Living Assistance Systems
- An Ambient Intelligence Approach -

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ABSTRACT
In this paper, we present an integrated system concept for the living assistance domain based on ambient intelligence technology and discuss the resulting challenges for the software engineering discipline. Automated living assistance systems represent a promising approach for the prolongation of an independent and self-conducted life of handicapped and elderly people thereby, enhancing their quality of life and minimizing the need for manual social/medical care. It is demonstrated that living assistance systems must realize flexibility and adaptability at the algorithmic, architectural and human interface level to an extent unknown in present systems. The construction of robust, trustworthy living assistance systems is an extremely challenging task and requires novel approaches for dependable self-adapting software architectures, resource efficiency, and self-adapting multi-modal human-computer interfaces. The resulting consequences and challenges for the discipline of software engineering are outlined in this paper.

Categories and Subject Descriptors
C.2.4 **[Distributed Systems]:** Distributed Applications, C.3 **[Special Purpose and Application-Based Systems]:** Real-Time and Embedded Systems, C.4 **[Performance of Systems]:** Reliability, Availability, and Serviceability, D.2.12 **[Software Architectures]:** Domain Specific Architectures, D.2.13 **[Reusable Software]:** Domain Engineering, J.3 **[Life and Medical Sciences]:** Health, J.7 **[Computers in other Systems]:** Real Time

General Terms
Design, Reliability, Security, Human Factors, Theory

Keywords
Assisted living, home care systems, elderly care, ambient intelligence, adaptivity.

1. INTRODUCTION
With sufficiently powerful and cheap computers on a small VLSI chip, information technology has stepped into a new era of computing called ubiquitous or pervasive computing [28]. The negligible size and costs of those computers make it feasible to integrate them in practically all items of our daily lives, such as furniture, clothing, tools, households, food, etc., making these objects smarter and easier to use. Instrumented with WLAN interfaces, GPS-based positioning systems and special sensors, these chips become even more powerful, providing the power of self-localization and the ability to sense their environment for useful context information, e.g., by means of RFID technology [15]. Environments equipped with such sensitive and responsive computer nodes are referred to as being *ambient intelligent*. Ambient Intelligence (short: AmI) [1] is considered the enabling technology for a new generation of systems, which provide their services in a flexible, transparent, and anticipative manner requiring minimal skills for human-computer interaction.

In general, applications of AmI technology can be conceived in many areas, e.g., intelligent working environments or home automation [13], to name but a few. However, there is a huge potential in the area of living assistance 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.

The ongoing aging process that is noticeable in all industrialized societies, especially in North America and Europe, has raised serious problems with the growing share of handicapped and elderly people being unable to conduct their normal lives at home, thereby becoming more and more isolated from family, friends, and public life. Governmental bodies such as hospitals, healthcare institutions, and social care institutions have expressed their concern about this development, which

(i) creates enormous costs for the public and the individuals, caused by the need for intensive care in elderly people care homes, and
(ii) dramatically decreases the quality of life of elderly people with the morbidity, which results in limitations to activities of everyday life:

In the last few years, ambient intelligence technology has been recognized as a promising approach to tackle the aforementioned problems. Unfortunately, engineering such systems is a non-trivial task, and convincing solutions are still missing. The purpose of this paper is twofold: (i) to propose an integrated system approach for living assistance systems based on ambient intelligence technology and (ii) to identify challenging research topics for the software engineering community.

The paper is structured as follows. In chapter 2, we will provide a classification scheme for these systems. An important class of living assistance systems are home care systems that provide support for handicapped and elderly people within their own homes. These systems are considered in more detail in chapter 3. Chapter 4 starts with a short overview of the main characteristics of ambient intelligence systems, followed by a description of a home care system based on this approach. Chapter 4 concludes with an examination of outdoor living assistance systems based on ambient intelligence technology. Chapter 5 discusses the impact of living assistance systems on the software engineering discipline and lists the most challenging open research topics to be solved in order to build and operate trustworthy, dependable and robust systems. Chapter 6 gives a short overview of related projects. Chapter 7 summarizes the most significant results of our discussions.

