Ambient Intelligence in Assisted Living: Enable Elderly People to Handle Future Interfaces

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Abstract. Ambient Assisted Living is currently one of the important research and development areas, where accessibility, usability and learning plays a major role and where future interfaces are an important concern for applied engineering. The general goal of ambient assisted living solutions is to apply ambient intelligence technology to enable people with specific demands, e.g. handicapped or elderly, to live in their preferred environment longer. Due to the high potential of emergencies, a sound emergency assistance is required, for instance assisting elderly people with comprehensive ambient assisted living solutions sets high demands on the overall system quality and consequently on software and system engineering – user acceptance and support by various user-interfaces is an absolute necessity. In this article, we present an Assisted Living Laboratory that is used to train elderly people to handle modern interfaces for Assisted Living and evaluate the usability and suitability of these interfaces in specific situations, e.g., emergency cases.

Keywords: Ambient Intelligence, Assisted Living, User-Interfaces, Learning, Elderly People.

1 Introduction and Motivation

In most industrialized countries, demographical, structural, and social trends tend towards more and more elderly people and single households, which have dramatic effects on public and private health care, emergency medical services, and the individuals themselves. Humans live longer, mainly because of progress in medical treatment and pharmacies. The increasing average age of the total population

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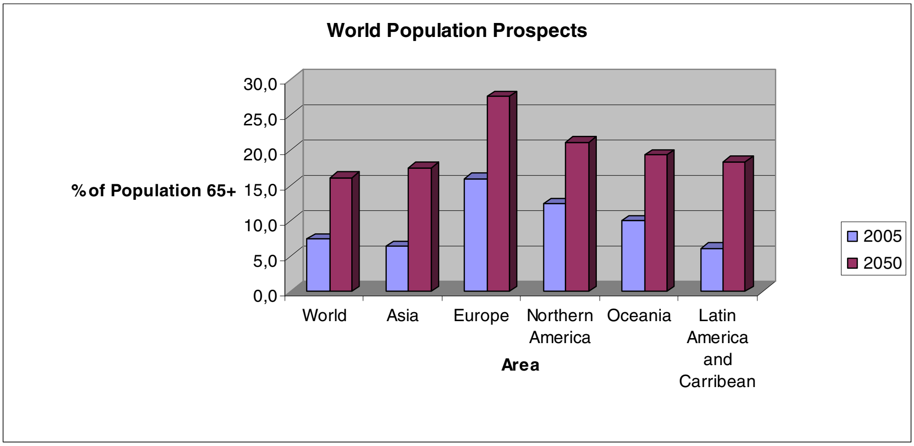

Fig. 1. Demographical Change according to the United Nations World Population Prospects: 2004 Revision, http://esa.un.org/unpp (last access: 2007-01-30)

(cf. figure 1) and the consequent rise of chronic diseases will result in a dramatic increase of emergency situations and missions within the coming years.

An exemplary study in the district of Kaiserslautern, Germany, shows that 44% of Emergency Medical Services' (EMS) system resources are dedicated to patients older than 70 years of age. This will result in even higher costs for such services or in a decrease of service quality or both. Assisted Living solutions for elderly people using ambient intelligence technology can help to cope with this trend, by providing some proactive and situation aware assistance to sustain the autonomy of the elderly, be helpful in limiting the increasing costs while concurrently providing advantages for the affected people by increasing *quality of life*. The goal is to enable elderly people to live longer in their preferred environment, to enhance the quality of their lives and to reduce costs for society and public health systems.

Today's commercially available products for emergency monitoring already use a broad range of modern technology (e.g., necklaces with emergency buttons, fall sensors in mobile phones with wireless notification of emergency services, vital data monitoring plasters, etc.). However, they are mostly closed, stand-alone systems with a limited ability to describe the actual situation, often just too difficult for the elderly people to operate and useless in emergencies.

Nevertheless, assisted living systems promise a huge potential for handicapped and elderly people suffering from all kinds of disabilities, e.g., gait changes, neurological alterations, visual acuity changes, vestibular compromise, spontaneous fractures and falls, cardiac alteration with syncope, or sudden changes in blood pressure. In our opinion this will only be the case if *three major requirements* are met:

1. They have to be ambient and unobtrusive to reach a high acceptance.
2. They have to adapt themselves to changing personal situations or capabilities of the individual and the environment to fulfill individual needs.
3. They have to provide their services in an accessible way to enhance usability.

Recent research and development in technology and software engineering produce a new generation of solutions that provide their services in a more flexible, adaptive, and anticipative manner compared to traditional products. Low energy consumption, wireless communication, non-traditional interfaces, small footprints, and the ability to sense the environment for useful information about the context of a situation allow designing and engineering solutions and applications that are ambient and unobtrusive, adaptive to the individual context, and provide easy to use interfaces for elderly and handicapped people.

