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Towards Ambient Assisted Shared Living for the Elderly

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Abstract. As of today, the number of elderly people living alone in their homes and needing care taking is growing steadily in the whole western world. One state-of-the art approach is to enrich homes with a multitude of sensors and actuators, but the problem of loneliness is not sufficiently tackled.
In our vision, smart homes are enriched with sensors, but also audio-visual components such as cameras, microphones, and beamers that allow opening the boundaries of one single home to interact with remote relatives and friends intuitively, feeling almost physical presence while, of course, minding privacy and non-intrusiveness. To decrease loneliness, social activities like playing cards with one another or having dinner together are supported. Additionally, the sensory equipped home helps with everyday activities, such as finding reading glasses, heating control, or preventing accidents. Finally, the system also includes anomaly detection like emergencies based on home sensor information and computer aided reasoning. The novelty of the approach lies in including the relatives in the loop of support and – thus – avoids increased isolation usually fostered by a fully automated home. In this position paper, we describe the technical concept of the solution as well as the evaluation methodology.

1 Introduction

The number of elderly people living alone in their homes and needing care taking is growing within Europe and the whole western world. Providing smart homes to support every day activities of elderly people is targeted in many related IT

solutions and a necessary prerequisite to support living at home, but it often neglects the loneliness of the elderly which will only increase when being surrounded by a fully automated household.

Hence, the overall aim of our interdisciplinary work is to include elderly people into the lives of their relatives and friends possibly living abroad or far away and vice versa. Technology ranging from sensors to audio-visual input and output as well as a reliable (tele) communication should therefore be exploited and used to create an *Ambient Assisted Shared Living (AMASL) space*. Hereby, the impression of intuitive, almost physical presence of remote relatives and friends should evolve supported by non-intrusive technological solution which can be afforded by households with medium income. In this new field of research, the remaining challenging open research questions range from technical and economical feasibility evaluations and proposing new technologies (including privacy provisioning) to user acceptance and well-care studies.

The technological challenges result from the economic requirements to use low-cost and off-the-shelf multimedia equipment, like consumer cameras, easy-to-use input devices, and beamers but still providing the impression of directly interacting with remote relatives and friends. Hereby, *intuitive interfaces* and new, *high quality remote multimedia services* will be provided. Similar to being physically present, the system should make the remote relatives aware of important conditions of the household of the elderly person, like the current room temperature (important to estimate whether the elderly person feeling cold suffers because of malfunctioning of the heating or illness). The necessary *sensors should be non-intrusive up to "invisible"*, low-cost, robust, and energy-efficient. Together with anomaly detection services, the system will also be able to recognize emergency situations (e.g., a person has fallen and is lying on the floor). To *assure privacy*, the technical solution follows the design principle to keep sensor data local at the households and just send necessary status information to "third parties", like the communication network service provider. As cameras are commonly rated as intrusive technology, we will not use cameras for observing every day activities.

With respect to user acceptance and well-care studies, it is most important to develop a best fitting *evaluation method for assessing user acceptance and an improvement in well-being*. The proposed evaluation method relies on intensive testing carried out by a selected group of elderly test users who will use the *AMASL* installations for a couple of months. During this time, the test persons will be accompanied by the research team, periodically visited, and interrogated to answer the crucial questions about acceptance and (subjective) well-being. We will evaluate the general idea of ambient assisted shared living along the following use cases: (i) joint activities (like playing cards, having dinner together), (ii) remote help (like, helping to find out why there is a particular noise or smell in the house, why it is so cold in the house, or where the wallet or reading glasses are situated[1]), and (iii) emergency detection (like a person who has fallen down the stairs).

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[1] We assume that elderly persons are not as familiar with new technologies as their relatives are and therefore prefer to ask a trusted person rather than to interact with an automated smart home directly. However,

This position paper gives an overview of related work in Section 2, introduces the technical solution in Section 3, and discusses the setup of the field study in Section 4. We conclude this position paper with a summary and an outlook of work that is planned for the near future.

2 State of the Art

As the proposed concept for ambient assisted shared living is based on telecommunication-based solutions, smart home support, and ICT for elderly persons in general, we will summarize related work in these domains.