2. LIVING ASSISTANCE CLASSIFICATION

The potential range of support systems belonging to the living assistance domain is huge. The matrix in Fig. 1 is an attempt to structure this domain into stereotypical subdomains:

	Emergency Treatment Services	Autonomy Enhancement Services	Comfort Services
Indoor Assistance	emergency prediction emergency detection emergency prevention	cooking assistance eating assistance drinking assistance cleaning assistance dressing assistance medication assistance	logistic services services for finding things infotainment services
Outdoor Assistance	emergency prediction emergency detection emergency prevention	shopping assistance travel assistance banking assistance	transportation services orientation services

Fig. 1. A Classification Scheme for the Living Assistance Domain

It is worthwhile distinguishing between indoor and outdoor living assistance. Systems for indoor living assistance work in a well defined locality scope: in apartments, homes, cars, hospitals, and elderly care homes. Indoor living assistance systems can be built upon a well-known hardware/software installation in the location, thereby providing a stabile environment.

Outdoor living assistance systems support persons during activities outside their homes: while shopping, traveling, and during other social activities. These systems are faced with highly unstable environmental conditions such as availability of wireless communication, accessability of network services, and context information acquired via sensors, which adds another level of complexity and uncertainty to those systems. Also challenging for outdoor systems are elders who cannot walk and/or coordinate their physical activites in order to participate in activities outside their homes, travel, and interact in social activites.

Another useful classification dimension is the type of service provided. According to Fig. 1, we distinguish between three types of services:

(a) Emergency treatment
(b) Autonomy enhancement
(c) Comfort

We consider emergency treatment to be the kernel of any living assistance system. It aims at the early prediction of and recovery from critical conditions that might result in an emergency situation and the safe detection and alert propagation of emergency situations. Examples of emergency situations are sudden falls, heard attacks, strokes, panics, etc.

Autonomy enhancement services are the term we use to denote all services that make it possible to abandon previous manual care given by medical and social care personnel or relatives, and replace it by appropriate system support. An example of this type of service is a cooking assistance system for people with visual defects. The appropriate instrumentation of a stove may enable those persons to cook safely without the need for assistance by social care workers.

Comfort services cover all areas that do not fall into the categories (a) and (b) above. Examples of comfort services are social contact assistance, infotainment assistance, logistic assistance, etc. It is clear from the discussion that comfort services do not have the same importance and social impact as the other two categories, although there might be a huge market for those systems.

3. AN EXAMPLE: HOME CARE SYSTEMS

Living assistance systems focusing on the support of handicapped and elderly people in their own homes are called home care systems.

Due to the phenomenon of the aging societies in the western hemisphere, home care for handicapped and elderly people creates continuously growing social and financial burdens.

Some figures from Europe [24] and the United States demonstrate this dramatic development [4]. According to estimates in 2003 [10], the number of people in Germany who are older than 70 will increase from 10% at present to 18% by the year 2040. About 1.5 million Germans currently spend their life in elderly care homes. This number will double by 2020. Italy presently has the largest proportion of individuals over 65, representing 18% of the population, with the average age of the total population being 40.

The United States remains at a rate of 13% senior citizens because of the demographic variables of immigration and increased fertility rates. In the United States, the population in institutionalized elderly care homes is 3-4% with community services providing for “aging in place”. This number will double by 2020 as the “baby-boom” generation begins aging.

Life expectancy has dramatically increased in Europe and the western hemisphere, with the average age being 78.

