Technologies and Applications for Active and Assisted Living. Current situation.

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1 Introduction

The world is addressing significant challenges due to the current and future demographic contexts. The number of people aged 65 years or over in Europe and the U.S. will almost double between 2015 and 2060 [1, 2]. This will be linked with an increase in people requiring long term care, *i.e.* a continuum of medical and social services designed to support the needs of people living with chronic health problems that affect their ability to perform everyday activities [3]. Currently, approximately 30% of people between 65 and 80 years of age require long term care. This percentage reaches 50% for those over 80 [4]. Longevity of people combined with the decline in birth rate will also put pressure on the economic support of this care. The Statistical Office of the European Communities (EUROSTAT) projects that, in the next 30 years, the ratio between working and retired people, *i.e.* the old age support rate, will move from four-to-one to two-to-one in the EU [5]. Nowadays, EU Member States spend approximately a quarter of their GDP on social protection [6]. These demographic and economic situations raise significant challenges towards health and social care of the older population in terms of increased costs and lack of resources.

Parallel to this social need by citizens and governments, there is an economic opportunity arising from the expenditure related to the specific needs of the older population, what is called the Silver Economy [7]. According to Euromonitor [8], the spending power of this population group will reach $15 trillion by 2020 globally. Moreover, older people wish to keep their independence as long as possible, trying

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to fend for themselves by having a fulfilling life in terms of everyday activities and leisure.

Simultaneously to these changes in demography and attitude, faculties, and economics of older people, there have been great advances in information and communication technologies (ICT), with a rapid deployment and adoption by the general population. This has been mainly due to the introduction of the Internet and mobile telephony, and in the near future, generalisation of home automation systems and intelligent environments.

Technologies and services for Active and Assisted Living (AAL) stand out as a possible solution to address these challenges. AAL systems aim at improving the quality of life and supporting independent and healthy living of older or impaired people by using ICTs at home, at the workplace and in public spaces. AAL refers to the use of ICTs in the environments in which users are, so that these spaces are able to interact with people in a natural way, wherever and whenever they are needed, being aware of the context (situational, temporal, emotional, etc.) of the user or the environment, and to act proactively. An AAL environment requires the use of a distributed network of sensors and actuators to create a ubiquitous technological layer, able to interact transparently with the users, observing and interpreting their actions and intentions, learning their preferences and adjusting the parameters of the system to improve their quality of life and work.

AAL establishes a new paradigm of how people use technology. This is due to its holistic and person-centred conception, so that AAL could be usable, acceptable, useful and providing social value. Of course, these AAL technologies and services must be feasible and provide business value for the companies that develop them. In order to fulfil this holistic view of technology, the solutions developed must incorporate in their conception, design and development, the involvement of experts with different backgrounds: technology, health and care, social sciences, etc. What is paramount is users' engagement, in particular of those groups that may have a greater reliance on technology or who can receive greater support in their daily lives.

The objectives of AAL are diverse, as stated by the AAL Joint Programme [9]:

- to extend the time people can live in their preferred environment by increasing their autonomy, self-confidence and mobility;
- to support the preservation of health and functional capabilities of the elderly, promoting a better and healthier lifestyle for individuals at risk;
- to enhance security, preventing social isolation and supporting the preservation of the multifunctional network around the individual;
- to support carers, families and care organisations; and
- to increase the efficiency and productivity of used resources in the ageing societies.

The stakeholders addressed by these objectives also cover a wide spectrum [10]:

Primary Older persons, their families and informal caregivers;
Secondary Formal caregivers, service providers, charities and voluntary organisations;

Tertiary Organisations supplying AAL technologies and solutions; and
Quaternary Service procurers, policy makers, insurance companies.

The wide spectrum of objectives and stakeholders offers many possibilities for researchers and innovators in order to provide valuable services. This book aims at offering a comprehensive review of the technologies and applications for AAL. That is how this book is structured, incorporating some associated issues that intervene in the design and use of those solutions.

2 Technologies for AAL

In order to provide AAL services in their place of need, such as care centres or personal homes of older people, researchers, engineers and technicians are challenged by the wide scope of involved technological infrastructure. Depending on the specific application, several technological areas and research fields can be involved. However, a common underlying infrastructure usually exists regarding areas as ambient intelligence and ubiquitous computing, that are closely related to sensor and smart home technologies. The present book's first part digs deeply into these areas, chapter by chapter, highlighting and analysing specific works that have addressed these challenges recently in the state of the art, as well as presenting their own contributions. In the following, these chapters and the main goals which they address are briefly summarised.

In *Current State of the Art of Smart Environments and Labs from an AAL Point of View: Critical Analysis*, current contributions to the AAL technology development, and more specifically to smart environments and labs, are synthesised to reflect the current state of the field. *Crandall & Cook* focus on the engineering, including infrastructure such as sensors and middlewares, and user needs of AAL systems, along two of the major applications of smart homes, namely health care and home automation. The current challenges and ongoing projects of the state of the art of smart homes is then laid out based on summarising the work of the globally most active research groups and commercial smart home technologies available.

