Ambient Assisted Living for the Motor Impaired

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ABSTRACT
The field of Ambient Assisted Living (AAL) has shown great potential in counteracting some of the effects of the worldwide population ageing phenomenon. Its main goal is to promote a safe, healthy, and functional living environment for the elderly and people with disabilities who wish to live independently in their home. To achieve this goal, AAL environments utilize Information and Communication Technologies (ICTs) and the emerging Ambient Intelligence (AmI) paradigm in order to provide sophisticated solutions that can support the needs of an elderly person or a person with disabilities, at home. This chapter will present examples of AAL environments found in research and academic literature and the solutions they offer to cater for the basic needs of motor-impaired people in order to support their independent living and quality of life. The challenges of using such technologies will also be discussed.

INTRODUCTION
The World Health Organization (WHO) World Report on Disability (World Health Organization, 2011), states that approximately one billion people worldwide experience a disabling condition. This is the first ever global estimate of persons with disabilities in the last 40 years. The term “disabled” according to WHO is used for people who are experiencing a limitation in their movement, activities, and senses due to a physical or mental condition. The report also states that almost everyone will be temporarily or permanently impaired at some point in his or her life, especially when at old age. At the same time, people with disabilities are more susceptible to poorer health outcomes and lower education achievements, which often lead to higher rates of poverty than people without disabilities. Disabled people are in need of rehabilitation services in order to maximize their functioning required to support independence. But in developing countries such access to rehabilitation services is often limited and in some cases nonexistent altogether. Even in high-income countries about 20%-40% of people with disabilities have limited assistance for their everyday activities. In the US, for example, 70% of adults have to rely on family and friends for assistance with daily activities. The number of people experiencing motor impairments and other disabilities is only expected to rise in the near future, as the world population continues to age at an unprecedented rate. According to the United Nations World Population Ageing report (United Nations, 2000), worldwide population ageing is enduring and has a growing rate of 2.6%per
year, considerably faster than the population as a whole, which is increasing at 1.2% annually. Europe is currently holding the highest proportion of older persons, with a population of 60 or over currently constituting 24.5% of its total population. In the United States that number is 19.1% respectively.

From the above, it can be argued that the increase of the ageing population will have major implications for all aspects of people’s everyday life particularly of socio-economic nature. The number of people that will need some form of institutionalized help is going to increase, adding on the burden of the existing health care systems. Governments around the world have taken serious notice of this reality and of the need to come up with strategies to adapt their social practices and processes in order to accommodate this dynamic population shift in the population. The need to find ways to make it easier for people with age and other related disabilities to live a longer, satisfying and independent life in their own homes is now more imperative than ever.

Ambient Assisted Living (AAL) is a domain that has attracted a steadily growing attention in the scientific community because it involves emerging innovative technological solutions that can counteract some of the challenges described above. The main focus in AAL is on supporting persons with disabilities in their own environment and providing the means to increase the degree of independent living. Its aim is to provide integral solutions in the areas of home care, independent living, and institutionalized care homes that will improve the quality of life and lower the costs involved with health, home care and related social services. In order to achieve the above, AAL depends heavily on Information and Communication Technologies (ICTs) and the emerging Ambient Intelligence paradigm.

This chapter provides an overview of how Ambient Assisted Living technologies can play a catalytic role in improving the living environment for people with motor impairments by providing solutions that can increase their level of independence. The chapter begins with an overview of the fields of Ambient Intelligence and Ambient Assisted Living, followed by a brief presentation of the latest research initiatives in Europe. It then discusses how AAL can provide solutions for the fulfillment of the four identified requirements for independent living: mobility, environment control, safety, health and emergency assistance, and social inclusion. Finally, the major challenges of AAL are discussed followed by the conclusion.

**AMBIENT ASSISTED LIVING (AAL) OVERVIEW**

AAL refers to the use of Information and Communication Technologies (ICT) in a person's living environment in an unobtrusive way enabling them to continue living a comfortable, independent, active life and staying socially connected well into old age. AAL’s main goal is to provide the technological platform to support individuals in living an autonomous life for as long as possible. The roots of AAL are in traditional Assistive Technologies for people with disabilities, ‘Design for All’ approaches to usability and accessibility, as well as in the emerging computing paradigm of Ambient Intelligence (Pieper, Antona, Cortes, 2011).

Ambient Intelligence (AmI) is a term that refers to the vision of a world in which smart, intuitively operated devices support users in an unobtrusive way in their everyday life. AmI has enabled the introduction of ubiquitous information, computational, and communication technology in a seamless yet unobtrusive way creating smart everyday living environments (Encarnação & Kriste, 2005). In such smart environments, intelligent applications and devices become aware of the human goals and needs by operating collectively and sharing information and intelligence through a hidden network that connects them in a way that is natural and intuitive to the user (Aarts & Encarnação, 2008). AmI infrastructures have gained a great momentum in today’s world in many industries such as home automation, entertainment, automotive, and healthcare to name a few. The technologies involved have the capacity to transform everyday common objects from CD players to coffee machines into...
smart objects that support context awareness, personalization, anticipatory behavior, and adaptation, all of which enable a certain degree of autonomous decision-making. Lighting, sound, vision, home appliances, and other electronic devices, all come into play in an AmI environment and share the same purpose, to improve user experience by facilitating the user’s interaction with it (Aarts & Kriste, 2005). Aarts and Encarnação (2008) stated that the notion intelligence reflects that the digital surroundings in a smart environment exhibit certain forms of social interaction, in other words they are able to recognize the occupants, adapt themselves to their needs, learn from their behavior, and possibly act on their behalf. Based on the described notion of intelligence they have synthesized the following list of the most important features of Ambient Intelligence:

- Integration through large-scale embedding electronics into the environment
- Context-awareness through user, location, and situation identification – the system uses sensors to perceive a situation, the location where that situation is taking place, and the user involved
- Personalization through interface and service adjustment – the system can change its behavior according to the needs of the user
- Adaptation through learning the user’s behaviors
- Anticipatory behavior through reasoning – the system acts on behalf of the user making decisions based on predictions and expectations about future actions

AAL with the help of the Ambient Intelligence (AmI) paradigm and new ICT technologies can now provide smart sophisticated solutions that offer the potential to change dramatically the quality of life for a disabled person, often making the difference from living with personal assistance on a daily basis to living an autonomous life. One of AAL’s focal concerns is also to offer user-friendly interfaces that are adaptable to the needs and abilities of the user and user-centric methods of interaction for the individual with his or her immediate environment (Pieper et al, 2011).

AAL RESEARCH INITIATIVES IN EUROPE

In the recent years, policy initiatives have been launched in Europe on the field of Ambient Assisted Living (AAL) in order to create a favorable ground towards research, development, and deployment of ICT technologies with focus on addressing the challenges, but also the opportunities of ageing. The “Ageing Well in the Information Society” Action Plan was adopted in June 2007 by the European Commission with the goal to bring forward a package of measures that should lead to greater uptake of ICTs by Europe’s senior citizens and stimulate industry to produce technologies appropriate for them (Stephanidis, 2011).

For that purpose, the European Commission launched a dedicated action in the 7th Framework Programme and partial funding of the Ambient Assisted Living Joint Research and Innovation Programme, involving most EU Member States (Stephanidis, 2011). By 2013, the EU and Member States, and the private sector will have invested more than €1 billion in research and innovation for ageing well: some €600m in the Ambient Assisted Living Joint Programme (AAL JP), and an expected €400m in the EU’s 7th Research Framework Programme (European Commission, 2012). Up to 30 Research and Development projects have been launched under Framework 6 and 7 up until now and another 50 are under way as part of the Ambient Assisted Living Joint Programme (AAL JP) (European Commission, 2012).

AALIANCE and AALIANCE 2

AALIANCE, (European Ambient Assisted Living Innovation Alliance), was one of the projects within the 7th Framework Programme with focus on AAL solutions based on advanced ICT technologies for the areas of ageing at home, ageing at work, and ageing in the society. The project had a duration of two years (2008-2010) and its main objectives included
setting up a sustainable network of partners, involving companies such as technology providers and system integrators, research organizations and user associations, defining standardization requirements, and supporting European and National entities to increase political awareness and promote activities for the advancement of new AAL technologies (Europa-Cordis, 2010). The AALIANCE2 project, which is also part of the 7th Framework Programme, was launched as a continuation of the AALIANCE project and aimed at transforming the existing AALIANCE Community in a long-term sustainable network, supporting the implementation of content strategies of the public and private sector, and finding solutions for major challenges in AAL (European Commission, 2012).