Elderly people have a high risk of suffering from typical high age diseases such as: (a) hypertension, (b) stroke, (c) heart disease, (d) cancer, (e) Parkinson’s disease, (f) dementia including Alzheimer’s, (g) multiple sclerosis, and (h) osteoporosis. It is also noteworthy that 50% of all injuries occur to elders in their homes. In the population of individuals between ages 65-74, 25% report one fall. This is also related to decreased physical abilities [12]. It is also critical that society be aware that 40% of people over 70 years of age have chronic illnesses with resulting activity limitations. Acute health events for individuals over 65 increase to 1 per year [4, p. 95-96].

The costs of providing care for this population increases with a decreasing age-dependency ratio defined by the number of working individuals divided by the number of handicapped people of a country. This ratio will dramatically approach 1 in the next 10 to 20 years.

It is obvious from the above figures that society has to react to this dramatic process. Therefore, innovative solutions for living assistance systems must be envisioned in order to cope with this development. Automated home care systems based on ambient intelligence technology are a promising approach. They aim at the prolongation of a self-conducted life of assisted persons in their own homes, reducing the dependency on intensive personal care to a minimum and thereby increasing the quality of life for the affected group while substantially decreasing the costs for society.

According to the classification scheme given in the previous chapter, home care system services include emergency treatment, autonomy enhancement services, and comfort services in general. Although all three service categories are desirable, emergency treatment is mandatory in any living assistance system. The following more detailed discussion will focus on emergency treatment as an example, since it puts extreme burdens on the robustness, accuracy, dependability, and adaptivity of home care assistance systems.

The ultimate goals of any emergency treatment system must be

(a) *high recall* in detecting every real emergency immediately

(b) *high precision*, to prevent invalid emergency detections and alerts as a consequence of misinterpretations.

Requirement (a) is mandatory to provide a trustworthy service quality to the affected persons in case of emergency situations that should be much safer than anything else they experienced before. Requirement (b) is essential for economical reasons, since invalid emergency alerts may unacceptably increase care costs and decrease trustworthiness. It is highly desirable to extend a pure emergency detection service by an emergency prediction service, which attempts to recognize a critical health condition before it escalates into an emergency. As a reaction to the detection of such critical situations, the service may assist the person in preventing the emergency, e.g., by suggesting appropriate medication.

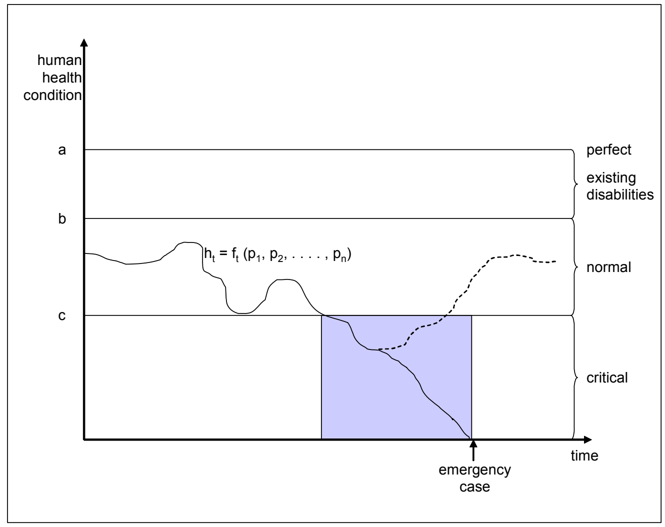

Fig. 2. A Human Disability Model

The realization of such a high quality emergency treatment service requires a sound disability model of the assisted people which has a precise notion for critical situations and emergency cases. Such a model must allow personalizing the service, i.e. customizing it by taking into account the existing disabilities of a person. The idea of a disability model is illustrated in Figure 2.

The figure shows three horizontal lines: (a) defines a fictive perfect health condition of a human without any disabilities, (b) defines a particular person's best possible health condition regarding existing disabilities, and (c) defines the borderline between normal and critical health conditions. Taking into account existing disabilities of a person is mandatory for any emergency treatment system related to catastrophic events such as hip fractures secondary to a fall, in order to prevent misinterpretation of situations. For instance, a person with locomotor disturbance will move slower than a person who does not suffer from this disability. Slow movement of such a person must not be misinterpreted as a critical situation resulting in a false emergency alert.

