderly and the disabled in a non-obtrusive way, allowing greater independence, maintaining good health and preventing social isolation. Smart homes are equipped with sensors, actuators, and/or biomedical monitors. The devices operate in a network connected to a remote centre for data collection and processing. The remote centre diagnoses the ongoing situation and initiates assistance procedures as required. The technology can be extended to wearable and *in vivo* implantable devices to monitor people 24 h a day both inside and outside the house. This review describes a selection of projects in developed countries on smart homes examining the various technologies available. Advantages and disadvantages, as well as the impact on modern society, are discussed. Finally, future perspectives on smart homes as part of a home-based health care network are presented.

Contents

1. Introduction

The UN Department of Economic and Social Affairs Population Division [1] predicts that, worldwide, life expectancy is expected to increase from the range of 46–89 years to 66–93 years in the 21st century. Between 2100 and 2300 the proportion of the world population in the 65 or over age group (the retirement age in most countries) is estimated to increase by 24% to 32%, and the 80 or over age group will double from 8.5% to 17%. Concurrently, the UN predicts a worldwide decline in the number of children and in total fertility; there will be more elderly people than children, particularly in Europe. Consequently, the ratio 15-year-olds to 65-year-olds is estimated to drop from the current 9:1 to 4:1 in 2050.

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Thus support from young individuals working in home and health care for the elderly will decrease drastically.

Industrialized countries are therefore facing the following issues:

- Diseases and disabilities are growing: the US Alzheimer Association calculated a growth of annual cost caused by Alzheimer disease from $ 33 billion in 1998 to $ 61 billion in 2002 [2].
- Health care demands and costs are skyrocketing: in 2002, the US and Germany spent about 13% of their national income on health care [3]; in the US this represented the largest segment of public spending [4].
- Demand for telehomecare to avoid long-term hospitalization or nursing home care is increasing [5]. Considerable research has been conducted in medical informatics and related fields to develop suitable technologies to support this shift in health care [6].
- Health care requires increased efficiency as the number of support workers falls [7].
- Rapid advances in electronics, information and communication technology (ICT), leading to miniaturization and improvement of performance of computers, sensors and networking technology, combined with active research and development of smart fabrics, new textiles, intelligent paper, power supplies, wearable devices, digital imaging, etc., will allow people to be cared for at home and will revolutionize the practice of medicine by enabling remote interactions between clinicians and patients.

This review describes a selection of projects in developed countries on smart homes, examining the various technologies available. Advantages and disadvantages, as well as the impact on modern society, are discussed. Finally, future perspectives of smart homes as part of a home-based health care network are presented.

2. Materials and methods

As the technology is still evolving, there is neither an appropriate definition of a ‘smart home’ nor an exact distinction from similar systems or terms used in relation to ‘smart homes’, such as ‘assistive technology’ or ‘telemedicine’ or ‘e-health’ or ‘telehealth’ or ‘gerontechnology’. The terms may be used interchangeably. This often leads system developers to describe their systems inaccurately as part of ‘e-health’ or ‘telehomecare’ sub-systems or simply not use any of these terms. Therefore for this literature review, a set of selection criteria had to be developed to identify papers in which systems or devices used in smart homes are covered. The selection criteria were defined to include a wide range of different systems and devices. They were also designed to search in wider areas such as ‘e-health’, ‘telehealth’, ‘telemedicine’ or ‘telehomecare’, etc.

2.1. Inclusion criteria for systems

1. Systems which feature:
   - Wearable, portable, or implantable devices,
   - Mobile or stationary devices, such as sensors, actuators or other ICT components embedded in the structural fabric of the smart homes or everyday objects such as furniture, etc.
2. Systems which had components with ‘intelligence’ in the sense of context awareness [8] or decision support properties.
3. Systems that perform data transmission or processing without human intervention.

2.2. Inclusion criteria for studies

Projects, prototypes, test beds, pilot studies, and case studies conducted in laboratories, health care settings, or systems involving end users as well as systems in routine use were included.