AAL JP
The AAL Joint Program (European Commission, 2012), a funding activity within the 7th Framework Programme, started in 2008, with 23 countries working together under the common goal of developing a joint program of activity to independent living through the application of ICT. The European Commission and the 23 countries that constitute the AAL JP partner states fund the Program, which is set up for duration of 6 years (2008-2013) and has a planned total budget of 600M Euros of which approx. 50% is public funding - from the AAL Partner States and the European Commission - and approx. 50% is private funding from participating organizations. AAL JP aims at funding research, development and innovation projects that show a clear promise to bring solutions, or service concepts to the market within 2 to 3 years after the end of the funding period. A total of five calls for proposals have already been published each specializing in a specific aspect of assisted living for the aged population such as chronic conditions, social interaction, self serve society, mobility, and daily life activities. These calls have produced approximately 60 on-going research and development projects that focus on shaping the future of ICT based solutions and bringing them closer to the actual production lines and the market (European Commission, 2012).

AAL SUPPORTING THE MOTOR-IMPAIRED
Motor impairments are not just a product of the ageing process. They can also be the result of a traumatic injury that has caused paralysis of the legs (paraplegia) or paralysis of both legs and arms (quadraplegia), or the loss of limb(s). Motor impairments can also be the result of a disease or degenerative condition, such as cerebral palsy, muscular dystrophy, multiple sclerosis, arthritis, Parkinson’s disease, and other conditions that can cause various levels of motor impairments in an individual. Regardless of the cause of the motor impairment, disabled people experience both physical and non-physical effects. According to Iezzoni, McCarthy, Davis, & Siebens (2001), people reporting mobility difficulties were more likely than others to be impoverished, poorly educated, and unemployed. In addition, as Simpson (2005) stated, people with disabilities often experience decreased opportunities to socialize which can lead to anxiety and depression, as well as further development of shyness and low self-esteem. In fact, it is estimated that about 31 percent of persons with major mobility difficulties reported being frequently depressed or anxious, compared with only 4 percent of persons without mobility difficulties.

It is obvious that the range of physical disability varies from individual to individual. The mobility aids market today offers an extensive range of specialized products geared to support the needs of motor impaired people and enable them to accomplish common everyday tasks that would otherwise be impossible. From simple assistive objects such as gripping and reaching devices, specialized knob turners, ergonomic keyboards and mouse devices, specialized penholders, to sophisticated walking frames and rollators, and motorized wheelchairs. But even though these mobility aids can facilitate the life of a motor-impaired individual a great deal, they often provide isolated solutions inadequate to provide a holistic platform for independent living. The needs of a motor-impaired person are indeed multiple and multi-leveled, whether in the context of indoor assistance or outdoor assistance. Based on Nehmer, Becker, Karshmer, & Lamm (2006) living assistance classification scheme, this chapter focuses on four main requirements as essential for living independently and for which
ambient assisted living technologies can provide feasible solutions. These requirements represent the basic needs that the home environment of a motor impaired person should meet in order for that person to live independently and are presented in the table below.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Description</th>
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<tbody>
<tr>
<td>Mobility and carrying out day-to-day operations</td>
<td>A motor-impaired person needs to be able to move around his or her living environment easily and on his or her own and to take care of daily needs such as preparing meals, doing mild household chores, washing dishes, showering, etc.</td>
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<tr>
<td>Home Environment control</td>
<td>A motor-impaired person needs to be able to control devices, appliances, and other elements of his or her living environment, such as lighting, sound, electrical appliances, windows, doors, locks, etc.</td>
</tr>
<tr>
<td>Safety, health and emergency assistance</td>
<td>A motor-impaired person needs to feel secure in the environment and have access to an emergency monitoring system that alerts third parties in case of an emergency such as a fall, illness, fire, etc.</td>
</tr>
<tr>
<td>Communication</td>
<td>A motor-impaired person needs to have the means to communicate with the outside world, friends and family in order to minimize social isolation.</td>
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*Table 1: Requirements for living independently*

The sections that follow describe AAL concepts and technologies that are currently being researched in labs worldwide and show potential in providing feasible solutions on how to fulfill the above four requirements.

**Requirement 1: Mobility Assistance**

According to the US Census (U.S. Department of Commerce, 2010), 11 million people aged 60 and older need personal assistance with carrying out simple everyday tasks such as getting around the house, taking a bath or shower, preparing meals and performing light housework. A survey of 1505 non-elderly adults with disability in the United States found that a staggering 42% of them reported having failed to move in or out of a bed or a chair because no one was available to help (Kaizer Family Foundation, 2003). Independent mobility plays a pivotal role in the realization of autonomous living for the motor impaired person and in maintaining a respectable quality of life. And while the needs of many individuals with disabilities can be satisfied with traditional walking or mobility assistive devices such as canes, rollators, manual or powered wheelchairs, etc., a large segment of the disabled community still find it difficult or impossible to use such devices independently. This population includes individuals with low vision, visual field reduction, spasticity, tremors, even cognitive deficits, etc. For these individuals maneuvering the wheelchair with accuracy through tied spaces and steering clear from obstacles can pose a great challenge (Simpson, 2005).

Substantial research and development has been done in recent years on how to apply existing robotic and AmI technologies to powered wheelchairs in order to enhance their functionality in a way that allows them to move from point A to point B without much interaction from the user. A number of such smart wheelchairs have been studied and developed in research labs and they all carry some common characteristics. The majority makes use of a combination of vision, acoustic and tactile sensors, mapping tools, and operating modes. Types of sensors
include sonar, laser rangefinder, computer vision, bump/contact, line following, infrared, web cameras, GPS, etc. Mapping tools include topological, metric, occupancy grid, natural landmarks, artificial landmarks, etc. Most wheelchair systems offer one or more operating modes such as autonomous and semi-autonomous navigation, collision avoidance, wall following, door passage, docking, target tracking, turn-in-place, three-point turn, bump and backup, etc (Simpson, 2005). At the same time, great attention has also been given in the interaction methods available for the user to communicate his or her intentions to the wheelchair. Recognizing the limitations a motor-impaired person can have in movement, a variety of alternative to the standard joystick and mouth-controlled methods of interaction are being tried out. Such alternative user-friendly human-computer interaction methods include, natural speech, head and face directional gesturing, gaze gesturing, Electromyogram (EMG) signals, and Brain computer interfaces (BCI) which allow communication with no movement at all. Some examples of smart wheelchair systems follow below.

Examples of Smart Wheelchairs
Tomari, Kobayashi, & Kuno (2012) developed a smart wheelchair system for users with severe motor impairment who may find it difficult to operate the wheelchair in tight spaces or when avoiding obstacles since they cannot control the wheelchair by means of a conventional joystick. They used an electric wheelchair equipped with a switch responsible for triggering several maneuvering modes (i.e., “stop”, “semi-auto”, and “manual”) and four types of sensors, standard webcam, an RGB-D Camera (Red-Green-Blue-Depth), a laser range finder, and an Inertial Measurement Unit sensor. The user can operate the wheelchair using a combination of the manual and the semi-auto modes. He or she can set the general direction of the chair to the goal location by performing a small head gesture (manual mode), and the computer will take over the responsibilities for navigating and avoiding obstacles (semi-auto mode). Sabatini, Genovese & Pacchierotti (2002) developed a motorized rollator, which aims at supporting people with motor impairments transporting objects. The prototype supports the functions of standing, support in walking and transportation of objects and it allows two separate control modes. In the direct control mode, the user drives the rollator with the bilateral grips, which are instrumented with force sensors. In the remote control mode, the user leads the way and the rollator follows while transporting an object. The user wears a belt with a transponder that communicates with the rollator and can be tracked. In addition, the prototype is equipped with an ultrasonic (US) ring that detects obstacles and performs simple collision avoidance. Dubowsky, Genot, Godding, Kozono, Skwersky, Yu, & Yu (2000) developed a PAMM (Personal Aid for Mobility and Monitoring) SmartCane system concept to provide mobility assistance and monitoring for the elderly living independently or in senior assisted facilities. The SmartCane PAMM has the ability to locate itself in the facility by visually reading simple sign posts that are strategically placed on the ceiling of the Assisted Living Facility. It also uses acoustic sensors to locate obstacles, which enables it to maneuver in crowded environments and a six-axes sensor that measures the forces and torques the user applies to the cane handle. Furthermore, the system communicates, via a wireless modem, with the local facility computer to obtain information such as the user’s schedule and the facility's updated maps and carries sensors that monitor the health and condition of their users and transmit their status back to the facility computer. The system could provide guidance to destinations via pre-programmed maps, schedules, user commands and sensed obstacles. The system has four modes of operation, autonomous and semi-autonomous. Moon, Lee, Ryu & Mun, (2003) proposed an intelligent robotic wheelchair with user-friendly human-computer interface (HCI) based on electromyogram (EMG) signal, face directional gesture, and voice. In their proposed system, the user communicates his or her intention to the wheelchair via the HCI, which interprets the signal and moves the chair to the intended direction. Additionally, the wheelchair can detect and avoid obstacles autonomously using sonar sensors. By combining HCI into the autonomous functions, it performs safe and reliable motions while considering the user's intention.
Examples of Robotic Assistants