The fictive curve below line (b) defines the overall health condition of the person as a function over time. The function depends on a large, unknown number of parameters and is virtually impossible to describe in a precise mathematical sense. The ultimate goal of any emergency treatment system is to detect the entering of the shadowed area in Fig. 2. In such a case, the emergency treatment system must undertake all possible actions to prevent the emergency (animation for medication, drinking, etc.), thereby bringing the health condition of the person back to normal (dotted line).

Approximation of this model may be achieved by continuously acquiring data about a person's body functions such as temperature, blood pressure, and pulse frequency, together with data on his short-term, medium-term and long-term behavior. These data are evaluated and condensed. Logical predicates called *situations* are used to identify states or state transitions of the person under observation. Examples for situations are:

- Person X has a blood pressure of 178
- Person X is sleeping
- Person X has not taken medicine M
- Person X has fallen down
- Person X has not responded to call

Several situations may be combined in logical expressions, resulting in a more complex situation, as for instance

- (Person X has fallen down) AND
  (Person X has not responded to call for S seconds)

If such a critical situation occurs, it is taken as evidence that a person's health condition has entered the shadowed region in Fig. 2, which now requires appropriate system actions. In order to decide on whether a situation is critical, it is necessary to test it against a set of critical situation indicators.

The principle operation of the system now works as follows: Whenever the system moves from situation s_i to s_{i+1}, a new evaluation cycle is triggered, taking the logical predicates of the actual situation as input for the test against the critical situation indicators in the data base. If one or more critical situation indicators are evaluated to TRUE, a critical situation is concluded and the appropriate system action is initiated.

It is obvious that the quality of an emergency treatment system heavily depends on the completeness of the set of critical situation indicators. Since this set is highly dependent on a person's existing disabilities, which may change over time, customization and dynamic adaptation of this set at run time is mandatory.

Each critical situation indicator s is bound to an action or action sequence $s \rightarrow a$ executed if the critical situation occurs, for example:

- (Person X has fallen down) → (Call Person X)
- (Person X has fallen down) AND (Person X has not responded to call for S seconds) → (Issue emergency call)

Situations, critical situations, and actions bound to them form the basic abstractions approximating the disability model of Figure 2. The feasibility of implementing these abstractions in a real system not only depends on the prediction precision for emergencies, but also on their usability for handicapped and elderly people as well as for medical and technical maintenance personnel.

It is obvious that any living assistance system in the described domain will fail if it requires special skills by the handicapped and elderly people for using and handling it. Instead, the assistance system should be completely invisible to those persons. This also means that the physical condition of the assisted person has to be sensed in an unobtrusive manner. Environmental sensors must be preferred to sensors directly attached to the body, even if this results in a lower precision of the measured values. The system has to compensate this by taking several environmental measurements into account and drawing conclusions from them. This is of course a challenging task, but that is way AmI-systems are assumed to work.

Based on the identified situations, the system operates proactively, does its job automatically with minimal human intervention. It interacts with humans by speech, gestures, and other forms of natural communication. It provides its service in a stable, robust and reliable way, even in the presence of component malfunctions, power/battery break down, or other exceptional conditions. Software release changes and maintenance actions will be performed remotely without interrupting the system operation and with minimal intervention by maintenance personnel.

It is apparent from this description that ambient intelligence is the enabling technology for this application domain. An ambient intelligence approach for living assistance systems will be outlined in the next chapter.