2.1 Telecommunication-based solutions to foster shared living

The Session Initiation Protocol (SIP) is an IP-based protocol meant for managing communication sessions between two parties (IETF RFC 3261). In the last years, SIP became very popular in the area of Voice-over-IP (VoIP), i.e., telephony over the Internet, but SIP can be used to manage sessions of any type, including VoIP, video conferences, gaming, CSCW, etc. SIP offers five categories of functions: (i) User location determines the current location or address where a caller can find the callee, (ii) user availability determines whether a callee is currently reachable, (iii) user capabilities, (iv) session setup is meant for determining and exchanging communication parameters that, e.g., describe the used codecs, and finally (v) session management for creating, adapting, and tearing down communication sessions. For exchanging data describing important properties of the session and session parameters, the Session Description Protocol (SDP), described in IETF RFC 4566, is used by SIP. It is important to note that neither SIP nor SDP themselves transport any media data. Once a session is established, the clients then may exchange media data either directly, or via proxies, here again using other protocols, e.g., the Real-Time Transport Protocol (RTP) for audio and video data or any non-standardized protocol designed by the application programmers (IETF RFC 3550).

As said, real-time data like speech or video usually is transported by RTP. Such continuous data requires a very smooth and regular transport by the network, and both sender and receiver are tightly synchronized. RTP is not suited well for discrete communication, where single events must be transported, like communicating that one user has just clicked on a button. For such cases, a set of protocols enabling so-called Web services fit much better. Web services have been defined by the World Wide Web Consortium (W3C, http://www.w3.org/) in order to support interoperable machine-to-machine interaction over IP networks. Web services are comparable to other approaches like the Common Object

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the system will be designed that way that elderly people will be also informed about the status of their household and can make use of this information.

Request Broker Architecture (CORBA) described by the OMG, or Remote Procedure Calls (RPC) described by Birrell and Nelson (1984). In contrast, they are based on techniques known from the World Wide Web. Similar to SIP, Web service protocols enable registering and finding services (Universal Description Discovery and Integration, UDDI), describing services (Web Service Description Language, WSDL), and finally calling services (Simple Object Access Protocol, SOAP). All of these protocols are based on XML (W3C, http://www.w3.org/).

For AMASL, a realistic visual presentation of each person is very important. Hereby, persons can be shown in several ways. The most basic way is to use a common TV set. Due its limited size and the fact that TV sets are often put at fixed locations in the living room, this is not an ideal solution. A similar approach would be to use a possibly large computer monitor. Since monitors are usually much cheaper than TV sets, several of them could be put into a household with affordable costs. However, similar to TV sets, monitors do not come in overly large sizes and thus they do not create a realistic impression of a shared living space. Another way of visualizing persons realistically is to use so-called Head-Mounted Displays (HMDs). These are like eyeglasses, but show the output of a computer instead. Unfortunately, HMDs are rather bulky and using them usually prevents people from seeing the real surrounding (so-called see-through HMDs are extremely expensive and often limited in their capabilities), and thus HMDs are not useful at all in the context of AMASL.

The best solution for visualizing other people and spaces seems to use off-the-shelf computer projectors. In the past there have been various research projects on how to use projectors for virtual reality human computer interaction, and e-learning (Cruz-Neira et al. 1992). Especially video wall displays have been used for many projects in the area of collaboration in working environments (Otto et al.). People are meant to stand next to such a display and interact with it, e.g., by moving virtual objects around. Interaction can be determined by touch-sensitive surfaces or through gesture recognition by video analysis. Because of the closeness, video wall displays must provide a high resolution, and shadows caused by front projectors present a problem. Therefore, video wall displays are usually built by an array of back-projected canvases. This way, no shadow is cast by people standing in front of the display, and the total resolution is the sum of the individual resolutions of the single projectors. On the other hand the costs and the need for space increase significantly. Alternative approaches use a projector that is mounted above the canvas.

