Technologies and Applications for Active and Assisted Living. What's next?

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Twenty-five years ago, Mark Weiser published his paper *The computer for the 21st century* [1], seminal work on ubiquitous computing. Weiser and his colleagues at the Xerox Palo Alto Research Centre conceived a new way of thinking about computers, taking into account the human world and allowing the computers to vanish into the background. They thought about rooms with hundreds of computers interconnected in a ubiquitous network, of different sizes suiting particular tasks, which would come to be invisible to common awareness, and that people will simply use them unconsciously to accomplish everyday tasks. That paper finishes with the sentence "Machines that fit the human environment instead of forcing humans to enter theirs will make using a computer as refreshing as taking a walk in the woods," as an analogy of the problem of information overload. But it can also be understood as a goal to locate the user/person as the centre/goal of all this ubiquitous technology.

Following and extending Weiser's ideas, some years later, the term *Ambient Intelligence (AmI)* was coined by Philips. Early references to it appear in several publications, providing different definitions highlighting diverse aspects of the technologies and services involved:

> "In the near future our homes will have a distributed network of intelligent devices that provides us with information, communication, and entertainment. Furthermore, these systems will adapt themselves to the user and even anticipate on user needs. These consumer systems will differ substantially from contemporary equipment through their appearance in peoples environments, and through the way users interact with them. Ambient Intelligence is the term that Philips uses to denote this new paradigm for in-home computing and entertainment.(2000)" [2]

> "AmI provides a vision of the Information Society where the emphasis is on greater user-friendliness, more efficient services support, user-empowerment, and support for human

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interactions. People are surrounded by intelligent intuitive interfaces that are embedded in all kinds of objects and an environment that is capable of recognising and responding to the presence of different individuals in a seamless, unobtrusive and often invisible way. (2001)" [3]

"Ambient intelligence will become a network of hidden intelligent interfaces that recognise our presence and mould our environment to our immediate needs. (2002)" [4]

"...a new paradigm in information technology is emerging, in which people are served by a digital environment that is aware of their presence and context, and is responsive to their needs, habits, gestures and emotions: ambient intelligence. (2003) " [5]

"An AmI system requires the use of distributed sensors and actuators to create a pervasive technological layer, able to interact transparently with a user, either passively by observing and trying to interpret what the user actions and intentions are, but also actively, by learning the preferences of the user and adapting the system parameters (applied to sensors and actuators, for instance) to improve the quality of life and work of the occupant. (2005)" [6]

From these definitions, AmI is based on four key aspects:

Ubiquitous computing Embedded processing into everyday objects like furniture, clothes or toys; *i.e.* there is an interconnection of embedded systems that are hidden in the environment. This includes computers, communication systems, cameras, microphones, and pressure light, motion, and temperature sensors. There is also a possibility of communication among objects and between objects and the user;

Awareness The system must know at all times the state of the environment and its dwellers, being able to locate and identify objects and people;

Intelligence The system must be able to adapt to new data and establish connections with the existing knowledge; and

Natural interaction The basic requirements must be able to be transmitted and interpreted without the user performing strange or unnatural movements or orders. This suggests the development based on the most common means of interaction for human interfaces, such as speech and gestures. Besides, interfaces must be mixed with the environment so that the user does not feel them present.

In 2001, Ducatel *et al.* [3] foresaw how ambient intelligence was going to be used in 2010, presenting several case scenarios. This is a relevant document, now that we have long passed that date and we can compare those expectations with the actual achievements. Regarding technologies, those scenarios required:

- very unobtrusive hardware: self-generating power and micro-power usage of devices/objects; new displays, smart surfaces and paints; active devices, nanodevices, embedded computers;
- seamless mobile/fixed web-based communications infrastructure: complete integration of mobile and fixed and radio and wired networks, optical networks, and seamless and dynamic reconfiguration;
- dynamic and massively distributed device networks: plug-and-play solutions, multi-domain networking, embedded intelligence, distributed data management and storage systems, middleware;

- natural feeling human interfaces: intelligent agents, adaptive interfaces, multi-modal (multi-user, multilingual, multi-channel and multipurpose) user interfaces for speech, gesture, and pattern recognition; and
- dependability and security: self-testing and self-organising software, secure ID authentication, micropayment systems and biometrics.

