MOBISERV: An Integrated Intelligent Home Environment for the Provision of Health, Nutrition and Mobility Services to the Elderly

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Abstract. Life expectancy increases and the wish to prolong independent living remains strong. To stay as independent as possible gives satisfaction to the individual and reduces costs for society. With advances in information and communication technologies, service robotics becomes important means for assisting older persons in their daily living. In this paper we introduce MOBISERV, a project aiming to develop proactive personal service robotics that will be integrated with innovative wireless (bio-) sensors, localisation and communication technologies, smart textiles and clothing and a wearable solution hosting monitoring equipment for supporting independent living for elderly. Health and wellness, nutrition and mobility but also social interaction, safety, security and privacy are examples of assistance that MOBISERV will provide to older people.

1 Introduction

The life expectancy in the EU – as in other developed countries – is continuously increasing, and the proportion of older citizens in the population is growing. As generations live apart, more and more older people live by themselves, as couples or singles.

Older people, their relatives and the civil society as such have a common desire to prolong the period of independent living for older citizens. To stay as independent as possible gives satisfaction to the individual and reduces costs for society. The move from "home" via "protected living" to "nursing home", in their various forms is regarded as something negative and should be delayed as much as possible taking into account the personal wishes, abilities and dignity plus the economic conditions in society.

Information and communication technologies (ICT) can play an important role in dealing with the aforementioned challenges, as they can help the older individuals to improve quality of life, stay healthier and live independently for longer [1]. ICT solutions for supporting independent living of older persons include: communication devices; sensory aids; consumer electronics/multimedia; smart home technology; medical assistive technology; tele-monitoring devices; walking aids and assistive devices for supporting mobility; automatic and intelligent devices and services capable of helping older individuals performing their daily chores [2].

Current and future developments in the area of ICT-enabled independent living for older persons are underpinned by some key emerging technologies, such as biosensors, new materials and robotic. Research in robotic technology for eldercare in particular, concerns assistive robots that can be both rehabilitation robots, i.e. robots featuring physical assistive technology that is not primarily communicative and is not meant to be perceived as a social entity, and social robots, i.e. systems that can be perceived as social entities that communicate with the user [3]. In this paper we focus on social robots, usually designed as assistants, companions, or pets, in addition to the more traditional role of servants [4], and especially on service type of social assistive robots to support independent living for older people.

In the following sections we shortly describe the state of the art in service type of social assistive robots for eldercare and we introduce MOBISERV, a work in progress that aims to develop proactive personal service robotics for supporting older people in maintaining their daily living situations.

2 Review of Service Type Social Assistive Robots for Eldercare

Service type of social assistive robots for eldercare may exhibit a range of functionalities to assist the elderly in daily activities. Some examples of such robots are presented below.

Nursebot Project: The Nursebot project conceived in 1998 by a team of investigators from three universities with the aim to develop mobile robotic assistants for nurses and elderly people in various settings. The first robot developed in the scope of this project was Flo and the second one PEARL. PEARL is Flo' successor and incorporates changes made mainly as result of feedback from nurses and medical experts following deployment of the first robot, Flo [4]. PEARL [6] is targeting at providing functional assistance to the elderly, by a) reminding people about routine activities such as eating, drinking, taking medicine, and using the bathroom, and b) at guiding them through their environments.

Care-O-bot: Care-O-bot [7] is a mobile service robot designed by Fraunhofer IPA with the aim to assist people in their home environment. To meet this goal, three generations of a robotic home assistant "Care-O-bot" have been developed so far (in 1998, 2002 and 2008 respectively). The third generation of Care-O-bot enables the execution of fetch and carry tasks that, according to Graf et all (2009), provides the basis for a large number of assistive tasks in home environments. Care-O-bot 3 is equipped with a number of components including omnidirectional drives, a 7 DOF redundant manipulator, a three finger gripper and an interaction tray, which may be used for passing objects between the human and the robot. The robot features a moveable sensor head which contains range and image sensors enabling autonomous object learning and detection and 3D supervision of the environment in real time. Current developments aim at applying the robot in an eldercare facility in order to support the personnel in their daily tasks.