The previous section presented some examples of how applying existing robotic and AmI technologies can transform traditional wheelchair devices into smart systems that can communicate with the surrounding environment and perform tasks on behalf of the motor-impaired user, assisting him or her to navigate through space avoiding obstacles, and reaching a point with minimal guidance from the user. Similarly, in research labs, robotic and AmI technologies have been used in an effort to integrate robotic service assistants into smart home environments to provide support for the older and impaired persons living at home independently. Robotic assistants can, not only support the user in carrying out everyday tasks such as fetching and carrying objects or providing physical support, but in some cases they can also act as a “companion” engaging in game playing activities with the user, reminding him or her of appointments, tasks that need to be completed (such as watering the flowers, calling a relative or friend), etc. In the table that follows, a list of robot functionalities that cover common user needs is presented.

<table>
<thead>
<tr>
<th>User Needs</th>
<th>Robot functionality</th>
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<tbody>
<tr>
<td>Assistance with everyday tasks</td>
<td>• Fetching and carrying objects, such as a book, a box, a glass</td>
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<td></td>
<td>• Reminding appointments, things to do, and medicine intake</td>
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<tr>
<td></td>
<td>• Controlling the living environment such as lights, air conditioning, windows, doors, temperature, etc.</td>
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<tr>
<td></td>
<td>• Picking up from floor and performing simple cleaning tasks</td>
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<tr>
<td>Mobility Aid</td>
<td>• Supporting body weight, so that the user can get up from a seated position to a standing position</td>
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<tr>
<td></td>
<td>• Work as an intelligent walking aid with obstacle avoidance, path recognition, etc.</td>
</tr>
<tr>
<td>Tele-health and Emergency handling</td>
<td>• Monitoring and supervision of vital signs</td>
</tr>
<tr>
<td></td>
<td>• Alerting third parties such as friends, relatives, physicians, authorities, etc, in case of an emergency</td>
</tr>
<tr>
<td></td>
<td>• Fall detection capabilities</td>
</tr>
<tr>
<td>Socialization</td>
<td>• Entertainment media management</td>
</tr>
<tr>
<td></td>
<td>• Initiating game activities that the user can play with the robot</td>
</tr>
<tr>
<td></td>
<td>• Communicating with friends and family</td>
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</tbody>
</table>

Table 2: User needs and robotic functionality

There are a few examples of robotic assistants that have been developed in academic and industry labs. Care-O-Bot is one such example of a mobile service robot that was designed by Fraunhofer IPA. The first prototype was built in 1998, and in 2000 three more robots based on the same hardware platform and control software were installed in the “Museum für Kommunikation Berlin” where they autonomously move among the visitors, communicate to and interact with them (Hans, Graf, & Schraft, 2002). A second prototype, Care-O-bot II, was built in 2001 and was equipped with a 6 Degree Of Freedom (DOF) manipulator arm, adjustable walking supporters, a tilting sensor head, and a hand-held control panel. This robotic assistant can perform most of the tasks described in the table above. A multimodal user interface with multiple sensing channels (speech, haptics, gestures) allows simple man-machine communication without misunderstandings. Commanding the robot is done by speech input and by using the input integrating touch screen and respectively, the feedback from the robot is also given by speech output and on the screen. The assistant’s knowledge about its environment is updated continuously based on sensor readings and its system.
architecture allows it to plan and execute complex tasks autonomously (Graf, Hans, Kubacki & Schraft, 2002).

Bien, Park, Bang, & Stefanov (2002), on the other hand, described bed robot application in the sweet-home project LARES, which features three intelligent components in a smart home setting: an intelligent bed robot, soft remocon and network. A bed robot is developed to help the elderly and the handicapped. The bed can change its pose multiple ways to accommodate various degrees of sitting and laying down positions. A robotic arm, MANUS, is attached on the side of the bed and can perform tasks such as transporting objects such as a book, or a newspaper, giving a message, and pulling a blanket over or putting it away, etc. The soft remocon is utilized to inform the bed robot of the users’ intention and operate home appliances by pointing the hand at the equipments and by gesturing with predefined hand shape. Finally, the network is equipped to transmit and share information between each device. The set up allows for the bed robot to be informed of the position of an object by a motion capture device, and for the home appliances to be operated by the command given via the remocon.

Srinivasa, Ferguson, Weghe, Diankov, Berenson, Helfrich, & Strasdat (2008), presented the Robotic Busboy, an autonomous multi-robot system that can collect objects from indoor environments and load them into a dishwasher machine. The mobile robot is capable of navigating through a populated environment receiving empty cups from people, and then bringing these cups to a robotic manipulator on a fixed platform. The manipulator, then, detects the cups, picks them up off the mobile robot, and loads them into a dishwasher rack. The development team used this very specialized task scenario because it requires robust solutions to several of the challenges associated with the development of general robotic assistants. According to Srinivasa et al (2008), the development of home assistant robots that can act autonomously in unstructured environments is still an open problem, due to the inherent difficulty of the associated perception, navigation, and manipulations problems. The robot must have complex mechanisms to be able to detect and recognize the environment itself and common objects within it, to navigate itself safely through populated environments while being able to differentiate between moving and static objects, and to perform complex manipulation techniques.

Another example of a robotic home assistant for the elderly and the disabled was developed in the context of the CompanionAble EC-funded research project, under FP7. Hector, the Companion Robot, is currently in the final stages of field trials and evaluations (University of Reading, 2012). Hector is designed to work in collaboration with a smart home infrastructure and a remote control center to better support older people living at home. Although, it is designed for elder people with mild cognitive impairments, its functionality can provide a services for people with other types of disabilities. Hector can perform a variety of tasks such as intelligent day-time activity planning and management, but its most important feature is monitoring and prevention of dangerous situations including fall detection and distress signal recognition and video communication with friends, family, and care givers. In an emergency situation, such as a fall, Hector can help the remote control center he’s connected to assess how serious the fall is and what kind of emergency help may be needed.

Japan and Korea have leadership role in the development of assistive robotics, in recognition of their ageing population problem. By 2025, Japan’s population of people 65 years and older is estimated to have increased to 28.7% of its total population. They have developed and marketed an abundant number of robotic devices in the recent years. In fact almost every major consumer electronics company in Japan has a personal robot in production or development (Mann, 2005). Honda’s Asimo (American Honda Motor Co. Inc., 2012) for example, is a humanoid robot designed to act as a personal assistant. Asimo can carry out an impressive number of complex tasks such as, fetching and carrying objects (i.e., a tray of drinks), turning on/off lights, closing and opening doors, pushing a cart around the room, remind the user to take medicine, etc. Matsushita Electrics developed a robotic bear with
health monitoring capabilities for the residents of a 106-bed retirement facility. Hiroshi Ishiguro Laboratory (Hiroshi Ishiguro Laboratory, ATR, 2012) has been doing extensive research on “Geminoids”, androids built to resemble human “models”. Korea, on the other hand, has the goal of developing a “welfare” robotic system in 20 years catering to the elderly and the disabled population (Mann, 2005).