2.3. Search methods

This literature review includes published work that has undergone peer review. Our search was restricted to articles in journals, chapters of periodicals and proceedings of conferences written in English and published between 1994 and 2009. Some Websites describing prototypes, projects and systems or devices were included. Keyword searches were conducted in PubMed, IEEE Xplore or using the Google search engine. The keywords used were: ‘smart home’, ‘telehomecare’, ‘e-health’, ‘telehealth’, ‘telemonitoring’, ‘telemedicine’, ‘assistive technology’, ‘wearable device’, ‘implantable device’, ‘cost’, ‘user satisfaction’, ‘ethics’, ‘laws’, ‘socio-economic impact’ and ‘intrusiveness’. These keywords were used alone or in combination.

3. Smart homes: Current features

The term ‘smart home’ is used for a residence equipped with technology that allows monitoring of its inhabitants and/or encourages independence and the maintenance of good health. In this paper, the term does not include reference to facilities designed to automate and optimize control of the home environment such as air conditioning and washing machines. The purpose of this section is to examine the technologies used to help people to overcome dependence and health problems.

3.1. Smart homes

As different people have varying needs, the provision of assistance must be tailored to each individual. Much research has been undertaken throughout the world in this area.

In the USA, the Georgia Institute of Technology has developed an ‘Aware Home’, based on ubiquitous computing that senses and recognizes potential crises, to assist declining elderly memory and find behavioral trends [9]. The University of Florida has developed Gator Tech Smart House for the elderly and the disabled. It is based on environmental sensors for comfort and energy efficiency, safety and security, activity/mobility monitoring, reminder/prompting technologies, fall detection systems, smart devices and appliances (smart phone, smart mail box, etc.), social distant dining with family members, and biometric technologies for physiological monitoring (weight, temperature) [10]. PlaceLab is a part of House_n project of MIT or ‘the house of the future’. It monitors the activity and vital signs of the residents, controls energy expenditure’, and provides entertainment, learning, and communication using ubiquitous sensors and wearable systems [11].

Many systems have been developed in Europe. In the UK, an assisted interactive dwelling house has been developed for the frail elderly and the disabled. A sensor system assesses vital signs and activity, and provides security monitoring and response. It includes environmental control technologies (doors, windows, and curtains) [12]. The University of Ostrava in the Czech Republic has developed a smart apartment to study individual activities with infrared (IR) sensors [13]. In France, the PROSAFE project in Toulouse aims to support autonomous living, and to sound alarms in emergencies. Infrared sensors embedded in the ceiling of the flat allow the assessment of mobility and activity [14]. In Grenoble, the HIS project is an apartment with IR sensors for activity assessment. Weight and vital sign sensors are connected via a CAN network for data processing, and an alarm is transmitted in emergencies [15]. In 1994, in Eindhoven, a model house was built according to the Dutch Senior Citizens Label requirements. In 1995, several model houses were built in the Netherlands. They are equipped with monitoring and assistive technologies. The aim is to use information technology (IT) to facilitate communication between the elderly and their caregivers [16].

In Japan, several projects aim to maximize the use of assistive technology, enabling the elderly to live autonomously at home by creating a smart and comfortable environment. The Japanese Ministry of International Trade and Industry built 13 'Welfare Techno-Houses' (WTH). The researchers collect data on residents' activity and vital signs by equipping the rooms with IR sensors, the doors with magnetic switches, and the bathroom with fully automated biomedical devices [17]. In Osaka, Matsuoka has developed a smart house that automatically detects unusual events caused by disease or accident through its 167 sensors [18]. Seventeen electrical appliances are also fitted with sensors (rice cooker, air conditioning, refrigerator, TV set, etc.). Each sensor is associated with one or more activities: working in an area, having a meal, having a wash, preparing a meal, etc. Matsuoka uses mathematical models to translate raw data into behavioral data. These models allow the detection of unusual situations [18]. The Ubiquitous Home project serves as a test facility for setting up useful services connecting devices, sensors, and appliances through data networks. The sensor system monitors human activities [19]. Each room has enough cameras to identify and follow the user, and microphones to collect complete audiovisual data. Pressure sensors in the floor track the residents' movement and locate furniture. Two radio-frequency identification (RFID) systems (one active and one passive) are used to identify the residents. A visible robot serves as an intermediary between the residents and the unconscious robot (i.e., the house). It may help with activities such as getting out of bed. The aim of the Ubiquitous Home is to help the residents to take advantage of user-adaptation technologies [19].