4. AMBIENT INTELLIGENT LIVING ASSISTANCE SYSTEMS

According to [27], AmI systems represent a new generation of systems showing the following characteristics. AmI systems are:

- *invisible*, i.e., embedded in things like clothes, watches, glasses, etc.,
- *mobile*, i.e., being carried around,
- *context aware*, i.e., equipped with sensors and wireless communication interfaces making it possible to scan the local environment for useful information and spontaneously exchange information with similar nodes in their neighborhood,
- *anticipatory*, i.e., acting on their own behalf without explicit request from a user,
- *communicating naturally* with potential users by voice and gestures instead by keyboard, mouse and text on a screen,
- *adaptive*, i.e., capable of reacting to all kinds of abnormal exceptional situations in a flexible way without disruption of their service.

We will first discuss an ambient intelligence approach for home care systems following the model in chapter 3. The system is composed of three subsystems (cf. Fig. 3): the body area network (BAN), the home network, and the central processing node, which also acts as a gateway to the Internet and other external services like the telephone network.

The body area network is composed of special sensors that monitor body vital functions like blood pressure, temperature, pulse frequency, etc. and transmit their results to the body gateway via a wireless connection. The body gateway collects the measurements from the different sensors and periodically transmits them to the central station for further processing. The body network is invisibly embedded in clothes like shirts, in watches and glasses so that the handicapped and elderly persons do not have to put on those sensors explicitly; in fact, they should not even be aware that sensors exist.

The home network consists of sensors attached to walls in rooms and their equipment for collecting data about the behavior of the person under observation. Part of the home network might also include loudspeakers, microphones, and video cameras for communicating with the person. It is assumed that video cameras are usually switched off; they will be activated only after detection of an emergency in order to provide external medical personnel the option of looking at the person. This constraint will guarantee privacy for the persons under observation.

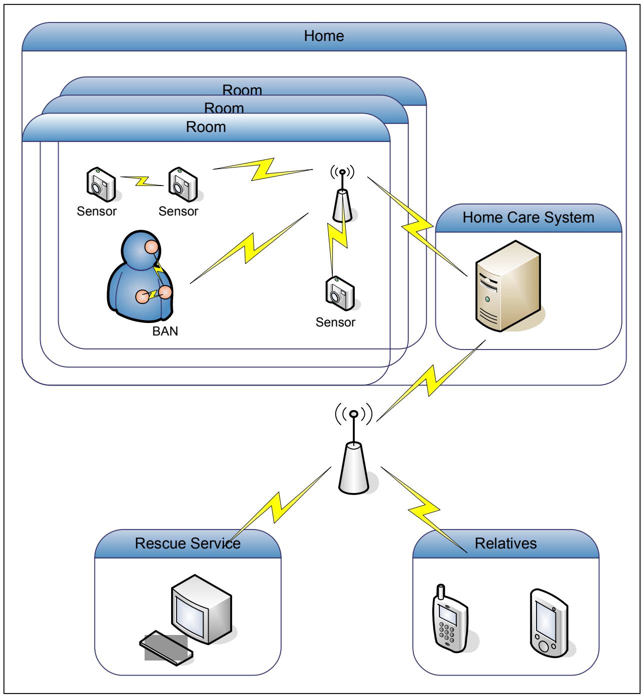

Fig. 3. Physical Architecture of an AmI-based Home Care System

Every node in the home network has a wireless connection to the central station and transmits its data in an event-style manner, i.e., after an intrinsic state change. There are two types of raw data delivered by the sensors: data describing a person's movement and data describing a person's activities. Movement data take the form of a sequence of snapshots taken every 0.1 to 1 second. Every snapshot ideally delivers the following data tuple:

<Time, Location, Position>

Position may ideally take the following values, e.g.,

- up (person is standing or walking)
- sitting
- laying

Presently available sensor technologies for in-house person tracking do not support such detailed and accurate tracking, but it is only a question of time when those technologies will appear.

Activity data are collected from activity centers such as toilet, stove, bed, etc. They produce data that inform about specific activities being performed by the person under observation. From activity data one can conclude that a person has cooked, has taken his/her medicine, etc.