In general, using projectors for creating an immersive presentation of real people is also problematic due to the strict 2D technology. However, technologies for 3D presentations in principle are available, always requiring that left and right eye of the observer receive different pictures. One technology for 3D displays is given by LCD shutter glasses, which must be worn by the users (Woligroski). The glasses must be synchronized with the display, usually an LCD monitor, which

sequentially shows images for the left and right eye, the other eye being blocked by the shutter glass. Another technology that is best suited for projectors is to send pictures for the left and right eye using orthogonal polarization. Again, users have to wear glasses, which have different polarization filters for left and right eye. Both approaches have drawbacks and are usually expensive when being used for projectors (e.g., require the use of two projectors), or require a high amount of skills to be realized (Bungert).

However it is known that when using only one eye (or ear), a pseudo-3D effect can be emulated by moving the head from left to right, i.e., an observer is able to construct 3D information from 3D information. By using head tracking this can be used for increasing the realism without a high overhead (Lee).

Human-Computer Interaction (HCI) can be done with various means, including dedicated input devices like the computer mouse, keyboard, etc. Additionally, wearing data gloves or video analysis allows to recognize gestures, here trying to make HCI more natural. However, gesture recognition demands learning gestures and requires a significant amount of concentration and skills, which make their use in AAL problematic. Recently the gaming industry has provided innovative HCI equipment to make HCI more realistic. This includes the Wii Remote (NINTENDO) and only recently the Project Natal launched (MICROSOFT) and Playstation Eye by (SONY). While the Wii works like a mixture between a 3D mouse and a TV remote control, both Project Natal and the Playstation Eye provide gesture recognition and face tracking through video analysis.

2.2 Smart home approaches

Living in the western world is increasingly assisted by a multitude of sensors and actuators enabling home service automation supported by local networks and available broadband access networks. International research projects focused on investigating new technologies for future smart homes are, e.g., AMBIENTE (Fraunhofer Institute: AMBIENTE), AMIGO (Amigo Project), inHaus (Fraunhofer Institute: inHaus), EasyLiving (Brumitt et al. 2000), AHRI (Georgia Institute of Technology), The PlaceLab (House_n), SmartHOME (Universität der Bundeswehr München), T-Com-Haus (T-COM), and MavHome (University of Texas at Arlington). These research projects demonstrate the international interest in technologies for future home environments, which are highly attractive to support in particular elderly people. Research is carried out to explore the technical feasibility of smart homes, but an increasing interest can be detected in usage and acceptance studies of these new technologies. For example, the living labs of the MIT project PlaceLab (House_n) investigate the behavior of test persons in longer time periods to derive realistic usage results. Our research for ambient assisted follows this line of research for elderly people to come up with realistic and helpful solutions in a field where these factors are not sufficiently clear yet.

The Fraunhofer IST project AMIGO proves that home automation products can be successfully developed for the market, but complex installations and missing interoperability or usage scenarios are inhibiting the breakthrough. A possible technical realization of smart living is usually implemented by integrating home automation technology based on interconnected sensor- and actuator technology, entertainment technology, and PCs (Technology Review 2007). For communication, Ethernet and wireless LAN is used to control heating and air conditioning, access to the house (e.g., using finger scans), alarming, novel displays integrated into furniture (like tables and walls) to display home status information of devices like the oven, washing machine, and air conditioning.

Smart living for elderly people and people needing care-taking envisions a step into new technology for better well-being and quality of live. Smart homes are envisioned to take away the burden of difficult every day activities which nowadays, e.g., often force people to leave their homes and change to an asylum for elderly people. The sensory equipped home should be able to detect important anomalies in the elderly person's behavior, such as, dehydration and collapses. By doing so, the medical risk of living at home can be minimized.

The AMASL project goes one step further to integrate relatives actively in such every day activities and to research, to which extend a telecommunication-based solution can integrate both smart home and communication for social inclusion (e.g., playing cards together), providing help for daily activities (e.g., controlling the heating), and assistance in cases of emergency while still providing privacy to a high degree.

2.3 ICT for elderly persons and their well care

Information and Communication Technology (ICT) characterizes today's society. Within the next few years, we will have to face an increased number of elderly people side by side with technological developments and it is not clear how to best use ICT for elderly persons.