3.2. Wearable, implantable and microcapsule devices

Wearable, implantable, and microsystems that can be swallowed such as microcapsule devices are now available. These devices are worn by the user or embedded in the house, and connected through wired or wireless networks to a service centre with environmental and diagnostic facilities. These devices can assess sounds, images, body motion, and ambient parameters (light, temperature, humidity, etc.), vital signs (blood pressure, respiration, body temperature, heart/pulse rate, body/weight/fat, blood oxygenation, ECG, etc.), sleep patterns and other health parameters, daily activities, and social interactions. The software elaborates a personalized profile of the user's physical and physiological patterns from the collected motor activity and health data, to detect emergency situations. These devices could help in the care of elderly people and in the management of chronic medical conditions such as heart disease, diabetes or pulmonary disease.

An example of a wearable device is 'memory glasses'. Here, a tiny computer display clipped onto eyeglass frames and wired to a lightweight computer embedded in clothing can flash reminders to the wearer to put on glasses. The system aims to be 'context aware', using a global positioning system and sensors to know where users are, and cueing them only when information is needed [20].

In the US, several projects feature a garment with electronic sensors, conductive elements and optical fibers: SmartShirt [21], Sensewear Armband (Body Media Inc.) [22] and LifeShirt (Vivometrics) [23]. SmartShirt measures heart rhythm and respiration using a three-lead ECG shirt. SenseWear is a wearable device for physiological sign measurement. It is composed of polyurethane with an accelerometer, a thermal conductivity sensor, a skin- and ambient-temperature sensor and a skin electrical-conductivity sensor. It can be connected to a wireless heart-rate sensor. LifeShirt is a miniaturized, ambulatory version of respiratory inductance plethysmography. The garment is a machine-washable, lightweight, form-fitting shirt with embedded sensors to measure respiration. A modified limb two-lead ECG measures cardiac performance and a three-axis accelerometer quantifies posture and activity.

Several projects involving the use wearable devices are under way in other countries. LifeMinder, a 'wearable health care assistant', has been developed in Japan [24]. An individual tracking and activity measuring system has been developed in Korea and Japan. It consists of a PDA, a biaxial accelerometer, a digital compass sensor, an angular velocity sensor and miscellaneous electrical parts. The system is used to locate the subject using a nearest-neighbor method [25]. In Europe, the Wealthy project is based on a textile wearable interface integrating sensors, electrodes, and connections in fabric, signal processing techniques and telecommunication systems. The system aims to acquire simultaneous biomedical signals (electrocardiogram, respiration, activity) [26]. The Amon consortium in the European Union has developed a wearable monitoring and alert system targeting high-risk cardiac/respiratory patients. It is an unobtrusive and wrist-worn system measuring blood pressure and SpO2 (blood oxygen saturation) and performing ECG [27].

An implantable glucose sensor for diabetics has been created based on the 'enzyme electrode' principle. The sensor gives the glucose concentration [28]. An *in vivo* drug delivery system has been developed in the University of Waseda, Tokyo. It is based on an endoradiosonde (a microelectronic device introduced into the body to record physiological data not otherwise obtainable) or radio pill. A small transmitter is swallowed to monitor digestive tract parameters such as pressure, temperature, and pH. The system is composed of a controller, a radio frequency (RF) power transmitter, and a receiver [29]. In China, a micromachined capsule has been developed to remotely control gastrointestinal drug delivery and fluid sampling. The system can be connected to a computer through a serial port (RS-232) [30].

3.3. Assistive technologies

Products or systems in assistive technologies designed to help the elderly or the disabled range from the simplest (e.g. a can-opener designed for persons with limited grip strength) to the most technologically sophisticated (e.g. an electrically powered wheelchair with obstacle avoidance). More recently, robots have been developed in assisted-living environments for elderly people. They can support basic activities (getting dressed, bathing, toileting, eating) and mobility, providing household maintenance, monitoring of those who need continuous care and maintaining safety. They can be designed with consideration of social, aesthetic, and emotional factors to support the quality of life of the elderly. They must be attractive, affordable and non-stigmatizing [31]. Some assistive systems are already widely available: electrically powered wheelchairs, stair lifts and through-floor lifts. Environmental control systems allow elderly people to live in more comfortable conditions [32]. Assistive technologies provide several ways to assist elderly or disabled people:

- Providing assurance [9–14] that the elderly person is safe, performing activities, and not alerting a caregiver,
- Enhancing impaired physical functions [33,34], assisting in the performance of daily activities,
- Assessing elderly cognitive status. Wired Independence Square is a project in which sensors are embedded in the kitchen and used to collect data while a subject at risk of cognitive impairment performs a task such as making tea [35].