2 Ambient Intelligence in Assisted Living

Systems that render their service in a sensitive and responsive way and are unobtrusively integrated into our daily environment are referred to as being *ambient intelligent* [1], [2]. Ambient Intelligence has been recognized as a promising approach to tackle the aforementioned problems in the domain of Assisted Living [3]. Living Assistance systems focusing on the support of people with special needs (elderly, disabled) in their own homes are called Home Care Systems (HCS) [4], [5].

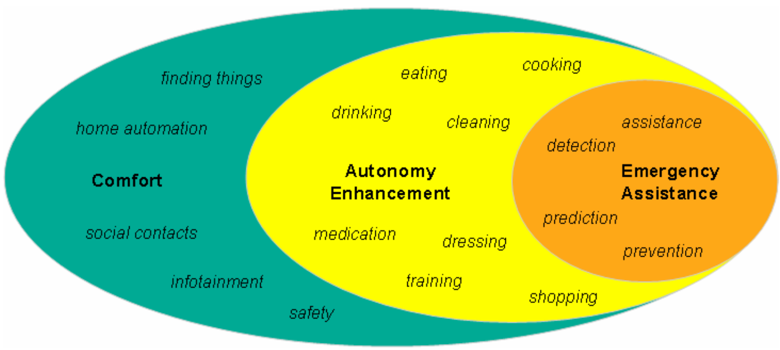

Fig. 2. Home care system domain

The aim of a HCS is to allow the assisted persons to live longer in their preferred environment at home, while retaining their independence, even when they have handicaps or medical diseases. As illustrated in Fig. 2 the HCS domain can coarsely be structured into emergency assistance services, autonomy enhancement services, and comfort services.

According to Oppermann et al. [6], AmI systems represent a new generation of systems that show the following *characteristics*:

- invisible, i.e., embedded in clothes, watches, glasses, etc.,
- mobile, i.e., being carried around,
- spontaneous (ad hoc) communication among the nodes,
- heterogeneous and hierarchical, i.e., they comprise different kinds of system nodes regarding their computational power and rendered functionality,

- context-aware, i.e., they are aware of their local environment and spontaneously exchange information with similar nodes in their neighborhood,
- anticipatory, i.e., acting on their own behalf without explicit extrinsic requests,
- natural communication with users by voice and gestures instead of keyboard, mouse, or text on screens,
- natural interaction with users by means of devices they are used to, e.g., clothing, watches, TV, telephone, household appliances. To this end the devices will be equipped with some kind of intelligence.
- adaptive, i.e., capable of reacting to all abnormal and exceptional situations in a flexible way.

With the aforementioned characteristics, AmI systems apparently bear some interesting potential for HCS. Because of its transparency, AmI technology enables novel ways of unobtrusive sensing. First, it will become possible to embed the monitoring and assistance devices invisibly in objects of our daily life, which reduces the stigmatization of these devices and thus increase their acceptance. Second, a considerable amount of sensors will be integrated in our living environment that can also be used to detect specific situations from an external perspective. With this, the availability of the sensing functionality does not depend on the actual usage of devices, e.g., the wearing of special devices, which is a serious problem these days. By fusing and drawing conclusions from different measured variables, the system can compensate the low accuracy and uncertainty of single sensor values, especially of environmental sensor values. On the one hand, an accurate automated system has a clear benefit compared to existing methods such as surveys in providing a continuous monitoring activity at home, i.e., a log along with times and durations for a wide range of activities. On the other hand, it also enables the system to recognize some mid-term or long-term trends and short-term deviations from the usual daily routine. Through enhanced self-awareness and context-awareness the systems are able to adapt themselves to changing situations (e.g., changing capabilities of the users). Thus, they can render their services at a new level of experience and enhance the quality of service.

Through early detection of upcoming or already existing problems, HCS systems can proactively assist people in preventing problems, e.g., by suggesting actions, or assisting them in critical situations, such as loss of consciousness, neurological, mental, or physical disabilities. Furthermore, the systems can provide an escalating assistance that also reduces the probability of false-positive or false-negative alarms. For instance, the system first provides early proactive assistance, e.g., by providing helpful instructions. Next, it integrates friends, family, or caregivers into the solution. In case of an emergency that cannot be prevented by the first two steps, it supports the assisted person to contact an integrated emergency medical service (EMS) and provides background information about the person's current state. The system interacts with humans in a multi-modal way using speech, gestures, and other forms of natural communication. Ideally, the users can interact with the system as they would do with other humans.