They envisioned that, in 2010, all the required computers and interfaces would be embedded in a wrist band, identification though immigration and customs would be automatic using that wearable device, mobile audio systems, cars had to be driven but they would use a navigation system, rooms would automatically adapt to the preferences of the dweller, video conference systems would be projected on the walls, files would be stored remotely, people would be connected through social networks, each one of us would have a Digital-Me who learns from the user and interacts with others, people would share transport, the fridges would be smart, people would do their shopping electronically being delivered to home or to local kiosks, cars would auto-pay when entering specific city areas, their speed would be automatically reduced by the city authorities due to pollution, cars would sense other vehicles and persons around them, people would work from home to reduce carbon print, and people would share face-to-face/remote meetings using virtual reality.

A couple of years later, the Institute for Prospective Technological Studies (IPTS) and the European Science and Technology Observatory (ESTO) network, published a thorough report [7] proposing a roadmap for the design and development of ambient intelligence technologies and services. Friedewald *et al.* predicted that, in 2015, some technologies would be widely used, for instance: beyond 3G mobile networks, GPS-like systems, integration of all types of wireless networks, body area networks, in-body sensors, emotion measurement, bio-sensors, molecular electronics, high-density storage, nano-systems that can move inside the body for clinical applications, self-organising and self-repairing software, large-scale distributed systems, embedded systems, new and open standards, use of ontologies, semantic web, context-aware systems, natural real-time language translation, multi-users -environment -language -mood speech recognition, computers surpassing human logic and learning abilities, autonomous robots, most software written by a machine, "affective" robots, artificial noses, natural speech-based user interaction, multi-modal interfaces, augmented reality with see-through displays, brain-computer interaction, personalisation in commerce in physical stores, rollable displays, electronic ink, holographic displays, large ($>$50") displays, PCs using a small battery with more than one year of duration, ambient power, privacy and anonymity protection, secure transactions and payments, and reliable and fault-tolerant systems.

The rationale to mention all these different technologies and services, which were forecast more than 10 years ago, is to show how difficult it is to predict which new developments will be in the market and adopted by the general public in the future, even the near one. The authors of those two documents stressed that either these were the views of a relatively small group, or they were pure wishes, mind-opening vision or science fiction. As it is explained in [3], there a number of socio-political factors, and business and industrial models that produce these differences in developments and early adoption by the users. However, in those scenarios anyone can see current companies as Amazon, Google, Skype, Facebook, Dropbox and FitBit, to mention just some of them. But, there are many others that were not foreseen and some other models that are far from being accomplished. An interesting paper, by Gunnarsdóttir and Arribas-Ayllon [8], critically reviews the evolution of AmI and how many of those initial expectations have not been achieved.

Ambient Assisted Living (AAL), or Active and Assisted Living as it is the term currently employed in Europe, arises from the application of the Ambient Intelligent paradigm to support the well-being, health and care of older people. In [7] this was expressed as prevention, cure, care, and health administration. Similarly to the achievements and unfulfillments for AmI, the expected progress in AAL during these years has had diverse degrees of accomplishment.

Therefore, the remainder of this chapter will critically analyse where the achievements in technologies and applications for AAL that have been presented in this book stand with respect to the foreseen progress. Next, some forecast challenges for the next decade are introduced based on the aforementioned analysis and the summarised book chapters' conclusions. Finally, this chapter and with it this book are concluded.

1 Foreseeing the future of AAL

There are also some recent roadmaps that address specifically the technologies and services for active and assisted living. The AALIANCE2 Coordination Action is aimed at building consensus upon research priorities in AAL. As part of their work, the AALIANCE2 Consortium published in 2014 an AAL Roadmap and Strategic Research Agenda for the upcoming decades [9]. They presented ten different scenarios for the use of AAL technologies:

1. Prevention of Early Degeneration of Cognitive Abilities
2. Healthy Living
3. Management of Chronic Diseases
4. Age-Friendly and Safe Environments
5. Fall Prevention
6. Management of Daily Activities and Keeping Control over Own Life
7. Keeping Social Contact and Having Fun
8. Outdoors Mobility (i.e. pedestrians, public transport and private cars)
9. Avoiding Caregivers Isolation
10. Senior Citizens at Work,

analysing the needs and opportunities for the different stakeholders (*i.e.* older persons, informal carers, formal carers, service providers, local communities, and healthcare systems) and the key enabling technologies involved (see Table 1).