**Requirement 2: Home Environment Control**

Another substantial area of research interest for AAL development and implementation has been that of home environment control. Many research projects have concentrated on the development of automation systems that allow the control of living environment elements usually from an interface that can support multiple interaction modes according to the needs of the user (i.e. voice command, scanning, brain wave, gaze gesturing, hand gesturing, etc.). Environmental control systems are prominent features of ambient intelligent homes (smart homes). Smart home technology refers to the integration of technology and services through home networking channels for facilitating everyday life operations. Smart homes allow the automation and control of home elements using controllers such light and door, window, ventilation, air-conditioning, and water, and home security devices (Carmen, 2011). Cook, Augusto, & Jakkula, (2009) referred to Ambient Intelligence as an environment enriched with technology and devices interconnected through a network that creates a system that acts as an “electronic butler”. This “electronic butler” is able to sense features of the users and their environment, then reason about the accumulated data, and finally select actions to take that will benefit the users in the environment.

**Research examples**

Many research projects referenced in scientific literature have focused on investigating intelligent components in a home and the various modes of interaction with them. Kartakis, Antona, & Stephanidis (2011), for example, developed, the Control Home Easily application, which allows the user to control electronic appliances using various interactive devices like touch screens, mobile phones, switches for motor impaired users, etc. Through this application the user can control any smart device that is connected to the system. Main functionality includes opening, closing and locking doors, opening windows and blinds, turning on and off lights and change their color, setting thermostat temperature, and so on so forth, for any room in the house and from inside the house or remotely (control appliances from far away). The application also allows the user to save his or her user scenarios in the system and retrieve whenever they want. For example, the user may create a “relaxation” scenario where the lights would dim to the desired level, a spot light would turn on above the reading armchair, the entertainment center would start the desired music CD, etc. At the same time, the advantage of this application is that it does not have to be modified every time a new appliance is installed in the smart environment. Instead, it can automatically identify the smart devices installed in each room and register them with different hardware technologies and auto-generate fully accessible User Interfaces (UI) based on information provided by the smart environment accordingly. Yu Zhong et al (2011) took advantage of the accessibility and usability platform of smart mobile phones and created a system called HouseGenie, which allows the users to control their living environment through their phones. HouseGenie is an interactive, direct manipulation application for mobiles, which supports a range of basic home monitoring and controlling functionalities as a replacement of individual remotes of smart home appliances. It also supports the creation of scenarios, short-delay alarm, area restriction etc. Olivier, Xu, Monk, & Hoey, (2009), created the Ambient Kitchen high-fidelity prototype for exploring the design of pervasive computing algorithms and applications for everyday environments. The Ambient Kitchen integrates data projectors, cameras, Radio-Frequency Identification (RFID) tags and readers, object mounted accelerometers, and under-floor pressure sensors. The main goal of the Ambient Kitchen is to create an evaluation test bed for developing and designing pervasive computing prototypes and an observatory of the possibilities of the simultaneous capture of the multiple synchronized streams of sensor data.
Researchers from the Czech Republic, Germany, Portugal, Spain, and Sweden have developed a solution to give elderly and disabled people easier control over the various electronic appliances and services in their homes using their mobile phone or other devices in the context of the "i2Home" European funded project. The "i2Home" project has developed a personalized and simplified Universal Remote Console interface based on existing and evolving open standards. The central objective of the project is to make the digital home accessible to all by following the “Design for All” paradigm and to create an open market for adaptable user interfaces for the digital home. i2Home has been tested in day-care centers and home settings in 4 pilot sites in the Czech Republic, Germany, Spain and Sweden and more than 100 organizations and companies in Europe already use or work with i2Home technology. Other applications of this technology are used in the EU-funded BrainAble project (Barcelona Digital Technology Centre, 2012) which also helps people with disabilities by improving direct as well as indirect interaction with devices thanks to brain sensors that can measure feelings like boredom, confusion, frustration or information overload. BrainAble is building a prototype that demonstrates an AmI smart home system controlled via a Brain-Computer Interface (BCI).

**Examples of Smart Homes**

A few research labs have constructed smart home environments in order to examine how emerging ICT technologies and emerging human-computer interaction methods can work in synergy to better support independent living for people with disabilities and the elderly. One such example of a smart home research project is AwareHome, a 3-story, 5040 square foot facility designed and built by Georgia Institute of Technology to facilitate research, while providing an authentic home environment (Kidd, Orr, Abowd, Atkeson, Essa, MacIntyre, & Newstetter, 1999). Each room of the AwareHome has sensors and tracking devices such as infrared, sonar, tactile, cameras, and microphones, which enable context awareness and facilitate the interaction of the users with their environment. Another example is the Gator Tech Smart House by University of Florida. It is built as an assistive environment to support independent living for older people and individuals with disabilities and it is equipped with a large number of sensors and actuators, and generates a large volume of data streams (Helal, Mann, El-Zabadani, King, Kaddoura, & Jansen, 2005). Mozer (2005) describes the features of the Adaptive House, a smart house that in contrast to standard computerized homes that need to be programmed to perform various functions, it essentially ‘programs’ itself by observing the lifestyle of its occupants, predicting their desires, and learning to anticipate and accommodate their needs. The smart home environment of the Adaptive House premised on the notion that no user interface (no speech input, gesturing, gaze tracking, or touch pads, etc.) beyond the sort of controls one ordinarily find in a house. The intelligence of the house arises from its ability to predict the behavior of its occupants and act accordingly by having observed them over a period of time. The system in place monitors the environment via an array of over 75 sensors for temperature, ambient lighting, sound, motion, door and window openings, and controls basic residential components such as heating, ventilation, air conditioning, lighting, and water heater by actuators. The system observes the actions taken by the occupants and it attempts to infer patterns in the environment that predict these actions. If the actions can be reliably predicted, the system performs them automatically, thus freeing the occupants from manually interacting with the home. So for example, on a rainy weekday when the inhabitant leaves the home at 8 a.m. and on the previous three days had returned by 7 p.m., the home predicts a return by 6:30pm and turns on the furnace in order to achieve a set-point temperature by the time the occupant is expected back in the house. Another example of an agent-based smart home environment that can adapt to the user’s behavior is the MavHome (Managing An Intelligent Versatile Home) that is presented by Cook, Youngblood, Heierman, Gopalratnam, Rao, Litvin, and Khawaja (2003). Just like Mozer’s Adaprive House, MavHome acts as an intelligent agent perceiving the state of the home through sensors and acting upon the environment through device controllers. The house can predict, reason about, and adapt to its inhabitants by using effective prediction algorithms.
suitable for each task. The MavHome intelligent agent needs to predict the inhabitant’s next action in order to automate the tasks that are repetitive for the inhabitant. Furthermore, it observes patterns in past inhabitant activities and uses them to determine how to control devices throughout the home. So for example, at 6:45am MavHome turns up the heat because it has learned that it takes 15 minutes to warm the place to optimal waking temperature. And when the alarm sounds at 7:00, the bedroom light and the kitchen coffee maker turn on.

Finally, FORTH-ICS is creating a state-of-the-art AmI Facility, targeted to support research, experimentation and multidisciplinary scientific collaboration at an international level. Such a facility is intended, amongst other things, to support the establishment and conduct of a line of research targeted towards the provision of accessibility to AmI technologies and environments (Margetis et al., 2012). The Facility occupies a three-floor 3,000 square meters building, comprising simulated AmI-augmented environments and their support spaces (e.g., computer and observation rooms), laboratory spaces for developing and testing related technologies, staff offices and public spaces. It is intended to primarily address the application domains of housing, education, work, health, entertainment, commerce, and culture and, through dedicated spaces simulating typical everyday environments, including a two-floor smart home. The entire building has been designed to be accessible by people with disabilities, and follows Design for All guidelines concerning stairs, elevators, ramps, corridors width, accessible bath-room facilities, multimodal signs and labels, etc. In particular, the house simulator will constitute a prototype accessible house for disabled and elderly people. The AmI Facility will constitute a real – test bed towards accessible AmI spaces.

Industrial efforts
Big industry names like Siemens, Philips, and Microsoft have also invested on research and development of smart home environment solutions. The EasyLiving project at Microsoft, (Brumitt, Meyers, Krumm, Kern, & Shafer, 2000), featured a high-technology living room. The project team worked on developing the software (prototype architecture) and related technology for supporting an intelligent environment that could be used in such places as smart houses. Microsoft has also been developing an “operating system” for the home, called HomeOS, which provides a centralized, holistic control of devices in the home (Dixon, Agarwal, Saroiu, & Bahl, 2012). Currently this operating system is been implemented and tested in about 12 smart homes and it can support many types of devices such as light switches, door/window sensors, dimmers, and cameras. AmI technology is also being tested at the Philips HomeLab (Koninklijke Philips Electronics, 2004-2012), a unique research facility on Philips' High Tech campus, the epicenter of Philips' global R&D activities, in Eindhoven, The Netherlands. HomeLab was created to test new home technology prototypes in the most realistic possible way; the facility is essential in speeding up the time-to-market for technological innovation.

