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Abstract. The growing of ageing population worldwide and the need to focus research efforts on a specific target group motivate our research to focus on frail ageing people with chronic disease and physical/cognitive deficiencies. The primary goal is to enable the frail and dependant persons, through reliable assistive technologies, to maximize their physical and mental functions, and to continue to engage them in social networks, so that he can continue to lead an independent and purposeful life. Our target is to analyze the users' habits at home through an extensive survey performed in France recently, and to design a suitable assistive system, which is mainly composed of devices available in the market. This research activity led to the deployment of a simplified hardware infrastructure (gateway, sensors, actuators) in the home of end-users with a limited number of wireless sensors, and to the outsourcing of all the software for data analysis in a framework running on a distant server. The research focuses on the quality of life of ageing people having cognitive and functional limitations, and on recent achievements realised in France and Singapore through several European and national projects, and through Quality of Life Chair (QoL) directed by Mounir Mokhtari and supported by two major health insurance companies in France, namely la Mutuelle Generale and REUNICA.

Keywords: Ageing people, Ambient Assisted Living (AAL), Activities of Daily Living (ADL).

1 Introduction

Today, providing assistive services for frail and dependant people could be done following two ways: the first option consists in looking for a reliable industrial solution to be deployed in the user's living space, which may not fit exactly with the users' specific requirements and usually imposes to modify extensively the living environment itself. The second option is to design a specific application, which meets exactly the needs of the end-users, but developers will be confronted with a wide spread of technologies and APIs which impose a huge amount of human-efforts and associated cost. This second option may require a long time (several years) to build a reliable running prototype. Consequently, in both options, the development cost is high, and this is also the reason why most smart home projects are still at a laboratory prototype level worldwide [1]. There are efforts trying to transfer these prototypes into homes or hospitals [2], but migrating systems from a well controlled research lab environment into a much more complex real-world environment introduces tremendous challenges in terms of correctness, reliability and fault-tolerance of the system.

Ageing is a highly individualized, irreversible and inevitable process by which a person becomes more vulnerable and dependent on others [3]. It proceeds at different rates and within different functions depending on people. Changes, that can occur in cognitive, physiological and social conditions, are not necessarily related to a disease since they are, in a certain magnitude, a normal part of the ageing process.

Cognitive changes related to normal ageing span across several aspects of the mind [4]. *Sensory memory* is the ability for each of the five senses to hold a large amount of sensory information for a very short period of time, and is independent of the attention to the stimulus. It suffers no major influence of ageing. *Short term memory* is a 20 to 30 seconds memory used to hold information for processing. It is a working memory that can hold 7 elements for direct manipulation. It is highly involved in Activities of Daily Living (ADL) as it enables multi-tasking and manipulation of information. The capacity to hold 7 elements is not affected by age, but the manipulation of this memory becomes difficult as elders have a limited capacity to divide their attention between two related tasks or inhibit unimportant information. *Long term memory* is a series of memory modules each responsible for holding different sorts of information. It is subject to three mechanisms (encoding, storage, retrieval) that are not affected by age in the same way. Encoding is usually subject to a less spontaneous organization of information, so elders might need support on this.

Conducting a survey that involves aged people and their associated caregivers will help to understand the needs of this portion of the society and to provide solutions that Respond to their requirements. Our ultimate goal is to maintain the quality of life of aged people in their own home as long as possible by the integration of ICTs in an acceptable way for both the end-users and the stakeholders [5]. This means that economical and social impacts are key issues in our approach.

2 Methods

To properly define and address this issue, our methodology consisted on performing 2 parallel activities, in one hand a survey investigating the need of 123 frail aged people living in their own homes, and on the other hand designing and developing a suitable system for the provision of assistive services.

2.1 Survey - The lifestyle of the elders

In order to observe the lifestyle of the elders within their home, we have sent a questionnaire to elderly people, in collaboration with a national association of retired people[1]. The same questions have been asked to both the elders and their family caregivers, so that we can observe the bias in their perception. We have gathered 246 questionnaires, making up a total of 35,178 questions answered. After investigating the population of the elders and the caregivers, this survey gives insights on the elders' activities at home and outdoor, as well as the healthcare services they receive. From this survey, we aim to determine the most critical needs of elderly people in their daily lives.