The German Commission for Electrical, Electronic & Information Technologies of the German Institute for Standardisation (DIN) and the Association for Electrical,

Sensing	Smart sensors, Micro-Electro-Mechanical System (MEMS), lab-on-a-chip, biosensors, vision sensors, acoustic sensors, olfactory sensors, environmental sensors, pervasive sensing and smart environments, in-body and on-body sensors, quantum sensors, and energy harvesting
Reasoning	Context awareness and sensor data fusion, artificial (quasi-human) intelligence, advanced controls for AAL robotics and devices, dependability and maintainability, and "Smart" everywhere! - miniaturization of processors
Acting	Service robotics, smart mobility, smart actuators, green technologies, neuro-robotics, wearable robotics, and cloud robotics
Interacting	Smart multimedia appliances and apps, smart wearable accessories, sensorial interfaces, spatial interfaces, natural language interfaces, multi-modal interfaces, neural interfaces and brain-computer interfaces, and service integrations
Communicating	Standardisation and certification, middleware, semantic technologies, self-configuration, self-optimisation, self-healing, self-protection, data protection regulations, body area network (BAN), personal area network (PAN), local area network (LAN), and wide area network (WAN)

Table 1 Key enabling technologies for AAL (adapted from [9])

Electronic & Information Technologies (VDE) published a roadmap for standardisation in AAL systems, with special attention to interoperability [10]. This document mentions all the available standards for sensors, actuators and house buses, for user interfaces, and for middleware/services/runtime platforms (including clinical standards). A repository of standards in technology related to AAL was also compiled by the AALIANCE2 project [1].

An interesting document [11] was published in 2015 by Nesta, the innovation foundation, about their vision of the UK National Health System in the medium-term future. Although this report focuses its attention to the challenges that the health systems will address due to the aging population, it is relevant as it proposes to empower people to track and analyse their own health data using ubiquitous technology for a personalised healthcare, and to share this data with others for promoting healthy living, prevention and management of chronic conditions.

As it can be observed from these examples of recent analysis of the state of the art and the future of AAL, and as it has been seen throughout this book, most of the technologies and services are similar to those that were proposed one decade ago. Are we still at the same point? No. Have we reached those predictions? Neither.

2 What have we reached so far and what is next?

This book provides a review of the current developments in technologies and applications for AAL, which can be compared with those expectancies that some early researchers in the area had some decades ago. This section summarises the current and expected advances in AAL.

[1] `http://nero.offis.de/projects/aaliance2/start` (Accessed in March 2016)

There are many important new players in the market, however, global adoption by the users is going much slower than it was expected some years ago. In many Western countries, only the use of gas or smoke detectors, or HVAC controllers, are mainstream. In most cases, far from being "smart."

While the use of ambient sensors seems to be limited to public environments, with the exceptions just mentioned, wearable sensors either embedded in mobile phones or worn by the user (*e.g.* smart watches) are currently getting the interest of people. There are a variety of mobile applications that allow the monitoring of vital signs or physical activity in order to provide solutions to support a healthy living. In the near future, research and innovation should focus on miniaturisation, lower energy consumption and comfortability.

Among ambient sensors, video-based devices stand out, as they can acquire a lot of information from the environment for a variety of services (safety, security, recognition of activities of daily living) as it is mentioned in several chapters. However, current systems for video analytics are not robust enough for a reliable use under unconstrained conditions, and there are privacy concerns that need to be addressed in order to increase user acceptance. However, recent devices (*e.g.* RGB-D devices as the Microsoft Kinect) may contribute to address these issues.

All these sensors offer different functionalities, are able to acquire different information from the environment and the user, and have different degrees of reliability. Therefore, instead of working in isolation, there is a need for information fusion to reduce uncertainty and develop more robust AAL solutions. There are current projects working on this fusion, as well as on the integration of other data sources, *e.g.* social networks, integration at different scales (home, city, transport), or user profiles.

An area where research is getting huge advances is that of assistive robots, which are able to support older people in their everyday activities, to monitor them, or to allow remote carers to interact with the assisted people [12, 13]. Relevant developments are also expected in exo-skeletons or wearable prosthetics for rehabilitation and support to people with motor impairment [14, 15].

Anyway, these sensors would need to gather and integrate as much information as possible about the status of the environment and the user/s in order to offer intelligent, proactive, context-aware and adaptive AAL solutions, which could be valid for the changeable health, physical, sensory, and emotional conditions of older people. These large amounts of data would need to be analysed to extract valuable information for the users. We are entering the era of the Big Data [16] and the quantified self [17].