RoboCare [8] [9] is a project funded by the Italian Ministry of Education, University and Research that had as a goal to build a multi-agent system which generates user services for human assistance. This three years project (2002 – 2005) has produced a prototype of integrated home environment, called ROBOCARE Domestic Environment (RDE) that is composed of a robotic interactive agent, some sensors for continuous monitoring, and additional intelligent systems that store and reason upon knowledge about the assisted elder's scheduled activities. RoboCare implements two forms of interaction, *on-demand* and *proactive interaction*, based on who takes the initiative to start a dialogue: the user or the intelligent environment guided by its internal reasoning. On-Demand interaction refers to the "Question/Answer" category of dialogues, whereas proactive interaction refers to "Danger" and "Warning" scenarios.

CompanionAble [10] is a four-year EU-funded project - started in 2008 - that aims to develop an assistive smart home environment within the home of elderly people, to support both the cognitive stimulation and therapy management of the care-recipient. This is mediated by a robotic companion working collaboratively with a smart home environment. Main CompanionAble developments include: realisation of an intelligent day-time-management (drug intake, appointments); content generation for cognitive stimulation and training and coherent delivery through multiple channels; Videoconference between user and professionals/relatives/friends, fully integrated in the robot and smart home's user interfaces; On-line recognition of significant distress signals/utterances/calls and sound source localization; Visual detection of person's poses and analysis of emotions; Multimodal and natural dialogue module (speech input/output, touch display, gestures).

KSERA [11] is an EU-funded ICT project started in February 2010 with the aim to develop a Socially Assistive Robot that helps older persons, especially those with Chronic Obstructive Pulmonary Disease, with their daily activities and care needs and provides the means for effective self-management of their disease. KSERA is expected to provide (1) a mobile assistant to follow and monitor the health and behaviour of a senior, (2) useful communication (video, internet) services including needed alerts to caregivers and emergency personnel, and (3) a robot integrated with smart household technology to monitor the environment and advise the senior or caregivers of anomalous or dangerous situations.

Florence [12][13] is an EU-funded ICT project, started also in February 2010, having as a goal to apply a Personal Assistive Robot to improve (cost-) effectiveness of home care for elderly people and to enable them to stay at home as long as possible. Within the project an Ambient Assistive Living home environment will be built, which integrates the robot, existing home automation infrastructures, and local and remote communication services, and which provides enabling technologies for AAL services. The Florence system is expected to support lifestyle and AAL services in the following categories: Family involvement; Video telephone; Home observation; Emergency Intervention; Direct coaching; Remote coaching; and Communication among caregivers.

3 Introducing MOBISERV

While MOBISERV shares some aspects with the aforementioned projects, as far as particular research and technology objectives and services available to the users are concerned, MOBISERV addresses the particular goal of developing an open, standard-based personal service robotic platform for supporting independent living for elderly. This platform will be an integration of innovative components delivered by the project and of existing standards-compliant technologies: in addition to home automation infrastructure and localisation and communication technologies (already tackled be some of the aforementioned projects (e.g. CompanionAble, KSERA, Florence), innovative wireless (bio-) sensor-actuators, smart textiles and clothing, and a wearable solution hosting monitoring equipment will be integrated with an existing robotic platform capable of self-learning and able to support the older people in indoor contexts. MOBISERV is proposing a holistic proactive and unobtrusive approach to support independent living covering health and wellness, nutrition and mobility but also, social interaction, safety, security and privacy. Nutrition support is also an innovative aspect introduced in MOBISERV.