The Norwegian Board of Technology has carried out investigations related to two major topics in this context. These topics are: (i) Use of ICT in the daily lives of the elderly persons, and (ii) Use of ICT in health care and welfare services for old people and people with dementia.

Hereby, it has to be noted that elderly people are a heterogeneous group. They have different needs for help, different capabilities, and different learning abilities. However, in many of these cases, smart home technology may be used for the benefit of the elderly persons as argued below:

(1) *Mastering the daily life*. For elderly people the use of smart home technology is expected to make them feel secure (e.g., warning in case of an oven overheating). ICT may aid elderly people to memorize things and,

thus, to master their own housing situation. As a consequence, it becomes possible to remain living at home for a longer time.

(2) *Increase social contact*. Social contact may be increased by user-friendly communication technology, including more human care from relatives, nurses and others. On the other hand, elderly people often have objections to ICT. Information and knowledge about ICT will be important to increase user acceptance (see, e.g., conference ICT for elderly people 2000).

In a study by Eggermont et al. (2006) based on dialogs with senior citizens about integrating ICT into their everyday living, some important results have been derived: The elderly would like to see that ICT enhances the quality of life. For instance, ICT may support the social relationships of the elderly and help them to fight loneliness. ICT may also enhance their physical condition and help them live independently. ICT may offer them possibilities to stay mobile, to relax, to learn and to work, in other words, to fully participate in society. Furthermore, senior citizens set two important conditions. First, new technology must be easily accessible to them, which requires that future ICT devices (and their developers) keep the typical physical limitations of the elderly in mind, as well as their lack of ICT related knowledge and skills. A second important demand with regard to future ICT applications is that they are reliable and safe and do not pose a threat to the privacy of senior citizens.

Because of age-related changes of potential test persons, multidisciplinary research on the technology-gerontology interface is important for better understanding how to adapt technology to the needs of older people and how to train the elderly to use technology (Oppenauer et al. 2007).

3 Technological Concept

The aim of the project is to provide a system for social interaction, communication, and remote help. Social isolation should be decreased by giving the impression that relatives, friends, or professionals are physically near, within the same physical space. This impression should be achieved by an audio/visual presentation, which on the one hand should be as realistic as possible, but on the other hand also affordable. Furthermore, the whole system should be simple to be used, since elderly people cannot be supposed to be able to master complex user interfaces.

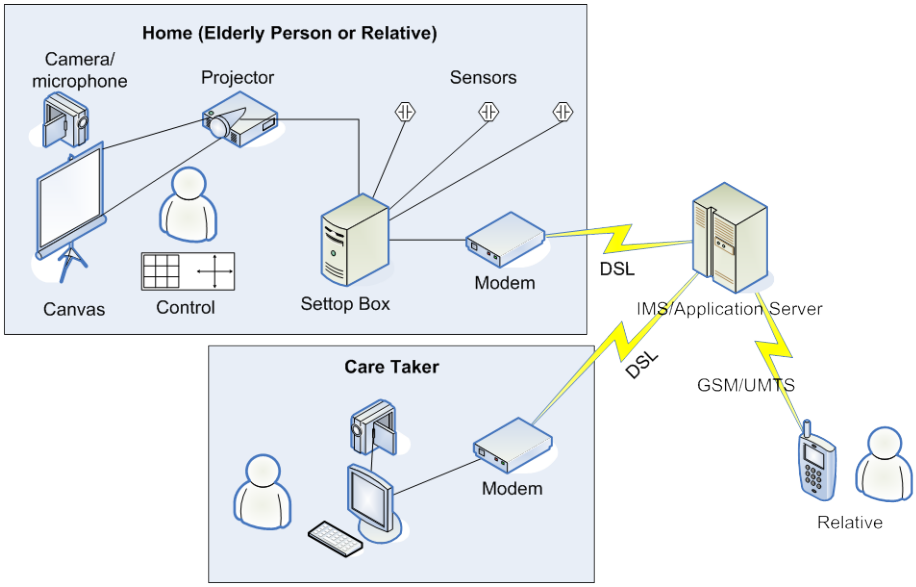

Figure 5: *AMASL* architecture.