Body vitality data, movement data, and activity data form the raw data streams from which situations will be constructed. These raw data streams will be processed periodically to derive a symbolic representation of situations describing behavioral patterns of the observed person at different time intervals. It is worthwhile to make a clear distinction between behavioral situations in the range of seconds, minutes, hours, days, months, and years. Examples of behavioral situations are:

- 13.09.2005 12:35:46 – 12:35:57
  Person X walked from A to B.
- 13:09.2005 07:00 – 22:00
  Person X visited kitchen 1x, bedroom 1x, toilet 5x.
- 02.11.2005 – 07.11.2005
  Person X did not enter living room.
- 01.03.2005 – 31.03.2005
  Person X used cup 3 times a day on the average.
- 01.01.2004 – 31.12.2004
  Person lost 5 pounds of weight.

These symbolic representations of situations describing behavioral patterns at different time intervals are now tested against the set of critical situation indicators in the data base as described in chapter 3, potentially resulting in certain system actions.

From the information above it is now possible to sketch the raw architecture for a home care system as depicted in Figure 3. The illustrated architecture is an extension on the reference architecture for context-aware systems described in [9]:

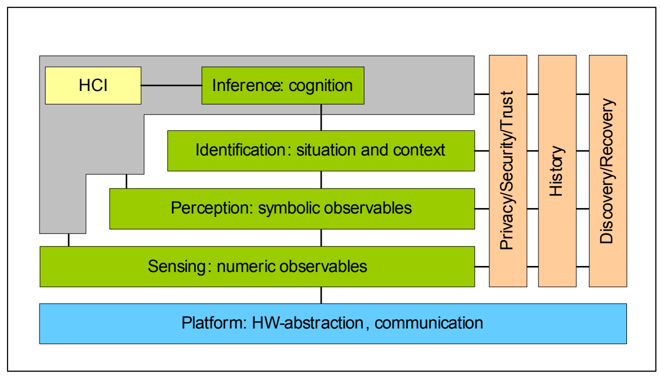

Fig. 4. The Logical Architecture of an AmI-based Home Care System

Compared to home care systems, outdoor living assistance systems have to cope with the following additional problems:

- While the type of context information collected via sensors in the home area is well defined based on body vitality checks and behavioral information, this is not true for outdoor living assistance. In particular, outdoor living assistance systems may acquire context information that describes unforeseen situations (traffic jams, etc.).
- Outdoor living assistance systems may never rely on a stable communication infrastructure, i.e. the quality (bandwidth, transmission delay, etc.) and the reachability of services may dynamically change by orders of magnitude.

It is unclear up to now how a stable service could be provided by a living assistance systems under those circumstances.

5. IMPACT OF LIVING ASSISTANCE SYSTEMS ON SOFTWARE ENGINEERING

From the discussion of the AmI-based home care system in the previous chapter, we are now able to summarize crucial non-functional requirements for AmI-based living assistance systems:

a. *Robustness*. The system must be extremely robust against all kinds of misuse and errors. Wrong inputs must not lead to a system malfunction or crash.

b. *Availability*. The system must do its job even in the presence of hardware component crashes, shortage of hardware resources such as storage or communication bandwidth, and other exceptional conditions.

c. *Extensibility.*The system must support its extension by new components at runtime, e.g., sensors to measure specific vital functions or actuators for active assistance, in order to adapt the system to changing disabilities over time.

d. *Safety*. The system should do exactly the job it was designed for. This requires precise system specifications and a guided design process including verification and validation steps, which assures that the specifications are met. Faulty system components and exceptions must never result in system misbehavior.

e. *Security*. A living assistance system, although continuously monitoring persons, must guarantee a well defined degree of privacy for the persons under observation. The privacy rules must be precisely formulated and verified [6].

f. *Timeliness*. Although living assistance systems are not considered hard real time systems [23], some of their services, such as the emergency treatment, have to be carried out in time. Long propagation delays after the detection of an emergency are not tolerable.