The particular objectives of MOBISERV are:

- *Social Objectives:* To develop a Personal Robotic System as a holistic approach to support daily living of older citizens in everyday activity scenarios in a living space context with an emphasis on supporting personal health care and improving independence in living environments and the quality of life; To Support the elderly in maintaining their social activities; To embrace a paradigm shift in health responders and emergency assistance, that is redefining the way of treating and managing health-related emergency calls and the way first responders, carers, family, health care service providers are coordinated, thus giving support to integrated care.
- *Research objectives:* To research, develop and implement self-learning techniques in relation to optical recognition, pattern recognition and autonomous navigation techniques; To research effective self-learning methods for predicting and detecting health-related adverse events of the older citizens from multiple sensors; To evaluate the Personal Intelligent Robotic System in terms of comfort, usability and safety; To investigate the most effective and efficient communication modes between the robot and human user in various scenarios, and the impact of cultural, gender, age and cognitive differences on this; To evaluate different types of robot embodiments in relation to user acceptability, and the relationship between criteria for acceptance and cultures, societal demographics.
- *Technological objectives:* To produce an efficient system design of the personal robotic platform; To develop the personal robotic platform components, which are a) a health status monitoring system integrated into wearable fabrics, b) a secure tele-alarm and health reporting system, and c) a nutrition support system; To integrate the aforementioned components into the personal robotic environment; To apply innovative personal tracking techniques for monitoring nutrition habits and vital signs of the elderly citizens while they are accomplishing their daily activities; To develop a reliable communication platform for various heterogeneous devices of MOBISERV by providing a unified interface to different wireless technologies to provide maximum reliability; To develop methods for securing sensitive and private communicated information while taking computing requirements.

MOBISERV started in December 2009 and at the time of the writing of this paper it has reached the state of initial requirements identification and a first definition of functional requirements.

Liaising with users through a range of requirements gathering techniques has been (and still is) an integral part of designing, shaping and realigning the MOBISERV concept to reflect the practical users' needs. Within MOBISERV one of our key research priorities is the development of evaluation methodologies to ensure validity of the research. We aim to ensure that validation doesn't only evaluate the human robot interaction but also how the system can be effectively integrated into the users' specific context.

4 Requirements gathering and analysis methodology

Our requirements gathering activities included a combination of observations, interviews, focus groups, questionnaires and cultural probe studies. The requirements gathering was carried out simultaneously in two countries, namely the Netherlands and the United Kingdom. We were interested in investigating the requirements from different groups of individuals, varying in terms of age, context, location and level of care required. As such we recruited participants from residential care homes, those who attended a day care centre on a daily or part-time basis, and individuals who lived independently, either in their own homes or homes which were part of the residential village. In total we elicited information from 67 older persons in the UK and Netherlands, as well as 34 secondary and tertiary stakeholders, including carers, managers and relatives. Stakeholders from this range of settings have helped us to consider the needs of a broad cross-section of the target user groups, encompassing individuals with a range of physical and psychological conditions which are natural consequences of ageing.

Analysis of the data gathered from across the different locations described in this report has helped to identify the following issues which will be vital to consider in the context of the MOBISERV system.

- *Technology acceptance will be a key issue to address.* A number of older residents in the care home setting found it hard to relate to the technology and most had not used a computer or mobile phone and were confused by things like the digital television switchover (in the UK). Use of metaphor to make the system familiar in some way might improve acceptance by end users. Many of our older participants admit themselves that they are not particularly receptive to change so any chance to build some familiarity into the product would help. Acceptance was also found to be linked to concerns regarding potential invasion of privacy. Age related differences, as well as cultural differences (if any), regarding attitudes to privacy need to be further investigated. One of the conclusions of Singleton et al's review [14] on public and professional attitudes to privacy in healthcare is that assessment of public attitudes is dependent on how the topic is framed, so consideration will have to be given to how the MOBISERV systems are presented to the stakeholders and the potential impact that the mode of introduction will have on acceptance.
- *Age related differences in relation to the use of technology need to be considered.* There are significant differences in the attitude towards technology between several age groups from 62 to 95, but there are no clearly identifiable borders. Younger participants (62-69) were generally more accepting of the proposed technology. Some already use computers in their daily lives and were more accepting of the idea of using the system. The group of people that are used to technology is growing, and the resistance towards the use of technology in care is decreasing. At this moment, there is the curious situation of some 70-year olds, who do have the skills to use technology, but do not feel the need to use it, and the 80-year olds, who need the technology, but lack the skills. In 10 to 15 years from now, this situation will completely change. However, the limitations in mobility, eyesight, hearing and sometimes memory, which are a result of the natural aging process, will always need to be considered in regards to the usability and accessibility of the technology.
- *Individual routine and familiarity will be important to maintain.* Older people tend to like to sit in the same place to watch TV, or to eat dinner. They like routine and familiarity in their everyday lives. So as part of the effort in designing and developing the technology, the work on user acceptance will also need to research into methods for introducing the MOBISERV technology so it is not seen as an intrusion on existing patterns of behaviour, and does not force people to modify their routines and habits in unfamiliar ways.
- *Ability to enable user-control over the functionality will be important***.** It will be important to allow users to switch off specific functions if they so desire. This is essential both from an ethical perspective, as well as in response to the concerns expressed by some of the older persons regarding some of the proposed features of the MOBISERV systems which could be viewed as an invasion of privacy in particular contexts. Empowering users to have control over the functionality will be a vital part of gaining their trust.