The AMASL system architecture is shown in Figure 1. The audio/video equipment is built into the homes of elderly people and their relatives, who can be also mobile. The canvas and projector should be installed at a convenient place where people plan to spend time with their relatives and friends. The main component is the settop box, which is planned to be a off-the shelf computer, like a Mac Mini or Linux-based PC. Interaction is planned to be done in an intuitive way, currently we are focusing on the Wii Remote as a simple controller which is very similar to TV remote controls, something elderly people are likely to be used to. Currently it is not planned to add 3D capabilities, since this would increase the price of such a system significantly. However, we plan to apply face tracking by using the open source library OpenCV (Bradski and Kaehler 2008) and use it to emulate a kind of window into the home of the communication partner. We expect that this simple technique adds a considerable amount of realism to the presentation.

Homes are additionally equipped with sensors that measure the state of the home, track items or the inhabitants themselves. To be most convenient and useful, sensors should communicate using standard wireless networks (like ZigBee) and work energy-efficiently and long lasting. The main task of the sensors is to support communication and cooperation between people, enabling for instance relatives to help their parents remotely. Tracking of objects, e.g., the key, the reading glasses, or the TV remote control should make it possible to find such things that are regularly lost. Object tracking is done by attaching a low-power small ZigBee sender to an object which continuously sends a beacon signal to base stations situated in each room (Figure 2). Base stations near the sender read the signal and provide information about the signal strength to the home's settop

box. The settop box then computes an estimate for the object's position. We have carried out several experiments using equivalent BlueTooth sensors and neural networks that have been trained for estimating positions. Results indicate that under ideal conditions, a positioning accuracy down to 10 cm in theory is possible. In practice, especially if objects move and are attached to human bodies, an accuracy between 1 and 4 meters can be expected. Identifying the room in which the object is lying can be done with very high accuracy, however.

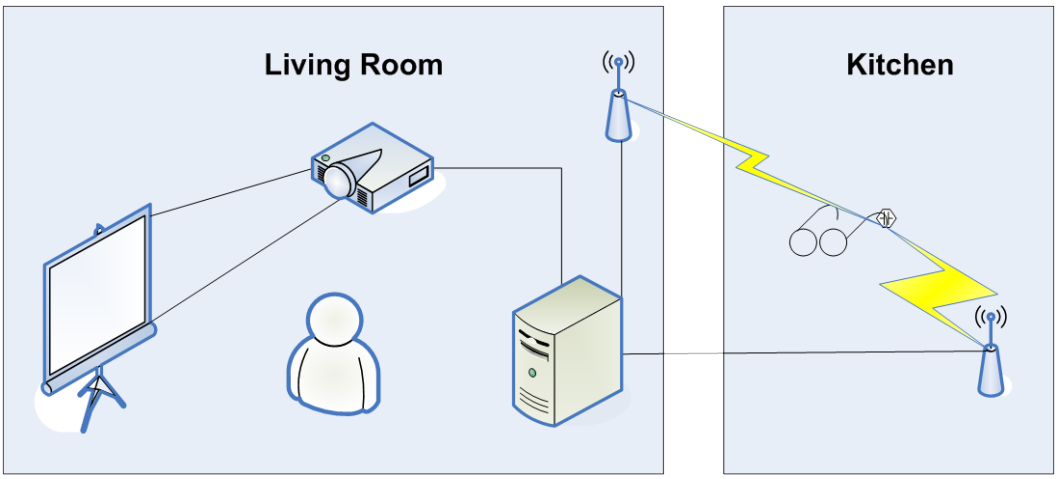

Figure 6: Object tracking using ZigBee senders attached to objects.