In the Fig. 1 below, we observe the causes of insecurity, as felt by the elders as well as their caregivers. We observe that, many of the elders have developed a fear of other people (20%). But only 14% are concerned by their own condition and the risk of having an accident. On the other hand, from the caregivers' point of view, 23% have fear because the house is not suited for the patient (e.g. presence of stairs). In total, 50% are worried for the health of the patient, dispatched between an unsafe house, cognitive problems, autonomy problem, and the risk of accident.

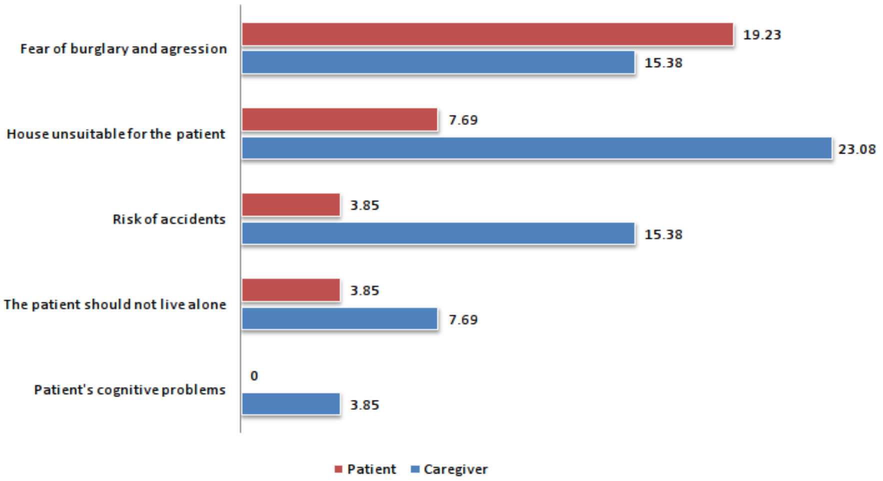

Fig. 1. Causes of patient's insecurity within the house

From this study, we observe a strong divergence in opinion between the patient and the caregiver. The caregivers tend to be more worried about the elders' condition, whereas the elders themselves may deny it, and develop social complications.

Fig. 2 shows the caregivers' opinions about healthcare services for elderly people. As we can see, 1% of them are concerned about health monitoring, while 29% want to support the elderly people for living independently, and 29% mention the improvements in the patient's quality of life. 18% of the caregivers acknowledge that

[1] Association Nationale des Retraités de La Poste et de France Télécom (ANR)

these services maintain a social connection for the elders (Fig. 1 has shown the importance of it, as patients may have social inabilities). Finally, 21% of the family caregivers say that assistive services are also a support for the family, giving a glimpse of the difficult condition of the family caregivers who support the patients in their daily life.

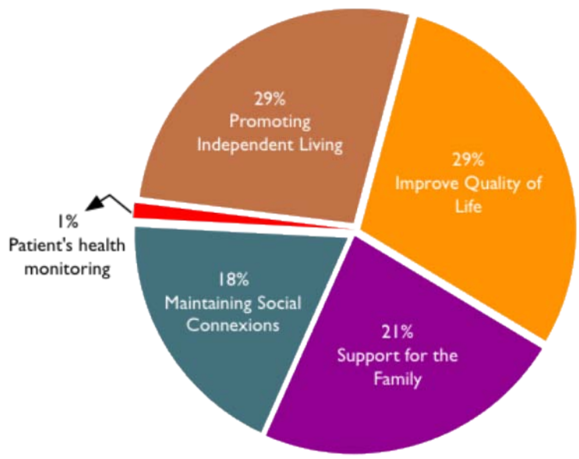

Fig. 2. Families' expectations about assistive services

As we can see from Fig. 2, the caregivers tend to be far more concerned by the quality of life and the autonomy of the elderly people, rather than by their medical condition.