g. *Resource Efficiency*. The available resources, i.e., processing power, memory, communication bandwidth and energy, have to be utilized as efficiently as possible in order to allow (i) an affordable price of the systems and (ii) the realization of highly integrated, autonomous sensor nodes with a high endurance, which is of particular interest if the sensor nodes have to be mobile.

h. *Natural, Anticipatory Human-Computer Interaction*. Living assistance systems have to provide human interfaces for three groups of people: the assisted persons, the medical personnel, and the maintenance personnel. Each of these groups has different requirements for interacting with the system. The human interface for the handicapped and elderly persons must be based on voice, gesture, and visual animation, and avoid any kind of particular skills. Multi-modal interaction paradigms that combine several modes are a powerful approach to enhance usability. Anticipatory interfaces, which proactively contact persons in certain situations, are considered mandatory.
The service interface for medical personnel should allow to input/output medical data such as critical situation indicators and behavioral patterns of the persons under observation in a domain-specific notation, avoiding any specific IT knowledge.

i. *Adaptivity*. The systems are able to adapt themselves at runtime [19]. Adaptivity on different levels and scales is considered one outstanding characteristic of living assistance systems. To support this, the systems must monitor themselves, i.e., continuously check critical system conditions such as resource bottlenecks, exceptions raised by components indicating upcoming crashes, low battery status, etc. before they lead to a disruption of operation.
Based on the identified situations, the system can perform a

- *self-optimization*, which denotes the ability of the system to adapt its algorithmic behavior to changing needs of the application. An example of self-optimization is the dynamic increase of the volume of loudspeakers for persons with increasing deafness.
- *self-configuration*, which denotes the ability of the system to integrate dynamically new software components and remove existing ones not needed any more. Self-configuration is a form of self-adaptation at the architectural level of a system. Self-reconfiguration may be triggered by changes in the hardware configuration aiming at a better use of resources or a higher degree of fault tolerance.
- *self-maintenance*, which denotes the ability of the system to perform standard maintenance tasks such as downloading new updates and releases automatically from a remote service center.

The combination of the aforementioned requirements substantially complicates the engineering of living assistance systems and raises a set of new software engineering issues. In the following, we discuss the ones we encountered during our development activities:

Software Architectures, and Models for Adaptive Systems

Dependable and resource efficient implementations of adaptive distributed software systems such as living assistance systems can only be built on sound architectural models. These models must be powerful enough, to allow precise specification of potential variations that could be encountered during the life time of a system, including development and run-time. The concept of variability known from family-based approaches can be applied to model the adaptation behavior of adaptive systems. To this end, the existing modeling approaches have to be revised into more formal specifications of architecture and their variations. In order to support the required extensibility and interoperability of the AmI-components, standard interfaces and services have be provided in form of reference platforms [2], supporting the various qualities mentioned above.

Model analyzing tools including model checkers and simulators must be provided to support the analysis, validation, and verification of specific system qualities at the architectural level.

Requirements Specification and Verification Techniques for Non-Functional Properties

Strong availability-, safety- and security constraints of living assistance systems require powerful specification techniques for those non-functional system properties. Construction approaches for systems that guarantee that non-functional properties are met, and verification tools that prove that a system implementation meets the non-functional system requirements are still in their infancy. However, without a powerful technology for the specification and realization of non-functional properties, trustworthy living assistance systems can never be built.

Natural Human Computer Interfaces

Living assistance systems put extreme burdens on the usability of a system. In fact, the human-computer interfaces should be based on the natural interaction skills of humans such as voice, gestures, and visual animation. They should operate proactively, i.e. contact persons if necessary without awaiting commands from them. They should be adaptive, i.e., interact with the humans using different media depending on a person's disabilities and their current context. Multi-modal interaction is a promising approach for adaptive HCIs and is presently under exploration by different research groups worldwide [22][25].