Next, in *Ambient and Wearable Sensors for Human Health Monitoring*, the authors *Rodgers et al.* study how monitoring of personal activity, vital signs and physiological measures can be enabled in a manner that minimises disruption to an individual's daily routine, while protecting their privacy at the same time. Ambient and wearable sensors that make this possible are reviewed, and special emphasis is made on favouring engagement of individuals to reduce the reliance on healthcare systems and improve self-care management of chronic conditions. Among other future challenges, the authors identify that both generating just-in-time actionable knowledge and creating a learning health care system are dependent of having scalable and interoperable systems, which can track behaviours concurrently and deal efficiently with the big data issues that result from a growing array of networking sensors and their data streams.

Visual sensors can be considered a very special type of sensors, since in most scenarios they are able to provide richer data about the environment than multiple other environmental sensors combined. The chapter *Computer Vision for Active and Assisted Living* analyses the state of the art of RGB cameras and depth sensors, detailing how pattern recognition and machine learning methods are applied to human motion and activity recognition and tracking. *Planinc et al.* use the traditional image processing pipeline to illustrate how current AAL projects take advantage of computer vision to approach a variety of applications from human behaviour analysis to physiological monitoring. The use of depth sensors, such as the popular Microsoft Kinect, for rehabilitation and robotics among others is reviewed, detailing skeletal pose estimation and tracking techniques, as well as methods based on depth maps, point clouds and plan-view maps. Finally, existing studies are synthesised related to the accuracy of infrared and time-of-flight depth sensors in comparison to stereo cameras and other marker-based tracking systems.

The different types of sensors and their readings, from binary to three-dimensional images, provide AAL systems with very heterogeneous information about the environment on which to act upon. The chapter entitled *A Data Fusion Approach for Identifying Lifestyle Patterns in Elderly Care* synthesises data fusion approaches which are aimed at combining information from multiple sensors of the same or different nature at varying levels of the system. A specific case of data fusion is considered, *i.e.* the combination of motion detectors and cameras, namely passive-infrared motion sensors, RGB cameras and depth sensors. *Eldib et al.* also introduce an in-home monitoring system which fuses a network of motion sensors and low-resolution cameras by combining the detected activities to identify the occupant's daily lifestyle pattern. Especially the deviations in these lifestyle patterns, such as *restful isolated days* or *busy social days*, can be very valuable health indicators.

Another challenge that arises from the heterogeneous sensors and actuators that can be employed in smart homes is their interoperability. Different underlying systems and protocols have to work together, since rarely one vendor can cover all in-home, wearable and mobile technologies, that users want to use transparently. This subject is addressed in *Towards Interoperable Enhanced Living Environments*, focusing on interoperability in Internet of Things infrastructures. *Spinsante et al.* summarise the basic challenges of interoperability as 1) device cooperation and discovery, 2) reduction of the number of gateways, and 3) user-centred personalisation. Specific design methodologies and existing projects and frameworks aimed at providing the necessary software architecture and the required network and data interoperability are reviewed.

AAL services maybe as simple as reminding a person to take their prescription each eight hours, or as complex as recognising that the average daily amount of movement of an individual has been decreasing steadily and that this could imply a health risk due to their medical condition. This means that sophisticated long-term monitoring and detection may be necessary. In *Reasoning systems for AAL*, *Azkune et al.* distinguish three functional layers in reasoning systems for activity monitoring, activity modelling and activity inference. Monitoring is achieved through visual, environmental or wearable sensors, whereas modelling and inference requires learning techniques, either data-driven approaches that learn models from user data and infer the corresponding class, or knowledge-driven approaches that apply domain-specific knowledge and rules. Last but not least, the use of ontologies in AAL as support for reasoning systems is considered, as these can solve the modelling of complex data domains (*e.g.* user context) in an expressive and formal way.

Intelligent environments that enable AAL systems are not passive systems that continuously read data and eventually show results on a screen, but interactive systems that have to be able to proactively engage with the user when necessary. In the chapter named *Person-Environment Interaction*, the author *Caleb-Solly* presents an overview of human-computer interaction methods and design issues for person-environment interaction that are related to AAL. Special consideration is given to the accessibility needs of people with age-related physical and cognitive impairments, exploring different interaction modalities and technologies depending on the specific impairment and other additional variables, such as stress and social context.

The last chapter of this part of the book dedicated to AAL technologies, deals with telehealth. Among the valuable services AAL systems can provide, telehealth stands out as a viable option for enabling individuals to live at home safely and independently despite requiring periodic or continuous assistance, which is nowadays provided only in clinical environments. Health-oriented data analytics methods are reviewed in *Data Analytics for enabling Connected Health* by *Naguleswaran et al.* Furthermore, a novel data analytics method is presented. This decision support system relies on data from smart phones to identify human activity patterns and detect deviations based on individual health requirements. The system is also able to select the appropriate features for this purpose and ignore irrelevant inputs.