The US Nursebot (an autonomous mobile robot project) aims to interact with the world through speech, visual displays, facial expressions and physical motions, to track people, to predict their behavior, and react appropriately. The goal is to assist nurses and to improve quality of life for the elderly in their daily activities [36]. The Chiba University researchers, in Japan, have developed airbags to assist in case of falls [37].

3.4. Smart homes: Users

Users who can benefit from "smart home" new technologies are:

- People living alone who are unable to seek help in emergencies (unconsciousness, falls, strokes, myocardial infarction, etc.).
- Elderly or disabled people who suffer from cognitive (Alzheimer disease, dementia, etc.) and/or physical (visual, hearing, mobility, speech, etc.) impairment.
- People who need help in daily life to perform personal care activities (eating, toileting, getting dressed, bathing, etc.) and instrumental activities (cooking healthy meals, dealing with medication, and doing laundry) [38].
- Informal (family, friends, neighbor people) or formal (care provider) caregivers for the elderly or the handicapped,
- People living in rural and remote communities or in urban communities with inadequate health service provision [39].
- People who suffer from chronic disease, and who need continuous monitoring (diabetes, cancer, cardiovascular disease, asthma, COPD, etc.) [40],
- People involved in telehealth care undertaking health care at a distance or telemedicine, with physicians practising 'virtual visits' [41].

3.5. Advantages

Smart homes contribute to the support of the elderly, people with chronic illness and disabled people living alone at home. This new mode of health assessment can improve the quality and variety of information transmitted to the clinician. Measures of physiological signs and behavioral patterns can be translated into accurate predictors of health risk, even at an early stage, and can be combined with alarm-triggering systems as a technical platform to initiate appropriate action. Telecare can provide the infrastructure for coordinating multidisciplinary care outside the hospital (scheduling visits with health staff and community health workers, automating collection of clinical findings and test results) [42]. Home telemonitoring of chronic diseases is a promising patient-centered management approach that provides accurate and reliable data, empowers patients, influences their attitudes and behaviors, and potentially improves their medical condition [7]. With telecare services, patients become more 'informed', 'expert', 'educated self-managers', and 'have responsibility'. The great benefits are accessibility to services and locations of quality care. In the studies described below, some respondents emphasized the importance of choice in terms of appointments and ways of accessing services. In the US, pilot projects have suggested that telemedicine is a satisfactory means of providing nursing services in the home [43–45]. Studies related to patients' and nurses' perceptions of home telecare services have reported good patient perceptions of the system as a valuable resource that offered great potential, although many saw no immediate benefits for themselves. The patients agreed that telecare systems could save time and cost by reducing hospital admission and practitioner visits and travel. The medical staff could improve the management of their patient's health while providing more accurate and up-to-date information, to help them take better decision. Telecare systems could have a role in prevention by providing early warning of deteriorating health, leading to timely intervention, reducing hospital admission [43–45].

Patients are generally favorable towards telemedicine [46–49]. Patients have agreed that there are definite benefits of telemedicine, including reduced waiting times to be seen, enhanced access to care, reduced costs to the health care system and impressions that distance examinations are more thorough than conventional ones. Most patients prefer to have a teleconsultation to travelling to see a specialist, as it saves time and cost. However, comparatively few studies have looked at cost-effectiveness and patient satisfaction with telemedicine. With telemedicine technology provided by the health care system, it seems that the time spent by a medical specialist and support staff is no less than with a hospital consultation; the economic benefits favor the patient rather than the health care system. In teledermatology, the patients benefit from reduced travel time and cost [50]. IT such as electronic health records, e-prescribing, decision support systems, electronic management of chronic illness and bar coding of drugs and biological products has been shown to reduce costs and medical errors [51].