3 Challenges of Future Interfaces in Assisted Living

Besides the considerable system functionality of *Ambient Home Care Systems* (AHCS) we consider the combination of non-functional properties especially challenging. They have a major impact on the overall acceptance of the system and the chance to let elderly people learn to accustom themselves to the assistance provided. AHCS have to fulfill the following interface related requirements:

- Adaptivity: The systems need to adapt themselves to the context at runtime [6]. Adaptivity on various levels is considered an outstanding characteristic of AHCS. In order to render their service in the best possible way, the systems adapt themselves, according to the current situation, e.g. they reduce the interface complexity in case of emergencies to reduce the cognitive load. To support this, the systems must monitor their environment continuously, reason on necessary adaptations and make these adaptations, while still preserving quality.
- Natural, anticipatory human-computer interaction: AHCS have to provide human accessible interfaces for different target user groups: Especially for the people being assisted, who have limitations and handicaps, but also medical and care personnel, relatives, and maintenance operators. Multi-modal interaction paradigms that combine several modes (e.g., gesture, sound) are a good approach to enhance usability and accessibility. Anticipatory interfaces that proactively contact persons in certain situations are considered mandatory.
- Heterogeneity: Full-fledged Assisted Living systems will integrate several subsystems provided by different manufacturers. However, the user should be confronted with a homogeneous interface that integrates the services of the different subsystems in a seamlessly way.

At the same time, ethical, social, medical, and technological constraints must be considered.

- Formalization of domain knowledge: Developing AHCS requires domain knowledge to be transformed for machine processing. In many cases, this knowledge is difficult to formalize, e.g., the diagnosis of a disease pattern – decisions depend mostly on the expertise of medical staff that cannot be translated easily into information models and algorithms.
- Elderly people as the most important stakeholders: Some of the currently available solutions put a strong focus on the technological solution and neglect usability issues. Any HCS, which requires special skills from the elderly people to handle it, will fail. In addition, requirements are usually elaborated together with the end users. This is a difficult task since elderly people often have insufficient knowledge of the possible technical solutions available and are usually unaware of their increasing disabilities.
- Late learning: Still many of today's elderly people (esp. in Europe) are not used to modern IT systems and even worse, they are afraid of using them [7], [8]. Here big cultural differences become apparent. To meet this challenge, AHCS must either rely on the interaction paradigms they are used to or there must be special training programs offered to teach the users.

- Low acceptance of health assistance solutions: Assistance solutions that solely tackle health problems are hard to sell due to the negative associations raised by them and the social stigma identifying the assisted person's disabilities [9].
- Integration of available technologies: Many different electronic devices are available on the market. However, most of them do not provide standardized interfaces or integration specification. Many of these technologies have been developed for other purposes or are not intended to be integrated in larger solutions with other components. Good Usability of applications is essential [10], [11].
- Immaturity: Driven by upcoming problems due to the diverse changes, it is common sense that the assisted living domain will be a huge market. However there is only limited knowledge on how products will look, how they can be introduced to the market, who will pay for them, and how they will be accepted. To meet this challenge, the products must provide some kind of flexibility that will also affect the HCI.

4 Environment for Testing Future Interfaces for Assisted Living

Developing, testing, and training the elderly end users and measuring the impact of the assisted living solutions requires a realistic near-life environment in which training and evaluation can be performed. In order to cope with the different research and domain challenges in parallel, we have set up an Assisted Living Laboratory to analyze and develop sound assisted living solutions as well as engineering approaches.

The Assisted Living Laboratory is located at the Fraunhofer IESE in Kaiserslautern, Germany, and looks like the typical apartment of an elderly person: 60m² with entrance, living room, sleeping room, bathroom, and kitchen. It plays a central role in performing research and development in the domain of assisted living. Firstly, it is used to perform accessibility and usability tests with elderly people in a realistic environment (cf. Fig. 3). Secondly, it acts as an evaluation platform for all developments. Thirdly, it provides results of the tests and evaluations in a direct feedback loop for further adjustment of research and development. Finally, it is used as a demonstration platform for representing the results of the research in demonstration scenarios.

It is equipped with different sensing, interaction, and assistance facilities to provide the basic technology and measurement environment for implementing and evaluating assisted living scenarios:

- ambient sensors and EIB[1]-based home automation with ambient sensors integrated in switches, blinds or power sockets to keep track of the elderly person's activities while using the devices.
- position tracking solutions, e.g. a smart carpet equipped with RFID[2] tags, RFID tags mounted in the ceiling, ultrasonic and radio-frequency-based movement sensors. RFID provides a lot of other possibilities [12], however, security aspects must always taken into consideration [13].
- intelligent household appliances, such as refrigerators that warn about spoiled food or cups that signal drinking activities

[1] European Installation Bus.
[2] Radio Frequency Identification.