Additionally, relatives should be able to remotely check the states of the houses, like whether windows or doors are open, whether water is flowing, or whether the oven is on. Therefore, we will install appropriate contact detectors, movement monitors, temperature sensors, etc. Finally, sensors should also be used to detect emergency situations, i.e., situations where elderly people require help but are not able to call for help themselves. Basically, alarm detection can be done in two ways. First, sensors can record normal behavior of the inhabitants, and learn what is to be expected. Any behavior that is abnormal in some way can then, in principle, trigger an alarm. This approach requires some time for training what is normal. This system detects alarms implicitly and is likely not to trigger an alarm immediately after an accident has occurred. Sensors can also be used for detecting accidents explicitly, for instance by measuring the acceleration of an arm. In our project we will mainly focus on implicit accident detection, but also experiment with explicit detection using various sensor technologies. However, the sensors are not meant for direct surveillance, i.e., audio/video is only used for calls, but not for alarm detection. If no calls are going on, the inhabitants must have the guarantee that they are not recorded.

At the center of AMASL we will use the IP Multimedia Subsystem (IMS), which is a collection of IP-based protocols defining the core of the next generation

telecom networks, allowing telephony, video conferences, and general telecom services to be run in an all-IP packet switched network. IMS is currently standardized by the 3rd Generation Partnership Project (3GPP, http://www.3gpp.org/), an industrial forum in charge of all specifications of 3G-wireless communication. However, IMS can be used for wireline access networks as well, including ADSL or cable. Signaling in IMS is done using SIP, and requires from the client only little more information like authentication.

All Web service based applications are run on a central IMS application server. AMASL applications will include for instance card games, a digital photo album shared with friends and relatives, and presenting news, weather and health information. Other services that might be of interest for elderly people include for instance mental training, Karaoke, fitness training, ordering food or medicine, etc.

For remote help and alarms in AMASL it is planned to run all sensor inference algorithms locally inside the settop box, and only in case an alarm is triggered, aggregated information is sent to the application server.

Scientific challenges from the technological side include improving realistic communication at low cost, experimenting with innovative and intuitive HCI technologies, and machine learning and inference of sensor data that describe daily routines and, consequently, also detect anomalies, all in the special context of AAL.

4 Planned Field Study

To evaluate the presented solution, a methodologically advanced field study will be carried out. In contrast to short term test evaluations lasting up to a few hours followed by asking the test persons to fill in a questionnaire, we aim at an extended user study over a few months to derive in depth results about user acceptance and well-being. The main research questions that should be addressed are:

(1) How does the *ambient assisted shared living* system influence the social life of the elderly and their family?
(2) Is it possible to support social integration of the elderly person in the family using the *ambient assisted shared living* services, in particular the multimedia communication services?
(3) Is it possible to support the elderly person in daily life activities using the *ambient assisted shared living* system?

4.1 Study design

To answer the research questions in the planned field study, a case study design with a mixed method approach is chosen. Due to the small sample size and the

openness of the questions, the focus is set on qualitative methods. Quantitative evaluations will be added where they are appropriate.

Case study design

The case study design involves an intensive exploration of a single unit of study, such as a person, family, group, community, or institution or a very small number of subjects who are examined intensively. Although the number of subjects tends to be small, the number of variables involved is usually large. In fact, it is important to examine all variables that might have an impact on the situation being studied (Burns, Grove 2005).
In a case study, the case itself is central to the researcher. The focus of case studies is typically on determining the dynamics of why the individual thinks, behaves, or develops in a particular manner. Data are often collected that relate not only to the person's present state but also to past experiences and situational and environmental factors relevant to the problem being examined (Polit, Hugler 1999). The greatest advantage of case studies is the investigation depth that is possible when a limited number of individuals are being investigated.

The study methods

The methods used in the field of this study to answer the research questions are both of qualitative and quantitative kind, where the focus is set on qualitative methods. Among the qualitative methods available, the following, selected methods will be used: notes of qualitative observations, in-depth interviews, and narrative documents such as diary.
The aim of any qualitative research data collection tool is to explore the "insider perspective" (Taylor 2005). For quantitative investigation, structured interviews will be used (e.g. questioner for social isolation, evaluation of impairments).