3.6. Disadvantages

The lack of studies related to user needs is a major barrier to the implementation of health care technology in smart homes. Inadequate comprehension of user needs and poor demands for products and services to be used in smart homes are partly explained by the fact that the industry tends to be dominated by suppliers providing a technology-push, rather than a demand-pull approach, causing user disappointment [52,53]. With regard to health professionals, those outside networking systems are faced with lack of ability to exchange clinical data with laboratories and hospitals. The majority of physicians have cited costs, vendors providing unacceptable products, concerns about privacy and confidentiality as major barriers to implementation of IT [46]. Significant barriers in social, ethical and legal issues impede widespread adoption of these tools, especially electronic medical records (EMR) due to complex electronic systems and lack of access to investment capital by health care providers, and lack of standards that allow exchange of clinical data. Physicians perceive a lack of financial support and high investment costs required for implementing EMRs, e-prescribing, and decision support tools. Additional costs are required to maintain the system and there is decreased revenue from patients during the transition from the old service (paper records) to EMRs, for example. A second barrier appears with the time and effort spent on learning how to use these technologies. One study suggested that technology has been the principal driver of the increase in health care costs in the last 50 years, and the potential of technology to escalate costs in the future is undiminished [54].

An older person's perception of privacy is one of the inhibitors of their adoption of smart homes that could enhance their quality of life and increase home safety. Privacy may be breached when e-health devices reveal more information than the individual desires. Mistrust can lead to withholding of information, disclosure of misleading information to health care providers, or avoidance of the health care system [55]. Smart home IT could negatively affect human interaction, response and relationships. People using this sort of technology may fear technology replacing personal interaction with their health care providers. Informal caregivers may fear that a greater burden will be placed on them. Users may worry about a technology affecting their lifestyle, financial status, emotional and psychological wellbeing of family members [56].

Ethical issues are major barriers to the routine use of e-health technologies. Physicians and care providers practising telemedicine must ensure that their patients are aware of the proposed service, and obtain consent to participate in any telemedicine service or study. In many countries (e.g. in Scandinavia), smart house technology cannot be used without informed consent. When the patient is cognitively impaired, the next of kin does not automatically have legal powers and the law varies between countries [57]. The ability of teleradiology to transmit radiological and other images electronically from one location to another has caused many issues to be addressed, such as state licensure and medical liability in the US [58]. Teledermatology is more expensive than conventional consultations because of the cost of the equipment and general practitioner time [50]. Introducing e-health systems raises several issues: accidental disclosure of individuals, contacting the wrong people, incorrect use of data, etc. [59]. A full legal framework for telemedicine is still lacking in the European Union. European and international telemedicine projects have often failed because they were too expensive for the patients and it was impossible to obtain reimbursement by public or private health insurance organizations. Some European Union states, such as Belgium, have stated that the physical presence of the physician is required if the patient wants to obtain reimbursement [60]. Some technologies lack communication between patients and specialists. The case of 'store-and-forward' applications in teledermatology is based on the concept of sharing information in an asynchronous and place-independent way using digital images and patient data transmitted to a remote specialist [61].

Most of the studies that we have analyzed were pilot or short-term projects. A recent review suggested that telemedicine research is insufficiently robust, due to a paucity of data analyzing patients' perceptions or the effects of this mode of health-care delivery on the interaction between providers and patients. Methodological weakness (small samples, specific context, study design) of the published research limit the generalization of the findings. The studies suggest that teleconsultation is acceptable in a variety of circumstances, but issues related to patient satisfaction have to be explored in depth with regard to patient–provider interaction [48]. There are few randomized controlled trials comparing telehealth interventions with conventional health care practices [62]. The majority of the studies in telemonitoring of chronic diseases were nonrandomized trials without control groups [7]. The authors suggested that future evaluation should consider randomized trials with larger numbers of patients and over longer periods of time. It is vital to demonstrate the feasibility of telemoniton-ing services at a population level, so that insurance companies and governments support this patient management approach and subsequent reimbursement for services is provided.

3.7. Impact of "smart homes" on societies

'Smart homes' and e-health have become common research issues in the past few decades but scientific evidence to support 'smart home' and telehealth use has been lacking. Recent literature reviews and research papers have reported that age, health status, racial/ethnic status, education, and gender are generally associated with patient satisfaction with health care [63]. E-health services may improve the quality and efficiency of care; however, there is little quantitative evidence on e-health use [64] and gender-specific studies are lacking.