Apart from the applications and systems that are currently been researched and developed in laboratories across the world, the accessibility market also has a number of assistive devices that act as agents for the control of home appliances. A quick search in the assistive technology market returns a large number of products that can interact with home control elements via touch screen, voice input, and other interaction technologies. Many of them take advantage of smart phone and tablet platforms and develop applications that can turn any smart phone device into a universal environmental control device that is fully accessible for people with all sorts of disabilities. Utilizing Infra-Red, Radio Control, and Bluetooth technologies, these products provide amazing automation features on any home. However, they are limited to the range of communication capabilities usually acting as stand-alone systems that do not act proactively in supporting the users’ needs.

Requirement 3: Safety, Health and Emergency Handling
One of the four main requirements identified earlier in this chapter as essential for transitioning to living independently for people with motor-impairments is having an
infrastructure in place that promotes safety and provides emergency handling services. Various situations can cause an emergency such as falling and slipping, fire, natural gas and carbon monoxide fumes, home invasion, or a medical condition that escalates into a serious life-threatening situation (i.e., asthma attack, etc). Any individual living alone is more vulnerable in any of the above mentioned situations, especially if the situation is severe enough that renders the person unable to move and call for help or unconscious. The vulnerability level increases even more when a home emergency situation occurs to a disabled person or an elderly person living alone. For example, a simple fall can become an emergency situation, if that person is left lying on the floor for an extended period of time before help arrives. Falls are actually one of the most prevalent causes of injuries. According to statistical data provided by the Centers for Disease Control and Prevention in the United States for 2010 (Centers for Disease Control and Prevention, 2010), the leading cause of Nonfatal Injuries treated in hospitals emergency departments was unintentional falls. Although not surprising, it is worth noting that that the number of unintentional falls more than doubles for the age group of 65 and above. From the above, it is safe to conclude that having a sense of safety and security in one’s living environment is indeed one of the main prerequisites for living an independent life.

There is already a large variety of commercially available assistive products for emergency monitoring and handling that use a broad range of modern technology. These products are designed to give people with disabilities a sense of security when living alone. Fall detection sensors and devices with wireless notification capabilities that send alert messages via mobile phones and wearable devices with emergency buttons are just a couple of examples of such products. However, these products act as stand-alone systems with a limited ability to describe the severity of the situation and often are too difficult for an older person or a person with motor-disabilities to operate (Kleinberger, Becker, Ras, Holzinger, & Müller, 2007). The advanced technologies and infrastructures of AmI and AAL environments have been shown in various research projects capable of providing more comprehensive remote healthcare and monitoring services than the traditional assistive technologies. There are, however, a few factors that have to be taken into consideration when designing such systems. According to Nehmer et al (2006), emergency is the kernel of any living assistance system. It aims at the early prediction of and recovery from critical conditions and the safe detection and alert propagation of emergency situations. AAL technologies can provide innovative solutions for emergency treatment systems. These solutions, however, need to carry certain characteristics in order to be successful in what they are intended to do. Nehmer et al state that the living assistance system should not require special skills for using and handling it. The system should be completely invisible to these persons. In other words, the physical condition of the assisted person should be sensed in an unobtrusive manner by environmental sensors that can read situations and act proactively with minimal human intervention. Such sensors can be attached to walls in rooms and their equipment for collecting data about the behavior of the person living in the house. Microphones, video cameras, loudspeakers are just some devices that can come into play in handling emergency situations. For example, if a person falls down, environmental sensors and fall detection systems can activate a dialog with the person, either with gestures, or natural speech, or through an interface, asking the person if he or she is ok. If the person states that there is an emergency that information can then be sent to the video camera which will get activated automatically to provide external medical personnel the option of looking at the person, while a phone call or an SMS is sent to a relative or friend or to an emergency care facility, if it is critical. If the person does not respond at all, the emergency system should make the decision autonomously to call for help. Apart from the unobtrusive nature of the emergency system of an AAL environment, the system should also be robust, reliable, and stable. It is imperative for the user to trust the system to provide the safety and security that it promises to provide.

The characteristics of AmI technologies that were presented earlier in the chapter (i.e., context-awareness, invisibility, anticipatory behavior, adaptivity, adaptability, etc) have a
great potential in offering innovative emergency monitoring and handling solutions in AAL environments. AmI technologies have all the characteristics that Nehmer et al described as essential for the success of emergency services systems. For example, the invisibility of AmI technologies makes them unobtrusive, in that the person does not have to wear a device in order to interact with it. Their sensing functionality can detect a situation and natural language dialog can help sort the severity of the situation with the individual thus limiting the probability of false-positive and false-negative alarms. Their anticipatory behavior capabilities can detect when deviations from the usual daily activities of the individual occur and act accordingly. Finally, their self-awareness and context-awareness can help make the emergency system adaptable to the abilities and needs of the user. In addition, in AmI environments the user can interact with the emergency systems in a more natural way that does not require an interface or a device, through a variety of modes such as gesturing (hand, leg, and head), natural speech, gazing, etc (Kleinberger et al, 2007).

Fall detection systems
Recognizing the fact that falls are the most prevalent types of accidents in a home for elderly people, a lot of researchers are focusing their work on coming up with systems that can predict and prevent falls from happening in the first place, but also can issue an alert mechanism should the fall actually happens. Earlier in this chapter, various walking assistive devices and robotic assistive systems that are being developed to support disabled people and the elderly to safely move around the house were presented. Some of these systems, such as Care-O-Bot also act as an alert mechanism in the case of an emergency by establishing communication between the person in the home and third parties. Apart from those devices a lot of research has been conducted in systems that issue alerts should a fall actually occur.

Alwan, Rajendran, Kell, Mack, Dalal, Wolfe, & Felder (2006) presented a floor vibration based fall detector system which is completely unobtrusive and passive. The system can be placed in any room and on any flooring surface and it can cover a range of approximately 15 ft. It detects a fall only when the vibration pattern (frequency, amplitude, duration, succession etc.) obtained from the floor over a small period of time matches the pattern induced when a person falls on the floor. When a human fall is detected, it then issues an alert call to the responder through an appropriate communications portal such as utilizing the telephone to send a message to a mobile phone. Popescu, Li, Skubic, & Rantz, (2008), on the other hand, presented an acoustic fall detector system (FADE) based on a linear array of audio sensors that uses sound height information to reduce the false alarm rate. Their system also incorporates a motion detector for further reduction of false alarms. So if motion is detected during a specified time interval (i.e 1 minute) after a fall has been computed, it is considered a false alarm and no alert is issued. This system like the floor vibration described above, automatically sends an alert signal to the monitoring caregiver when a fall is detected. The system is inexpensive and built from off-the-shelf components. Litvak, Zigel, & Gannot, (2008), lastly, presented a system that incorporates both of the above principles. They developed a unique and inexpensive solution that is based on floor vibration and acoustic sensing, and uses a pattern recognition algorithm to discriminate between human or inanimate object fall events. The proposed system can detect human falls with high precision for distance up to 5 meters and it is adaptive and can be calibrated to any kind of floor and room acoustics. Ambient noise or music does not influence the detection because the algorithm has to detect a vibration event in the first stage. Overall, the system is promising and the researchers are looking for ways to improve it so that it can be sensitive to low impact falls as well.
Telecare and Health Smart Homes