2.2 System design hardware & software

Our main approach for an easy adoption of an ambient assistive living solution, is to limit both the number of devices to be deployed, and the types of sensors to be used. The goal is to provide a smart home in the box approach that is easy to install on site and maintain remotely in order to allow a large-scale deployment in several homes while leveraging a server based software architecture able to instantiate each home and analyze the data coming from its deployed sensors independently. Fig. 3 illustrates a typical home environment and its associated sensors. The idea is to deploy low-cost and non-intrusive sensors (motion sensors, contact sensors) with an internet connected gateway in each home.

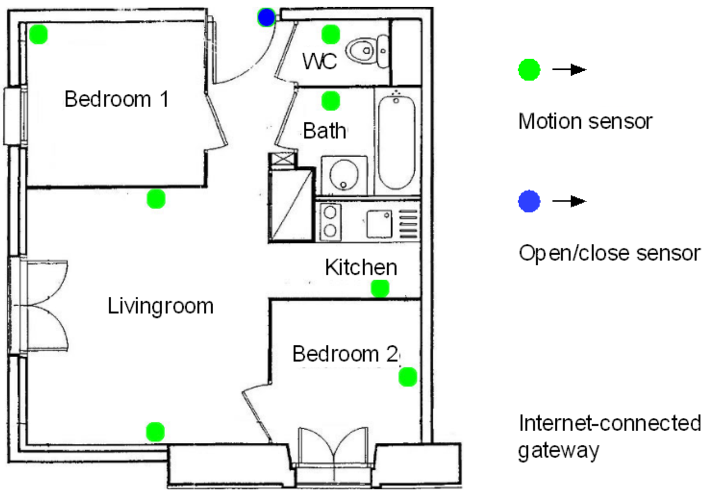

Fig. 3. Smart home is a box setup for activities recognition

On the server side, a framework is in charge of processing events sent by each home gateway and providing assistive services [6]. Our software framework is based on the OSGi (Open Service Gateway initiative) modular principle. This allows decomposing the platform into several modules, having each its specific functionality, and all communicating with each others. These modules are responsible of sensors' events reception, reasoning, taking decisions about users' situations, and providing the assistive services. A semantic model is used by the platform to represent the environment and the end-user profile.

The platform's OSGi modules are identical for each deployed house and the abstract semantic model is instantiated with information concerning each new house. Therefore, on the server side, a new instance of our framework is created and launched after the deployment of our system (sensors and gateway) in a new house and the semantic model is instantiated with the new user profile (name, address, disease, etc), as well as the description of the house and the deployed sensors characteristics (type, code, possible events, localization, etc). Fig. 4 represents the architecture of the framework developed on the server side.

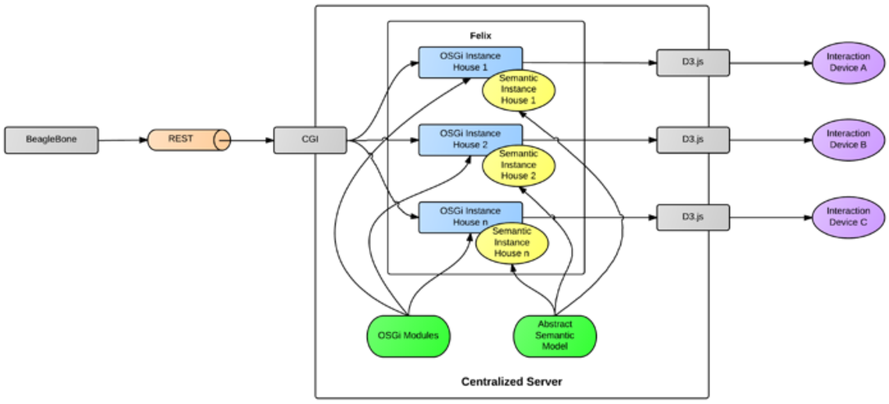

Fig. 4. Server based Software architecture

The gateway (BeagleBone Black[2]) of each house sends events received from the sensors deployed to the central server (hosted by CNRS LIRMM Lab. in Montpellier city in France). The CGI (Common Gateway Interface) on the server receives these events and routes them to the appropriate OSGi instance. After reasoning and making decisions, assistive services are provided to the end-users (patients or caregivers) on different interaction devices using the D3.js (Data-Driven Documents) library.