Assisted living facilities (Senior Care, TigerPlace [65], and Elite Care [66]) have implemented ICT to facilitate care of senior residents. Robotic assistants in nursing homes [36] are now available but very few other facilities provide ICT systems. Home teleheath and telemedicine seem to remain in the research domain [67]. The term 'big brother' is uppermost [68], but it is anticipated that, over the next decades, there will be technological advance and also changes in national policies and legal systems. The increasing costs of providing health care services to an aging population are going to shift delivery from hospitals and residential care to private homes. In Spain, a home health care program aims to increase patients' quality of life considerably as it eases their care in the family and prevents risks associated with hospital admission [69]. In Australia, the home is becoming the new site for high-technology 'hospital' care [70]. The socio-economic benefits of telehealth have been studied in a systematic review [62]. It concluded that the best economic studies were found in teleradiology and mental health. Measurements resulting from analysis of costs, cost-savings or cost-effectiveness have been common to many telehealth studies, but they have been often imprecise. There are socio-economic benefits for specific applications, but there is the continuing problem of limited generalization [62]. In the USA, home care is a dynamic service industry. Approximately 20,000 providers deliver home care services to 7.6 million people who need services because of acute disease, long-term health conditions, permanent handicap, or terminal disease. Annual expenses were estimated at $38.3 billion in 2003. The number of home care agencies grew from some 1100 in 1963 and to about 20,000 in 1997. Home care is a cost-effective service not only for people recuperating from a hospital stay but also for those who, because of a functional or cognitive disability, are unable to take care of themselves [71]. In Australia, since 2000, a study in telepaediatrics in Queensland, demonstrated significant savings made by the health department through reduced expenses associated with reduced patient travel [72]. Families in Queensland save time, money and the stress of traveling to Brisbane. A unique model is used to receive and respond to referrals with a telepaediatrics coordinator, and videoconference facilities are also available. These factors are key to the success of the Queensland telepaediatrics service [72]. The introduction of telehomecare raises two major challenges for managers and providers: the organization of work must adapt to answer users' needs and alerts, and constant communications between the traditional and new models of service delivery are mandatory [73].

4. Future perspectives on smart homes as part of a home-based health care network

Home health care services were originally designed to transmit patients' health status data to dedicated centres, especially in the context of elderly dependency or social isolation. Thus, vital sign measurement devices and mobility/activity sensors at home may send data (such as blood pressure, respiration, body temperature, heart/pulse rate, glucose rate, body/weight/fat, blood oxygenation, ECG, and/or blood/urine components, activity/mobility assessment) through a network linked to a health care centre. The vital signs and the activity or lifestyle patterns are used to build personalized data to warn the family or safety providers of adverse events. The 'smart home' becomes part of the home-based health care system linked to the hospital, which is the centre of the system (Fig. 1). This idea has been promoted in several projects [19,74]. We strongly believe that the user-centered, home-based system will become the basis of health care in the future.

This integrated system will consist of:

1. Hospital-based health professionals giving teleconsultations and virtual visits.
2. Devices capable of integrated analysis providing support for making decisions and diagnoses, improving access to health care services and optimizing resource utilization for high-risk patients [73].
3. Hospital-based management only for acute illness or investigations which cannot be undertaken at home.
4. Patients with the help of health professionals receiving care at home (postoperative, chemotherapy, asthma, chronic obstructive pulmonary disease, diabetes, etc.) [75].