Another field that has also dedicated a lot of research in providing health monitoring services is that of telecare. Telecare refers to remotely delivered healthcare and support and includes rapid response mechanisms to emergencies in the home, treatment and medical advice and continual monitoring of the person with certain medical conditions in their home (Tang & Venables, 2000). Up until now, the majority of computer-supported health care tools designed focused mainly on supporting care-givers and medical personnel. This trend has been gradually changing with the introduction of assistive technology for providing supportive and adaptive services to ill or disabled people at home (Röcker, C., Ziefle, M., & Holzinger, A., 2011). In recent years, research in this field has been focusing on examining how to best combine telecare services with ICT found in smart home environments in order to provide a solid platform for better and safer living conditions for the elder and the people with disabilities. According to Tang & Venables, the latest generation of telecare systems involves the use of the Internet to deliver such services. In their work, they described a few examples of how such systems operate. In these examples, patients and physicians can communicate with their physician or case-worker through the Internet infrastructure for routine check-ups, but also in case of emergencies where an alert mechanism notifies healthcare providers of the situation. An example of such a set-up is described in the EC-funded AAL project Viedome in the Netherlands (European Commission, 2006). With the Viedome project, the North Brahant region funded an experiment to help the elderly and the disabled live longer independently by providing distance care through a variety of technologies such as video phones, domotic tools for distant commands, cameras for surveillance and safety, and security mechanisms. The main objective of the Viedome project was to replace life in a traditional institution, where elderly and disabled people are obliged to forgo their privacy, with a life in a new organization where they could enjoy comfort and safety without giving up their independence. The project also aimed at reducing the cost of accommodation and healthcare for elderly people and their families and to reduce the financial burden for public institutions. The project was designed through a partnership between an experienced large health care organization, a private technology company and a housing cooperation forum. By the end of the project 150 people lived in three Viedome centers while there were plans for expansion. The apartments can be rent and come equipped with the technologies mentioned above and are connected to the care center. The care center can:

- Communicate with a client using a two-way audio-visual connection
- Operate systems remotely if necessary, such as opening the front door in emergencies
- Monitor a client as required. The system is flexible to provide services proactively and reactively and can be adjusted as needed
- Function within the limits of the laws for the protection of privacy. The inhabitants can choose between a ‘light’ control package and a more intensive control package according to their needs. The difference of the light and the intensive the degree the care center monitors the inhabitant in his environment.

Viedome project is a prime example of how AmI and ICT technologies can help provide a new model of institutionalized care. The project was deemed a success and proved that such care can be affordable and cheaper than traditional institutionalized care.

Rialle, Duchene, Noury, Bajolle, & Demongeot (2002) in their work described extensively the concept of Health ‘Smart’ Homes (HSH) and its potential through the use of telemedical information systems and communication technologies. HSH systems aim at providing health
care services for people with special needs who wish to remain in their home environment and live independently. According to Rialle et al, home health care includes two main categories of services – remote advice and remote medical assistance – implemented using various devices and smart technologies. Usually such HSH environments are equipped with automatic devices and various sensors to ensure the safety of their patient status and are linked to a local intelligence unit which is responsible for analyzing the sensor data and detecting deviations from normal patient behavior and for critical or suspicious situations. HSH environments are also connected to a remote control center that dispatches the appropriate response to an emergency by notifying a set of people involved in the health care process. Scanaill, Carew, Barralon, Noury, Lyons, & Lyons (2006), in their study of approaches to mobility telemonitoring provided a comprehensive list of typical sensors employed in Health ‘Smart’ Homes. The list includes the following:

- **Pressure sensors**: an unobtrusive pad placed under a mattress or a chair to detect occupancy
- **Pressure mat**: an unobtrusive pad under a mattress to detect movement
- **Smart tiles**: footstep detection tiles, which can identify the direction in which a subject is walking
- **Passive infrared sensors**: detect movement by responding at any heat variation
- **Active infrared sensors**: consist of an infrared emitter and receptor and are placed in a doorway to estimate size and direction through doorway
- **Sound sensors**: sensors used to determine activity type
- **Magnetic switches**: switches used in cupboard, doorframes, etc., to detect movement or activity type
- **Optical/ultrasonic system**: measures gait speed and direction as the subject moves through the doorway

Earlier in the chapter, an agent-based smart home environment called the MavHome was described. MavHome acts as an intelligent agent that uses sensors to learn about the status of the environment and prediction algorithms to automate the control of home devices and appliances. Das and Cook (2004) in their publication explained how they extended MavHome’s functionality to provide healthcare monitoring services to assist the elderly and persons with disabilities. MavHome is equipped with sensors that record inhabitant interactions with various devices, medicine-taking schedules, mobility patterns, and vital signs. Novel algorithms were developed in order to learn patterns of activities from the data that was recorded by the sensors. These capabilities of the MavHome environment were applied to health monitoring in the following steps:

1. Perform secure, context-aware collection of health and activity data
2. Use data mining and prediction techniques to identify patterns in collected data
3. Identify trends that could indicate health concerns or a need for transition to assisted care
4. Detect deviations from regular patterns that may require intervention
5. Provide reminder and automation assistance for inhabitants

A number of examples of fall detection systems that use vision, acoustic and other sensors to track inhabitants in their environment and detect falls have been developed. Although such systems can be useful, they are specialized and have a narrow scope. Intelligent agent-based platforms like the MavHome can provide more holistic solutions in the field of remote
healthcare monitoring and have proven that this is the way to move forward in healthcare monitoring.

Requirement 4: Social Inclusion and Communication
In the previous sections it has been presented how AAL can provide feasible technological solutions in the areas of mobility, environment control, safety, emergency and remote healthcare assistance which were identified as the most important requirements that have to be met in order for a motor-impaired person to live an autonomous life. The fourth requirement for living independently is that of social inclusion and communication. Social inclusion is indeed a very important factor for the well being of any individual. However, it is true that certain groups of people are more susceptible to social isolation than others. These groups include the elderly, the disabled, and people who live in remote areas.

Leading an independent life does not only mean to be able to live at home alone, but it also to be socially active. Both ICT and robotics technologies can contribute in achieving both goals. In earlier sections, the chapter described examples of technologies that can provide assistance with common everyday tasks, but also act as agents of establishing communication connections and reinforce social ties with the outside world. Hector, the robotic assistant for example, has a video camera and a screen that can connect an outside person with the person living in the house. Such technologies enhance communication and prevent social isolation by allowing the persons at home to have face-to-face communication with friends and family or healthcare providers through telepresence technology.

Telepresence
Telepresence has long been advocated as an approach to enable virtual face-to-face communications for people located far away from each other according to Coradeschi, Kristoffersson, Loutfi, Von Rump, Cesta, Cortellessa, & Gonzalez, (2011). In fact telepresence and mobile telepresence concepts, have been developed since the 1980s. Some of these concepts have even reached the commercial exploitation stage. However, whereas telepresence provides a fixed platform for virtual face-to-face communication usually including a video camera, a screen, and a communication protocol, mobile telepresence or “telerobotics” offers a mobile platform that offers the users a “walking around” experience. This newer variant of telepresence proposes the integration of ICT technologies onto robotic platforms in order to enable actuation in a remote location. Up until now robotic telepresence has been used in dangerous or unreachable environments, but lately this technology is emerging in domestic and office environments (Coradeschi et al, 2011). Recognizing the potential of using such technology as a way to alleviate the ageing society issue of social isolation and loneliness, a few systems have been developed and studied in laboratory settings. Cesta, Coradeschi, Cortellessa, Gonzalez, Tiberio and Rump (2011), present such a telerobotic system in the project ExCITE. The project is funded as part of Call-2 of the EU Ambient Assisted Living (AAL) Joint Programme. The basic idea of ExCITE is to help develop a technology that is able to facilitate social interaction of people potentially isolated in their home or in a health institution and to increase their level of social participation. For that purpose, they introduced Giraff, a remote controlled mobile, human-height physical avatar with an integrated teleconferencing system that includes a camera, display, speaker, and microphone. The robot is powered by motors that can propel and turn it in any direction. A person (the visitor), such as a friend, a relative, a caseworker, or a healthcare provider, who wants to establish contact with the elderly or disabled person (the user), can operate the robot remotely within the user’s living environment. In other words, the client can actually drive the robot through the user’s house through simple installed software on a computer. The robot has a low center of gravity to ensure stability when moving on wheelchair ramps, weighs 14kg, and has carrying handles that allow easy transportation, placement in a car, or carrying it up stairs. The ‘head’ of the robot consists of an LCD panel display with highly variable viewing angles that can be tilted and panned to simulate eye-to-eye contact using servomotors. The robot also features a patented suspension system that allows the 15cm wheels to climb over
small obstacles and rugs. The remote user can also charge the Giraff by driving it onto a docking station. The Giraff is accessed and controlled via a standard computer system, desktop or mobile, over the Internet, using an application that can be downloaded for free from the Giraff web site. This application allows the visitor to navigate the robot down hallways, through doorways and around tables and chairs in order to reach the person in the house. The steering details are taken care by the robot, so all the client has to do is just point in the direction they want it to go. Through the camera the visitor can also have a view of the living environment of the user and look around in order to assess the situation, for instance in case of an emergency. Gonzalez-Jimenez, Galindo, & Ruiz-Sarmiento, (2012) presented the results of the user-based evaluations that were conducted in 5 separate houses and involved a total of 15 users teleoperating the robot prototype. Based on the results from the user-based evaluations, the developers introduced a series of improvements. These improvements included:

- The development of an algorithm that a) uses the onboard camera to automatically detect the docking recharging station, and b) takes the Giraff control to approach it. That way the burden of docking the robot in order to be recharged is taken off the user and it is now done automatically.
- The integration of an obstacle detector based on the sensory data provided by a radial laser scanner. This mechanism prevents Giraff from bump into into obstacles unnoticed by the operator or simply to warn him/her about their presence in the nearby.
- The enhancement of the tele-operation graphical interface with a 2D sketch map that shows the position of Giraff in the house and is marked in real time. This information has demonstrated to give the visitor a clearer spatial sense about where the robot is and what is being seen.