Currently, fall detection is one of the main AAL applications related to safety. Systems such as those that have been presented in this book employ inexpensive accelerometers and gyroscopes, which are embedded in mobile phones or in specific devices (*e.g.* pendant alarms). These are wearable systems that can be employed ubiquitously. However, they will not detect any fall if the user forgets to wear it, what can regularly happen with older people or people with dementia. Therefore, some other systems using radars or cameras in the environment are currently being developed. Nonetheless, they are not robust enough in real conditions, for instance, in a home where the environment can be cluttered with furniture.

Frailty is very related to fall detection and, in particular, fall prevention. A measure of frailty can be obtained by analysing human gait. Systems for gait analysis usually employ the same sensors than those for fall detection. Only in specialised facilities other devices such as sensorised walkways are employed. However, they are too expensive to be used in a home. Further research in the near future should be focused on making the systems more robust, and designing systems that allow long-term gait analysis in order to find variability over time.

Another application where long-term analysis and continuous learning would be required is in the recognition of activities of daily living (ADLs). These systems would be able to learn users' routines and behaviour, and detect deviations from those routines. There are still many challenges that AAL systems have to address for an effective recognition of ADLs: multiple occupancy of the environment, context-awareness, recognition of complex activities, fusion of data captured with environmental and wearable sensors, etc. Although common to all the AAL services provided at home, one of the main issues with recognition of ADLs is the requirement of sensorising the usual environment of a person, the home. Installation of multiple sensors and actuators in every room is, in many cases, not accepted by the users as it requires retrofitting the house, wiring all those devices. Although there have been advances in wireless devices, most of them require being connected to mains power. The autonomy of battery-powered devices is still very short. Therefore, research needs to be carried out on lower-consumption or self-powered devices.

Regarding systems to support mobility of older people, either outdoors or indoors, great advances have been obtained in the last years. Navigation in outdoor environments is integrated in most smart phones, while systems for indoors navigation are improving. Efforts may be directed towards the support of mobility of people with disabilities, *e.g.* visually-impaired people. Another area where mobility will be improved in the near future is the use of autonomous cars [18, 19], as they will not require attention from the driver, facilitating their use by older and disabled people.

While some of these AAL solutions will not require any active input by the users, other systems will involve some person-environment interaction. Following the AmI paradigm, this interaction should be natural using gestures, speech and touch as input; and using images, voice synthesis, scents [20, 21] and haptics [22] as output. Current WIMP (windows, icons, menus, point-and-click devices) [23], and even tablet devices, are not natural to use, and this is exacerbated with older people, who are less accustomed to Information and Communication Technologies. Some other more advanced interfaces, as virtual and augmented reality [24], brain-computer interfaces [25], and affective interfaces [26, 27] will be very relevant in AAL.

However, in order to actually fulfil a complete integration, not only of sensors but also of actuators, as well as of processing and communication systems, there is a need for standards and effective interoperability among them. Since some years ago, there have been different initiatives to reach that interoperability, however this has not been obtained yet, limiting the global deployment of the Internet of Things [28], smart homes and technologies for AAL.

3 Conclusion

Last but not least, in this section, we want to clarify the objective of bringing together the broad fields of technologies and applications involved in AAL in this book. *Active and Assisted Living: Technologies and Applications* is aimed at being a handbook for researchers, as well as technical and healthcare professionals from any of the related fields who may need to acquire or refresh their knowledge of the recent state of the art and obtain a well-balanced in-depth and broad know-how of the field's technologies and applications.

This goal is pursued by covering all major technologies used in the field, including but not limited to smart homes, environmental and wearable sensors, visual monitoring, information fusion, standards and interoperability, reasoning systems and person-environment interaction. On the other hand, AAL applications are important also to healthcare professionals and caregivers. In this part, the book has reviewed tele-care and tele-health, as well as gait analysis, fall detection, support of ADLs, outdoor and indoor mobility, well-being and social interaction and decision support systems. Finally, associated issues such as accessibility, privacy and human-centred design; and study cases for smart cities and smart homes are presented.

In this sense, this book gives a unified view of the significant amount of scientific fields that are emerging from and coming together in AAL. As such, it can provide not only a way of precise and direct initiation in the field, but it may also serve as reference for similar state-of-the-art reviews and retrospections in the future.

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