3 Results

The goal of this experimentation was to confirm the feasibility of reasoning in an AAL solution based on a stripped-down hardware deployment. This means that we must demonstrate that valuable knowledge can be extracted about an elderly person's lifestyle from coarse sensor data. Moreover, we must verify that the scalability of the incurred processing remains within an economical level, where an economy of scale is possible with one server providing enough processing power to cater for hundreds of houses.

Multiple assistive services can be provided for the end-users. These services are based on the patients' locations and activities inferred by our platform deployed on the centralized server. Fig. 5 represents a Real-time visualization of a patient's activities during the day.

[2] beagleboard.org/Products/BeagleBone+Black

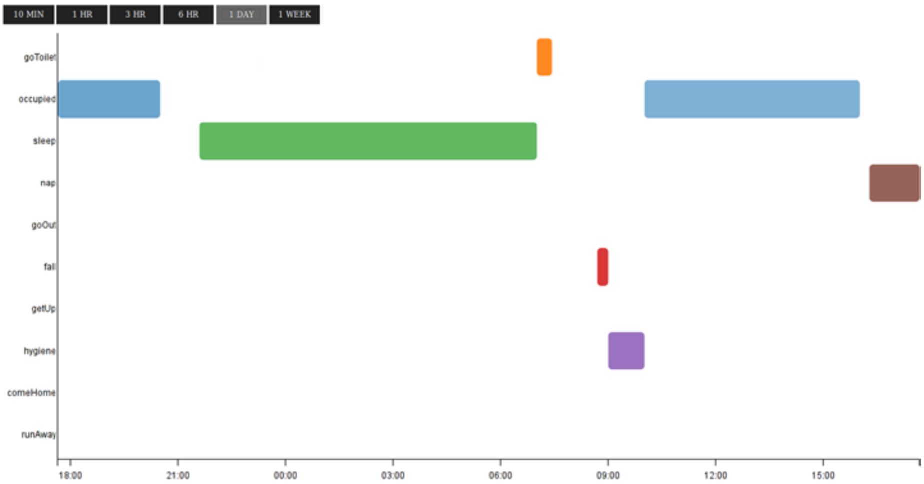

Fig. 5. Real time visualization of ADL

Relying on our conducted survey, we have identified several assistive services which are requested by the end-users and that can be provided based on the inferred information from our platform. Table 1 illustrates some of the assistive services that can be provided.

Table 1. Assistive services deduced from the conducted survey

End users expectations	Assistive services
Improve Quality of Life	Serious games for memory stimulation Wandering at night alert
Promoting Independent Living	Meals time reminders Medication agenda
Support for the Family	Elderly ADL visualization Emergency calls in critical situations
Maintaining Social Connexions	Video conferences with families and friends

4 Discussion

Several technical issues have emerged from deploying technological systems in real living spaces. To perform the validation, these issues had to be dealt with, which is often considered as a "waste of time" by researchers and engineers developing systems in their lab. However, this experience allowed us to learn a lot about the targeted users and stakeholders in general, and it provides us with essential and extremely valuable knowledge related to bringing value out of our research work and making an impact in society. This knowledge, collected through an extensive survey, is mainly related to the feedback received from the stakeholders, the acceptance of the solutions, their ease of deployment and maintenance, usage issues, etc. Even though such deployments felt like a burden at some point in time, we can only recommend to researchers in our field to get out of the lab, deploy their solutions, and include stakeholders early in the research work.

After deploying in four bedrooms in a nursing home in Singapore [7] and three individual homes in France [8], we have improved the system along two aspects, on one hand, to simplify the hardware architecture by limiting drastically the number of devices; and on the other hand, to design a server-based framework able to instantiate each deployed site independently in a scalable manner. Experimentation within living labs in Grenoble (France) and Starhome (Singapore) provided promising results. Our next target is to deploy 10 individual homes and one nursing home in France within the Quality of Life Chair.

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