As we conduct evaluation studies and field trials, more specific requirements will start to emerge and be refined as end users and stakeholders gain a clearer understanding and experience of the scope of the technology and the consortium sees how the technology needs to be further adapted to suit needs.

4.1 Personas and Scenarios

Personas were first introduced by Alan Cooper [15] as a practical interaction design tool. Personas have been found to help the design team to better consider the perspectives of people who will be using a system and more realistically hypothesise answers to questions relating to what they might do in a particular scenario. A persona helps to give the invisible, nondescript "user" a personality. By designing for the persona, the needs of the broader group that the persona is an archetype for, can be better satisfied.

For this project we compiled a total of seven personas. These personas were based on our requirements data we had gathered and we used the characteristics of the older people we had met to typify particular groups of people, and the personas compiled are representative of the range of issues that were found.

As part of the user-centred design process the consortium team has adopted these personas to help consider the design, development and use of the MOBISERV technology through the eyes of these personas. A summary of these personas is shown in table 1.

No	Name	Cognitive	Physiological	Psychological	Setting
1	Aalbert	None	Mobility, Weak heart and lungs	Loneliness	Independent
2	Brenda	Forgetfulness	Diabetes, weak eyesight, Mobility, shortness of breath from exertion	None	Independent
3	Carol	None, mild forgetfulness	Limited mobility in hand, knee replacement	None	Independent
4	Dafne	None	Impaired mobility	None	Semi-independent
5	John	Dementia	Mild mobility impairment	None	Semi-independent
6	Lilian	None	Severely impaired mobility, hearing loss	Mild depression	Residential
7	Terry	None	Limited mobility, incontinence	Loneliness	Residential

Table 1. *Summary of issues for each persona.*

These personas were then used to help us construct scenarios. A scenario is a short story about a specific persona with a specific goal. Scenarios comprise the people, tasks, and contexts that help define what might be expected from an application in a given situation. Scenarios are helping us explore in more depth, the non-functional aspect of the individuals' context, which in addition to ensuring that the functional components are technically viable, we hope will also greatly increase the probability of user acceptance by considering enhanced flexibility for adaptability and customization. Table 2 summarises the scenarios identified as well as the personas targeted.

No	Scenario with MOBISERV	Personas						
		1	2	3	4	5	6	7
1	Being reminded to eat		x			x		
2	Being reminded to drink		x			x		
3	Being persuasively encouraged to eat	x	x			x		x
4	Being persuasively encouraged to drink	x	x		x	x		
5	Being reminded which food is in the fridge and pantry		x	x		x		
6	Being able to call someone in an emergency / a panic responder (yelling, falling)	x	x	x	x	x	x	x
7	Being reminded to take medication		x			x		
8	Being encouraged to do some activity, when sitting for a certain period of time	x	x		x	x	x	
9	Being reminded to wash / personal hygiene					x		
10	Being able to carry items to another room	x	x	x	x	x	x	x
11	Communicating / socializing with friends and relatives	x	x	x			x	x
12	Social caregiver remotely checks in on the older person	x	x					
13	Being reminded of diary appointments or social engagements, when no social contact has taken place for a while		x	x	x			
14	Finding out about the weather and news	x	x	x	x		x	x
15	Communicating with someone at the front door from any room	x	x		x		x	
16	Controlling the environment in the house through a mobile robot (lights, heating, curtains, locks)	x	x	x	x	x	x	
17	Guarding against accidents (gas, water, windows, doors)	x	x	x	x	x		
18	Finding out if everything is medically okay / self-check platform / telemedicine / detection of irregular patterns (sleep, heart-rate, breathing, temperature, activity level)	x	x	x			x	x
19	Being cognitively and socially stimulated with computer games	x	x	x		x	x	x
20	Communicating with health professionals to report problems	x	x	x			x	x
21	Prescription / medication management	x	x	x			x	