- an intelligent walking aid that recognizes falls and notifies a central assistance system
- vital data monitoring devices that collect basic vital information, such as pulse, skin temperature and skin humidity in an unobtrusive manner with bracelets and transfer this information to the emergency monitoring and assistance application
- an autonomous robot transportation platform: a robotic device that can act as an assistant and which is controlled by remote users involved in emergency assistance scenarios for multimedia interaction and transportation purposes
- an interactive TV-based video-telephony system for communication with relatives, health care staff or the emergency medical service
- remote care and information applications for relatives and care personal
- audio and visual devices in several rooms for multimodal interaction with the elderly end user to provide reminders or to ask for feedback in specific situations.

Fig. 3. A view into the living room of the lab

The software application running in the Assisted Living Laboratory is called amiCA[3]. Its goal is to support elderly people so that they can live longer in a self-determined way in their preferred environment. To this end, it monitors the daily behavior of elderly people and assists them to maintain their well-known daily routine (nutrition, movement, sleeping, and other regular activities) as a fellow occupant would do. Of special interest is adequate emergency assistance integrating relatives, health care staff, and emergency medical services. AmiCA will be iteratively evolved into a full-fledged AHCS prototype within the coming years.

5 Assisting Elderly People to Handle New Technology

Learning is a lifetime process of cognitive and social change. Consequently, when referring to the support of elderly people, life long learning is not just a catch phrase, indeed it is a chance to promote learning, through their lives. Especially the new and

[3] Ambient intelligent Care and Assistance system.

ambient technology offers us both the challenge and the opportunity to support elderly people by assisting them to participate in the information society [14], [15]. However, in order to understand the issues involved in enabling the elderly to cope with the new technology, it is essential that one of the primary objectives of our research should be enabling the elderly to become aware of the benefits of new technology [16], [3], [17], [18]. To include people who are rarely involved in technological activities, such as the elderly, they must be encouraged to involve themselves in our experimental studies aimed at improving the quality of their lives. It is possible that these studies will be faced with multiple methodological challenges, some of which, together with the delicate nature of some of the issues in question, could be detrimental to the implementation of the participation of elderly people. One possibility of reaching these goals is by the application of user-centered design methods to involve elderly people in the development from the very beginning [19]. This includes usability methods [20], such as thinking aloud studies, which can provide insight into their behavior, their attitudes and their anxieties and can, most of all, provide ideas of what technology would be beneficial to them in order to enhance their daily life.

6 Evaluation Approach for Assisted Living Solutions

The impacts of the Assisted Living solutions are measured in the Assisted Living Laboratory from several perspectives: The end users' point of view (elderly person), the professional point of view (medical impact), and the technological point of view. To consider the stakeholder interests adequately, all stakeholders (medical professionals, health care staff, the end user target group, and their relatives) have already been integrated into the requirements analysis and development process. They participated in the requirements elicitation, the validation of the underlying theoretical models for the application, as well as in test and evaluation. Our *evaluation program aims* to:

1. prove the validity of our application model,
2. enable the developers to decide on optimization of the solution, and
3. enable end users/stakeholders to draw conclusions on the benefits (as well as limitations) of adopting the solution in real life.

The *Objects of evaluation* are in compliance with the aims of the evaluation program:

- the verification and validation of the assessed needs and requirements of all stakeholders,
- an empirical validation of the application model of AmiCA,
- the adequacy of specific assistance settings (technology, interfaces, interaction schemes),
- the accessibility of specific human computer interfaces in different emergency situations,

- the effectiveness of environmental sensors for activity tracking and situation recognition, and
- the effectiveness of interaction schemes to resolve upcoming or acute emergency situations.

In order to perform the evaluation process, we use a) continuous interviews of lab visitors regarding usability, acceptance, suitability, relevance, b) formative evaluations of specific objectives, c) summative evaluations of specific objectives; and d) external field tests for long-term evaluations and long term simulation data.

7 Conclusion and Future Outlook

Assisted Living Systems with Ambient Intelligence technology raise new challenges to system and software engineering. The development of Assisted Living applications requires domain-oriented interdisciplinary research. Adapted engineering approaches are required to cope with the specific characteristics of ambient intelligent systems. Our experience showed that test and evaluation of technology and prototypes should be done in controlled environment simulating real-life, such as the Assisted Living Laboratory. Further evaluation then should be done under real life conditions with different perspectives. Finally, in any Assisted Living solution including Ambient Intelligence technology, adequate information and training activities must be arranged/planned to make the elderly people aware of the ambient and unobtrusive assistance in their home environment. We found out that elderly people are the most demanding stakeholders for IT-development – even highly sophisticated systems will not be accepted when they do not address the real needs of elderly and are not very easily accessible and usable.

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