Communication through the use of computer and the Internet

Advancements in assistive technologies have made it possible for people with even severe mobility problems to interact with computer systems. Alternative keyboards featuring larger keys, different key configurations, and keyboards for use with one hand, trackballs devices to move the cursor on screen, joysticks, wearable devices that can strap to the chin and used to press keys on the keyboard, sip-and-puff systems, are just a few examples of such assistive devices for the motor-impaired. These devices have been on the market for a long time, but their functionality and design features are constantly improving. Apart from the advancements observed in the traditional computer assistive devices, there is the emergence of alternative interaction methods that do not require the use of an input device necessarily to interact with the system. Such alternative interaction methods include: eye-gazing gestures, hand, leg, and head gestures, natural speech recognition, Electromyogram (EMG) signals, and Brain computer interfaces (BCI). These methods are especially useful for people with disabilities and the elderly, and are being explored extensively in AAL applications (Margetis, Antona, Ntoa, & Stephanidis, 2012).

Both the traditional methods and newer ones have assisted in breaking communication barriers that motor-impaired people face. Through the use of a computer, it is now a possibility for people with even the most severe of motor-impairments to access all sorts of information and to communicate through emails, make chats, and Internet calls with friends and loved ones (Kaye, 2001). Through voice-over-Internet Protocol (VoIP) services that support calling and videoconferencing over the Internet, people can now, with no extra cost, connect with each other at the click of one button and have a face-to-face conversation no matter where they are located. In addition to these technologies, there is tremendous growth in the number of social networks on the Web, such as Facebook, Twitter, Instagram, etc., and virtual game worlds. These social networks and game platforms have truly revolutionized the way people associate with each other, partake in socialization activities, and form groups based on common interests and goals. Nowadays it seems that there is a blog or a social
network for just about any interest. Groups of users that share same interests have taken advantage of the Internet technologies and form social networks (i.e., forums, blogs, Facebook groups, etc.) that enhance the exchange of comments, ideas, opinions, and thoughts on the topic of interest. It is a fact that millions of users are connected through such networks on a daily basis. People with any health condition or disability can now find information related to their health issue, participate in online discussions and support groups with other people that have the same or similar conditions, and find information on any aspect of the condition (i.e., symptoms, treatments, management, etc.). For some people just knowing that there are others with similar conditions and being able to reach out to them and have conversations, reduces significantly the feeling of social isolation. Obviously, the use of assistive technology does not automatically give users’ access to Websites and other applications. The majority of the sites on the Web are not designed and developed with accessibility in mind (Kaye, 2001). The same is true for most social networks. There is still a lot of room for improvement in this area.

Challenges of AAL Technologies
The dynamic increase of the ageing population due to, at least in the so called developed societies, the decline in birth rates, an increase in life expectancy, and an increase in the number of single households, has caught the attention of the scientific research and academic community. The scientific community is in turn looking at ICTs and the emerging AmI platform for feasible and economically sustainable solutions that will counteract the above problem. This chapter presented examples of how current AAL and AmI technologies can be combined to support autonomous living for people with motor-impairments. Along with these opportunities however, a number of challenges to surpass are emerging in order to promote the transition of these solutions and services from the labs to the production lines and ultimately to the market shelves. And more importantly, along with the benefits that the penetration of smart technology brings into our everyday living and working environments, important social and ethical implications arise. One can wonder whether AAL environments act as a bridge between people with disabilities and the outside work, or do they actually promote an individualistic way of living. If people no longer have the need to get out of the house to see their physician for regular check-ups, if they do not have to actually go to the store to get groceries, if they do not have to drive down the street to visit friends and family, because they can conveniently do all that from the sanctuary of their homes, how is this living scenario going to solve the issue of social isolation? This issue is open for debate with analysts and researchers making valid arguments that support both sides. One thing is for sure, according to Bohn, Coroama, Langheinrich, Mattern, & Rohs (2005), that apart from personal prejudices, the wide range of social consequences that Ambient Intelligence may have needs to be addressed extensively in future systems and debates because these challenges are of fundamental importance and may even have a decisive influence on the large-scale acceptance of these technologies by the users. As also stated by Bohn et al (2005), only by identifying and addressing the great challenges of technical and social change, as well as their environmental sustainability, it may be possible to steer this development in a direction that holds an optimistic view of how this technology can be integrated in a fruitful and positive way in our lives. This section will briefly present some of the major challenges and social implications that come with AAL technologies.

Privacy
The loss of privacy in AAL and AmI environments is a big concern, if not the biggest. As Bohn et al (2003) pointed out, sayings such as, “the walls have ears” or “if these walls could talk” is a reality that is disturbing to many. The main reason behind this reality stems from the fact that in order for a smart environment to support context-awareness, adaptability and anticipatory behavior functionality, it needs to contain historical and current data about the individual’s daily activities and his/her preferences (Punie, 2003). In other words, it needs to keep a detailed ‘diary’ of the user’s tasks and an up-to-date profile with details on the users’ traits, behaviors, preferences, etc. The success of such a system depends heavily on the user’s
acceptance of the fact that there is a crucial, but inevitable trade-off between protecting the privacy of certain personal information and receiving convenient, efficient services (Punie, 2003). To make things even more complicated, what is considered obtrusive and privacy invading is not the same for everyone. In fact, it depends on many factors such as age and cultural background (Cook et al, 2009), and the level of support that the individual requires in order to live independently.

The matter of privacy becomes even more complex in Health ‘Smart’ Home environments that support telepresence and remote healthcare monitoring services. As it has been seen in some examples of such environments, sensors feed sensitive health related data from the house to the healthcare institution. In some instances, secondary users (friends, family, healthcare providers) have visual access to the living environment of the individual being monitored, through the use of cameras. Cook et al (2009) also state that the use of image processing through video cameras as a potential kind of sensor is a very controversial topic. And even though the amount of information that can be collected in that way is very valuable in terms of assessing, at the same time, the “big brother” nature of the system raises clear issues of privacy. Still there are situations where users consider the benefits outweigh the drawbacks of such monitoring systems and may decide to accept it as part of the system that is build to benefit them. In any case, it is ultimately at the user’s discretion to decide the level of privacy that they are willing to give up in order to enjoy the AAL services. The AAL systems offered should be able to provide and support different levels of privacy. Developers and researchers will have to take seriously into consideration the diversity in opinions among users as to what constitutes loss of privacy and consequently provide multiple privacy levels for the various services (i.e., low, medium, higher privacy levels).

Security
Along with privacy another very important challenge is to secure the systems from “malicious attacks” and hacks. As Friedewald, Vildjounaite, Punie, & Wright, (2007) pointed out, complex AAL and AmI systems like the ones previously described can become a target of active attacks (viruses, denial of service) and passive attacks (unauthorized monitoring), which may result in a partial or even a complete failure of the entire AmI system. Such attacks can cause a loss of convenience at the best-case scenario, or severe damage ranging from financial loss to death at the worst-case scenario. Another concern is that of identity theft, the act of obtaining someone’s identity information and using it without his/her consent. The likelihood of something like that happening increases tremendously as personal information becomes more widely available. For example, intimate and sensitive data like health information is often stored either locally in the home system or in another personal/wearable device – which can get lost or stolen – or in a central database of a hospital or an institution which may not be sufficiently secured (Friedewald et al, 2007). A lot of the Healthcare AmI applications presented earlier in the chapter, required large amounts of data transmission usually in more than one place. For example, in the case of an emergency, an alert may be issued to various recipients (i.e. a relative, a physician, a hospital, or even the police). There is also regular transmission of new data from all sorts of sensors to central databases and extensive ad hoc communication. The transmission of sensitive data to multiple recipient systems complicates the task of achieving a high level of security even more.