Table 2. *Summary of scenarios indicating which personas could benefit from these functions.*

Working in tandem, personas and scenarios are helping us achieve a deeper integration of real user needs into the development of the components.

5 The MOBISERV Platform

Following requirements gathering and analysis, the project proceeded in designing the MOBISERV platform. This relies on modular design where different functions are implemented in independent components or component groups, which can be brought into the system. The general architecture (simplified version of the rather complex architecture) of the MOBISERV platform is presented in Fig. 1. According to this, the MOBISERV platform consists of a number of interconnected devices:

- *Physical Robotic Unit (PRU):* PRU is the MOBISERV Personal robotic platform able to coordinate a number of different components. It will be able to navigate indoor, follow a specified user and handle the interaction with an older person. PRU will be based on Robosoft's Kompaï [16], an indoor mobile platform that is used as a generic platform and designed to ease the development of advanced robotics solutions. Kompaï is equipped with an embedded controller and a tablet PC. Within the project, Kompaï will be adapted to the MOBISERV context.
- *Camera's:* Cameras are used for capturing video feeds to support a number of functionalities and user services. One of the cameras - part of the PRU - is mainly used for supporting videoconferencing and for providing input to facial expression recognition component. A number of additional, static cameras are placed in the user's home environment for monitoring pre-specified positions where eating/drinking activity takes place.
- *Smart Home Automation and Communication Unit (SHACU):* SHACU will be a fixed computer in the older person's environment that can establish connectivity to the home automation system and to internet end-points. SHACU can also host deployments to functionalities where PRU mobile nature is not suitable, for example reliable tele-alarming or computing power intensive functionalities. Furthermore, SHACU will host video analysis tools for the provision of nutrition support.
- *RemoteSite:* It refers to a device (computer) in a remote site that is connected to the internet. Through this, carers (family, doctors, and emergency health responders) are able to receive alarms and related reports in case an abnormal activity has been detected.
- *HomeAutomationDevice:* It is a generalization of device in home automation (home automation device). *Door:* It refers to an external set of devices at the door of the older person's apartment, which can be remotely used/ controlled.