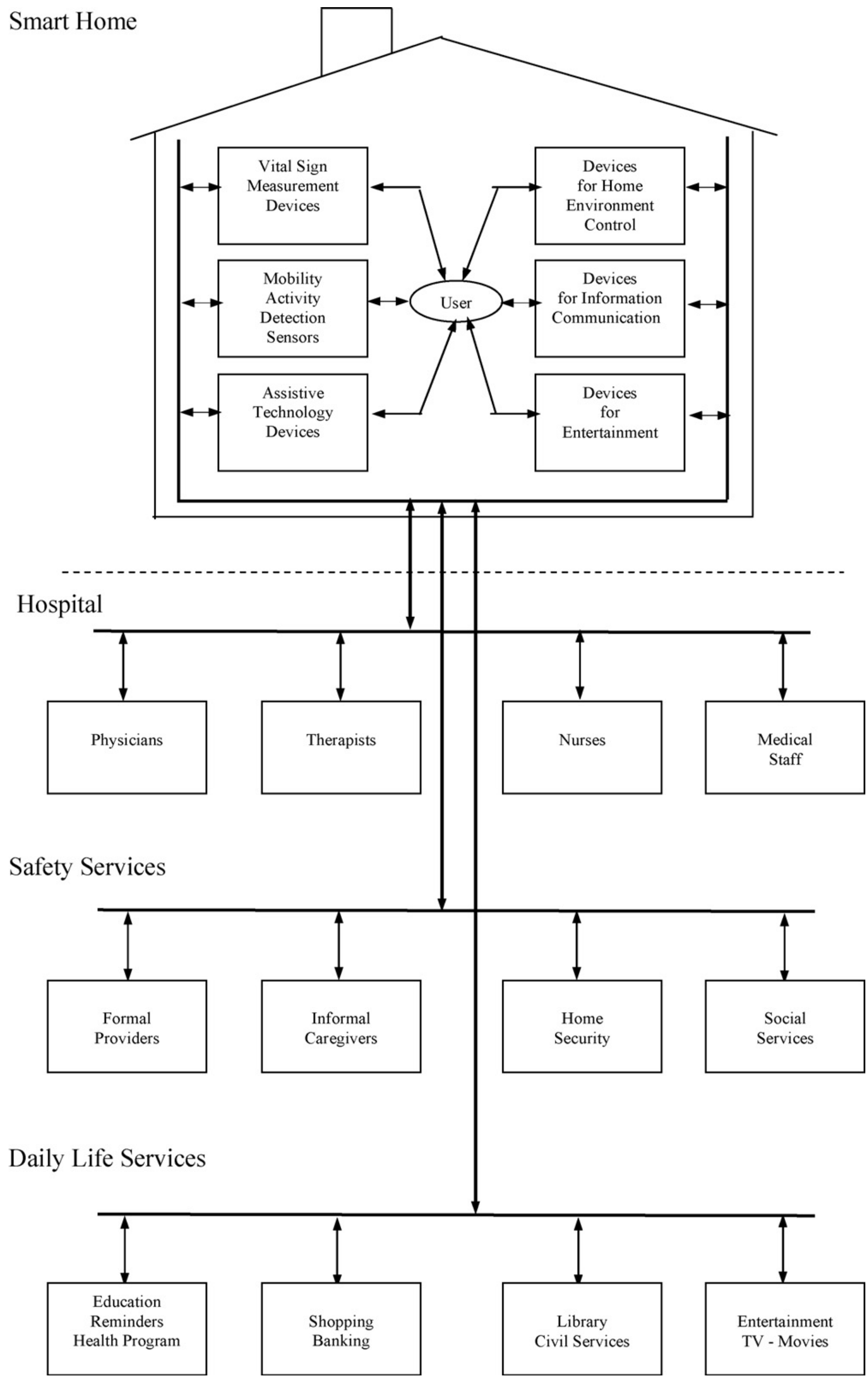

Fig. 1. Key organization in Smart Home.

5. Hospitals becoming health information system centres where all data are kept [5].

In daily life, smart homes will provide:

1. Devices capable of home appliance control (heating, air-conditioning, bath water control, windows, doors, etc.) [76,77].
2. Assistive devices (robotic-assistant, companion robot, autonomous wheelchair, stair lift, etc.) [78,79].

The Swedish Handicap Institute has developed a two-room SmartBo project (meaning smart living) for people with mild to severe disabilities. The project focuses on ICT and assistive devices and solutions and comprises basic systems enabling the user to supervise and control functions present in a home (windows, doors, locks, water outlets, electric power, cooker, and bed) [77].

Funding patterns of the health care system and smart homes will vary between countries and may involve both the public and the private sector [80].

5. Conclusion

Technological maturity and increase in health costs will lead to the decentralization of healthcare from the hospital to the home. Care may be provided more efficiently in the home rather than in hospitals. The challenge is that people have different needs and provision by this decentralized system has to be tailored to individuals. The devices to monitor health and activity and provide assistance in the home must be non-obtrusive and acceptable to users. The needs of users require more research. Cooperation and communication between all agencies providing care must be maintained. Privacy and confidentiality need to be respected. Finally, the ethical and legal issues of 'monitored' living need to be established to improve acceptability before the technology becomes widely promoted.

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