Due to the sensitivity of the data involved in these environments, the security mechanisms these systems must have in order to safeguard them against attacks must be reliable, robust, and as impenetrable as possible. According to Cook et al (2009), some steps have been taken to better understand privacy issues and to address these in AmI systems, but the dependability of AmI systems has not been researched to the same extent. AmI researchers should focus their attention on designing self-testing and self-repairing AmI software that can offer quantitative quality-of-service guarantees.
Accessibility
The benefits of AmI and AAL environments can only be fully achieved and enjoyed if such technologies can guarantee seamless accessibility for diverse functional limitations, including motor limitations. The accessibility of such environments poses different problems and is more complex than the accessibility of desktop or web applications and services, as AAL environments do not simply introduce a new technology, but an integrated set of technologies (Stephanidis, 2011).

AAL environments cannot be made accessible simply through the applications of guidelines or the use of conventional assistive technologies, and multimodality and the availability of alternative interaction techniques become key features towards supporting accessibility.

Although several interaction technologies, such as voice output, are already widely available, and other, such as eye-tracking, are reaching a maturity stage where they can be robustly exploited for accessibility purposes, a number of fundamental research challenges need to be addressed towards the provision of accessibility solutions in AmI and AAL environments:

- Knowledge of user requirements. Age-related factors are crucial, and the current understanding of the interaction requirements of older users in complex technological environments is limited.
- Ready-to-use accessibility solutions supporting alternative interaction techniques. Most available assistive technologies are limited to specific devices, and cannot be easily made compatible with complex environments including a variety of devices.
- Architectural frameworks supporting the integration and management accessibility solutions.
- Tools supporting the development lifecycle of accessible AAL environments (e.g., requirements analysis, design and prototyping, evaluation).

Addressing these fundamental issues is a necessary step towards further developing AAL technologies so that they have the potential to support people with motor impairments in everyday life and be widely adopted and used in practice.

Overall, here is limited understanding of user needs. Approaches like inclusive design or Design-for-All are not yet widespread (e-inclusion, 2010), and there is a general lack of in-depth understanding of the difficulties and everyday challenges motor-impaired and the elderly face. As a result, many of the produced services and applications in AmI and AAL environments are still too technical for an elderly person to understand and too difficult for a motor-impaired person to use on a regular basis.

Integration and reliability
AAL environments also present technological challenges regarding integration as well as reliability issues.

The AAL platform requires connectivity among heterogeneous components such as sensors, middleware, and networks that use different communication protocols. Establishing interoperability between the devices and the components over a unified platform is technically very challenging. Moreover, there is a lack of interoperability and standardization principles that developers, designers, and ultimately manufacturers could follow, resulting in ICT systems that often do not communicate with each other. This reality drives the costs of such services and solutions abnormally high and makes it difficult to enter the markets (e-inclusion, 2010).

Also, unless the promised technological solutions prove themselves very reliable, robust, and dependable, unless they deliver exactly what they promise, unless they react in ways they are supposed to react, then it will be difficult for them to be accepted by the public (Punie, 2003).
Especially in health related applications that may often deal with critical situations, a 95 percent accuracy level of the system, for example, may simply be not acceptable. And currently, a lot of these technologies are struggling to reach this level of performance in the labs.

Conclusions
This chapter has presented an overview of the field of Ambient Assisted Living and the solutions it can provide for people with age-related and health-related motor-impairments, in an effort to increase their level of independent living. The effect of an ageing society is multifaceted and governments around the world have taken notice of this problem and the major impact it will undoubtedly cause on the socioeconomic structures and processes of a country. Research and academic communities are turning into emerging Information and Communication Technologies for potential solutions that will help counteract the problem. Ambient Assisted Living is currently one of the important research and development areas that are showing promising results of technological solutions for assisted living environments. The main goal of AAL solutions is to apply ambient intelligence technology and ICTs to enable people with specific needs and demands, e.g., disabled or elderly, to live in their preferred environment longer independently (Kleinberger et al, 2007). In this chapter, four main requirements have been identified as essential for supporting independent living for people with motor-impairments. These four requirements are mobility and the ability to carry out everyday living tasks, environmental control, security and health monitoring, and social inclusion. If the living environment of the motor-impaired person does not provide features and services that support the above requirements to the degree needed by the user, living an independent life would be too difficult to achieve. The chapter provided several examples of AAL applications that address these requirements and that show great potential in becoming solid solutions for real life problems of the motor-impaired. Along with the opportunities that AAL technologies can bring, there are also many challenges that need to be overcome in order to bridge the gap between the labs and the markets. The main challenge is privacy and security. In order for the assisted environment to provide context-aware and anticipatory services, it needs to capture, record, and analyze sensitive data about the inhabitant/user. In many instances this data has to be transmitted via various devices to many ‘recipients’, increasing the risk of getting compromised, stolen, or used in unauthorized ways. Moreover, AAL environments require the embedding of sensors in everyday objects and components of the house in order to monitor the user behavior and extract patterns. This creates for the inhabitants a feeling of constantly ‘being watched’, which is not always welcomed and raises a lot of ethical concerns and questions. The field also requires new approaches to accessibility, capable of taking into account the accessibility of the environment as a whole and not only of each individual technology it contains. Moreover, there are also technical challenges observed in the realization of such environments due to the lack of standardization and interoperability principles. The complexity of their nature, which requires heterogeneous components connect through various networks in order to communicate with each other, poses several problems to the developers and the designers of the systems. Whether AAL and AmI environments will become a fixture in our future or succumb to the pressures of the challenges discussed remains to be seen. However, if AAL is to become a success story, the human factor has to be the main focus, at the center of the whole design, development and operation of such systems. It must be ensured that the design and development processes and environments are the ones to adapt to the users’ needs and not the other way around. In order to preserve the human as the central focus, more effort should be put into understanding, examining, and analyzing people’s needs and behaviors and the different ways of interaction with systems. The human-centered design principles should be the backbone of the entire system lifecycle process.
References


ADDITIONAL READING

Anastasiou, D. Survey on Speech, Machine Translation and Gestures in Ambient Assisted Living.


Yuksel, B. F., Donnerer, M., Tompkin, J., & Steed, A. Novel P300 BCI Interfaces to Directly Select Physical and Virtual Objects.

KEY TERMS

**Ambient Intelligence:** is a term used to characterize electronic environments that are sensitive, responsive, and adaptive to the presence of the people. In such environments, devices operate collectively using information and intelligence that is hidden in the network connecting these devices.

**Ambient Assisted Living (AAL):** refers to intelligent systems of assistance for a better, healthier and safer life in the preferred living environment of the user. AAL technologies cater for the different abilities of their users.

**Ubiquitous computing (also called pervasive computing):** refers to information processing that has been thoroughly integrated into everyday objects and activities.

**Information and Communication Technology:** refers to the integration of telecommunications (telephone lines and wireless signals), with computer networks and other audio-visual systems in order to enable the user to access, store, and manipulate information.

**Smart Homes:** refers to an environment that has as highly advanced automatic systems for monitoring and controlling various components of the house such as lighting, temperature, windows, doors, security systems. Smart homes can also collect, analyze, and store information about its inhabitants in order to make decisions on their behalf, i.e. house knows that inhabitant wakes up every day at 6am, so it turns on the heating at 5:45am in order to warm up the room by the time the inhabitant wakes up.

**Telecare:** refers to the concept of remotely delivered healthcare and support services to the elderly and people with disabilities in their own home environment.

**Telepresence:** refers to a set of technologies (videocamera, screen, communication protocol) which allow a person to feel as if they were present or, to give the appearance of being present, at a place other than their true location.

**Telerobotics:** refers to the concept of controlling robots from a distance, chiefly using wireless connections (like Wi-Fi, Bluetooth), the Internet, or other connections.

**Health ‘Smart’ Homes (HSH):** home environments that utilize ambient intelligence technologies to provide health care services for people with special needs who wish to remain independent and living in their own home.