Software Engineering Environments for Adaptive Systems

The specification, design, implementation, and test of adaptive systems following the program family approach requires appropriate guidance and support by a software engineering environment. Such a software engineering environment connects all the tools for the specification, modeling, analyzing and verification described above in a concise process development model. An essential part of this environment is a pattern library of architectural artifacts. The artifacts represent standard solutions for frequently used subsystems in a generic style which may be customized for a specific application. Expert agents guide developers through this selection of patterns and assist in finding the most appropriate pattern for a given problem.

6. RELATED WORK

An overview on assistive technology in elderly care is given in [17]. It addresses video-monitoring, remote health monitoring, electronic sensors, and equipment such as fall detectors and door monitors.

Toshiba has two teams working on "home life support robots" designed to aid Japan's aging population [26]. Japan's population growth is near zero and its citizens' average age is climbing rapidly. The assumption is that by 2050, there will be not enough kids care for their aging relatives.

The objective of the PHMon (Personal Health Monitoring System with Microsystem Sensor Technology) project [21] has been the development of the world's first Personal Health Monitoring System, which allows measuring all of a patient's relevant vital parameters either continuously or at determined time intervals without restricting the patient’s mobility. The system enables the patient to spend much more time at home during examination, treatment, and rehabilitation periods compared to the ordinary procedures, which leads to an immense cost reduction for in-hospital treatments.

Starting in 1993, the TIDE Technology Initiative for Disabled and Elderly People (TIDE) has promoted research and technological development to meet social and industrial goals, stimulating a single market in Assistive Technology in Europe, to facilitate the socio-economic integration of disabled and elderly people. [8]

Withing the 6th Framework Programme, the EU will fund research and development of Ambient Assisted Living (AAL) solutions for the Aging Society [11]. The aim is to extend the time during which elderly people can live independently in their preferred environment with the support of ICTs. It therefore targets the needs of the individual elderly person, their families and caretakers, rather than the health care institutions. This includes, for example, assistance in carrying out daily activities, health and activity monitoring and enhancing safety and security. It also covers means to improve access to social, medical, and emergency services, and to facilitate social contacts as well as provide access to context-based infotainment and entertainment.

Established in 2003, the Center for Aging Services Technologies CAST [7] has become a national coalition of more than 400 technology companies, aging services organizations, research universities, and government representatives working together under the auspices of the American Association of Homes and Services for the Aging (www.aahsa.org).

The following projects (an excerpt) aim at helping elderly people with reduced abilities to maintain their independence and go on living in their own homes:

- Assisted Living Project [3].
- Information Technology for Assisted Living at Home (ITALH) [14]. The project web-site lists further related work.
- Millennium Homes LINK [16].
- ORCATECH (ORegon Center for Aging, Technology, Education and Community Health) [18], a collaboration of academic, industry, and community partners, which is funded by the National Institutes of Health.

The BelAmI (Bilateral German-Hungarian Collaboration Project on Ambient Intelligent Systems) project [5] aims at developing innovative technologies and system development methods in the area of Ambient Intelligence. One of the addressed application domains is assisted living. In this context, the researchers devise integrated methods that can be used to develop assisted living solutions with the characteristic requirements, i.e., adaptivity, dependability, interoperability, resource efficiency, safety & security, and usability in a goal-oriented way.

7. CONCLUSIONS

Ambient Intelligence technology is developing fast and will foster a new generation of IT systems with outstanding characteristics in the area of context awareness, anticipatory behavior, user friendliness and flexibility. As a prominent application domain with a huge potential market we have considered living assistance systems in greater detail. It has been shown that the construction of trustworthy robust and dependable living assistance systems is a challenging task which requires novel software engineering methods and tools, particularly in the area of generic self-adaptation mechanism at the algorithmic and architectural level, adaptive, multi-modal user interfaces and the realization of non-functional system properties. We hope that the paper will stimulate additional research activities in the software engineering community.

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