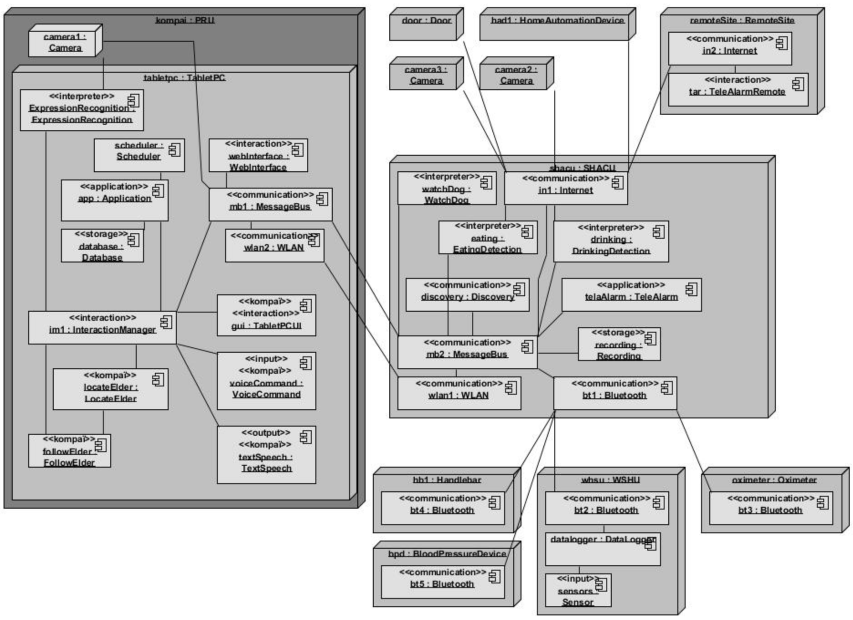

Fig. 1. *Deployment of MOBISERV components.*

- *Wearable Health Status monitoring Unit (WHSU):* WHSU refers to garment(s) where sensors for vital-signs monitoring and human activity classification and fall detection are placed. These include textile electrodes (ECG), a piezoresistance sensor and a 3-axis accelerometer, which are used to extract the following parameters: heart rate; heart rate variability; breathing rate; activity classification and fall detection. The following raw data will be also available: ECG; respiration; orthogonal component of the acceleration. The WHSU includes a data logger, which retrieves and process signals from the different sensors.
- *Handlebar:* It is a fitness device that can be used to measure and communicate health related parameters while the older person is exercising.
- *BloodPressureDevice:* It is device used to measure the older person's blood pressure.
- *Oximeter:* It is device to perform blood oxygen measurements.

Handlebar, Oximeter and BloodPressureDevice are devices that can be used to obtain punctual measurements of vital signs in case an older person is not willing to wear a monitoring device.

As mentioned above, PRU will handle interaction with the older person, and will be responsible for coordinating information across the various sensors, modalities, and components, which are used within MOBISERV for supporting the scenarios selected for implementation.
In particular, the PRU's Interaction Manager will handle events that other components generate. These events and data should have been initially interpreted and formatted in a common format; the resulted information will then be used for accessing and updating the appropriate application data and then channelled to the appropriate components (output modalities).

The Interaction Manager will receive input coming from a number of components, including:

- Voice commands issued by the older person and recognised by the speech recognition component.
- Tactile commands issued by the older person though the graphical user interface on the robot's tablet.
- Eating activity reports coming from the eating detection component located in SHACU.
- Drinking activity reports coming from the drinking detection component located in SHACU.
- Facial expression recognition reports coming from the facial expression recognition component in the robot.
- Alarms issued by the WHSU, based on the analysis of the data coming from the sensors described earlier in this article.
- Input events coming from the smart home infrastructure components.
- Events and data from applications, such as reminders, or the scheduler. The latter arranges time-based events such as eating time, or meetings. Application data are stored in a database, when persistent data is required.

The Interaction Manager communicates output as follows:

- Information channelled to the speech component on the robot. This component is responsible for generating vocal messages.
- Information channelled to the tablet PC.
- Commands issued to the navigation component. This component dynamically guides robot to the older person's location or to other target locations.
- Commands issued to the component responsible for locating the user in his/her apartment.
- Pass Events to smart home automation components.
- Channel alarms or critical reports to the tele-alarm component, when a critical abnormal activity is detected by the MOBISERV system. In these cases, PRU may be accessed by a remote caregiver through a web interface.

The envisaged MOBISERV system can be applied in different locations from private homes to large care facilities. Independence of the components allows dynamic deployment of the MOBISERV system, where the applied capabilities can be selected based on the requirements and available resources of target location and people.

7. Conclusions

In this paper we presented MOBISERV; a work in progress that aims to implement a framework and a platform for the provision of health, nutrition and mobility services to the elderly. After providing an overview of service type Social Assistive Robots for eldercare, we introduced the MOBISERV project and, subsequently, we presented the methodology applied for gathering and analysing requirements of all stakeholders. We summarised the main issues identified, which are considered vital in the context of MOBISERV, and briefly presented personas compiled and scenarios used to inform the design of the MOBISERV system. Finally, we have presented the MOBISERV platform and components.

We expect to have a first integrated prototype of the MOBISERV system by 2011. Thereafter, laboratory and field trials will be conducted in order to evaluate the proposed solution in terms of comfort, usability and safety and study user acceptance.

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