Ethical issues

Ethical issues have to be addressed to base the study on serious ground and to enable a trust-relationship between the test users and investigating researchers. From an ethical perspective, the following issues have to be addressed:

(1) *Informed consent*. To avoid harming participants in a study it is essential to gain their agreed consent to taking part (Iphofen 2005). The participants in this study are fully informed about the study purpose, participant status, sponsorship, procedures, type of data, participant selection, their right to withdraw, and contact information. The researcher presents a summary of essential information in a short form orally and the full information in

writing as well. The researcher documents the informed consent process by having participants sign a consent form.

(2) *Right to privacy and anonymity*. All research with humans constitutes some type of intrusion into the people's personal lives. Researchers need to ensure that their research is not more intrusive than it needs to be and that the participant's privacy is maintained throughout the study (Polit, Hungler 1999). To safeguard the confidentiality of participants, the researchers in this study implement following steps:

- The research information will not be shared with strangers or with family members. Identifying participant information (name, address) will only be obtained when it is essential.
- The access to identifying information is restricted to the researcher.
- Identity related information is not entered to computer files.
- Identity related information is destroyed as soon as possible.
- Because of the small number of respondents and the rich descriptive information it is essential to protect the identities of the participants adequately (Polit, Hungler 1999).

(3) *External review*. Before the proposed research plan and procedures are implemented, the ethical dimensions were subjected to external review. The highlighted issues of the ethical report are implemented in the procedures of the project and some are pointed out in the following conclusion. At first, it has to be insured that all information for the participants are given in a clear and concise way. Furthermore, the researchers in the planned field study have to prove that the application causes no risk of injury (e.g. risk of falls through cable). The project leaders have to define the liability and the participants have to be informed. Moreover, the potential test users must have the ability to express consent to attend the research project. Nevertheless, the researchers have to ensure the protection of data privacy.

4.2 On selecting test users

For this project, one of the challenges is to find a suitable set of persons willing to participate in the study. A first step is the development of a profile description of the potential test users and a second step is the advertisement and selection of participants. In particular when working with elderly people, experiences in other projects have shown that a trust-relationship is very important for a successful selection and satisfactory participation in such a study. As a consequence, we will establish the contact between the accompanying researcher and the elderly participant in early stages of the selection process.

The critical first step in qualitative sampling is the selection of a setting with high potential for information richness. Hereby, the key in qualitative studies is to extract the greatest possible information from the few cases. The profile description of the persons (elderly and relatives) contains (i) age, (ii) physical and cognitive abilities (e.g., we will focus on test users experiencing some impairments to move easily out of the house), (iii) living facility (including technology available), and (iv) the fact that they live alone.

In the second step so far, we used the possibility to advert the research project in one of the project's partner's (Red Cross, one of the biggest NPOs in Austria) newspaper and journals for elderly people to attract suitable candidates, as well as contacts to forums of elderly people. To give an impression of the responsiveness of the people, we can only present preliminary numbers. The customer's response regarding to the newspaper article was an amount of nine elderly people within approx. two months who showed interest in participation. Interested persons were in general female and in average 80 years old. Most of them suffer of chronic diseases which complicates leaving their homes. The request they share all together is, that they want to have more and easier contact to their family.

5 Conclusions and Future Work

In this position paper, we described the requirements, the design, and the evaluation methodology of an ambient assisted shared living space. The approach aims at using sensory and multimedia communication technology to include elderly people into the homes of their relatives and friends. While the sensory equipment should be non-intrusive and nearly invisible, the multimedia communication equipment should provide high quality and intuitive user interfaces. The technical solution therefore includes sensors for in-door object location tracking and sensing of important states of the house (e.g., heating, closing status of doors and windows). The multimedia I/O system includes components such as cameras, microphones, and beamers. First prototypical implementations have been carried out using the Wii Remote for intuitive user interactions. For providing the telecommunication infrastructure, the IP Multimedia Subsystem (IMS) is currently evaluated.

The approach is followed in a recent interdisciplinary research project termed AMASL which will answer research questions about the feasibility and usefulness of the envisioned technological solution along three classes of applications: (i) supporting social contacts, (ii) helping with daily routines, and (iii) emergency detection. In all use cases, the inclusion of relatives and friends is supported. In future work, we will provide prototypes and, finally, the results of the field study planned.

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