3 Applications for AAL

These technologies can be applied to offer a variety of services in different environments, *i.e.* at home, in public spaces, and at work. The AALIANCE2 Coordination Action presented several scenarios where AAL technologies can provide support to older people [10]: prevention of early degeneration of cognitive abilities, healthy living, management of chronic diseases, age-friendly and safe environments, fall prevention, management of daily activities and keeping control over own life, keeping social contact and having fun, outdoors mobility, avoiding caregivers isolation, and senior citizens at work. The second part of this book includes chapters discussing in detail some of these applications, the technologies employed in each case, and presenting their own work to provide valuable services.

Activities of Daily Living (ADLs) are those common tasks that people do everyday. Basic activities such as bathing, dressing, toileting and eating; and instrumental activities, including, for instance, shopping, housekeeping, food preparation and ability to handle finances. In *Supporting Activities of Daily Living*, *Shewell et al.* review how AAL technologies, in particular smart environments, enable older people to perform some of these activities. They present several approaches to make environments intelligent: data driven, knowledge driven and context aware. Finally, the authors describe some challenges to design robust and reliable systems to support ADLs. These include data heterogeneity, interleaved activities, multiple occupancy, and ethical and security issues.

Gait is noticeably closely related to a person's well-being and personal autonomy, but it is also a very valuable metric for their physical and mental health state. In *Human gait analysis for frailty detection. Quantitative techniques and procedures.*, *Fontecha et al.* study specifically the frailty syndrome considering gait activity as main predictor of the functional disorder of frailty. Multiple sensors, as accelerometer-enabled devices, pressure sensors and cameras, and analysis methods, based on different gait parameters and classification algorithms, are presented. Next, the authors present their own methods and results in three different case studies using accelerometer-enabled smartphones, wireless sensorised insoles, and a structured light sensor, respectively.

Increase in frailty may lead to a higher risk of having a fall incident. First, chapter *Fall prevention and detection* focuses on automatic techniques to assess fall risk, as a mechanism for prevention. *Baldewijns et al.* present different spatial and temporal parameters, which can be obtained from gait, in order to estimate an increase in fall risk. They also review the sensors that may be employed to calculate those parameters, next, different alternatives to visualisation and automatic interpretation of the gathered data. Finally, as the authors indicate, although these techniques may prevent falls, they cannot eliminate them completely. Therefore, they present different methods for fall detection using body-worn sensors (*i.e.* inertial measurement units) or sensors located in the environment (*i.e.* doppler radars, cameras, and RGB-D devices).

Mobility is key to carry out many ADLs, for instance ensuring that older people can continue their interaction with others to avoid social isolation, that they are able to do their shopping by themselves, or that they can move independently at home. Most mobile devices incorporate pre-installed applications for location and navigation, however, commonly, they are not appropriate for being used by pedestrians or they miss valuable information required by people with physical or sensory impairments. *Hempel et al.* in their chapter *Outdoor Mobility Assistance – Technologies Helping on the Way* present different systems for localisation and positioning, as Global Navigation Satellite Systems (GNSS), infrastructure-based systems, dead reckoning methods, and hybrid methods. They also introduce other aspects that are relevant when designing navigation systems, as how to model the environment, and how to facilitate the interaction with the user. Finally, the authors review several products available in the market and relevant research projects in the area.

The chapter *Location And Orientation Technologies Based On Wifi Systems For People With Disabilities In Indoor Environment* complements the previous chapter, by studying the specific case of indoor systems, in which GNSS are not applicable, as the line of sight between satellites and the users is blocked. *Coret Gorgonio et al.* follow the Human Activity Assistive Technology (HAAT) model [11] to present the different aspects involved in mobility support systems for people with impairments.

The involvement of occupational therapists is very relevant at the moment of prescribing the appropriate AAL technologies and services to support independent living of older people. *Young* introduces the Person-Environment-Occupation Model (PEOM) [12] in chapter *Enabling health, wellbeing and engagement in life through ambient assisted living technologies: An occupational therapist's lens*, as a framework for that prescription. Next, the principles for universal design are enumerated. Finally, the author reviews different examples of solutions to support older people in their well-being, health, social interaction, and engagement in life.

Other systems carry out a continuous monitoring of vital signs using wearable sensors, interpret the acquired data, support the medical staff or the carers to take a decision, and present the feedback in a meaningful and valuable way. *Baig et al.* review different decision support systems for inpatient care which provide data and feedback using tablets. This chapter, *Tablet-based Clinical Decision Support System for Hospitalised Older Adults*, analyses the current issues and challenges involved with the use of tablets in hospital care. Finally, the authors propose a decision system to provide individualised monitoring and interpretation of the vital signs in order to diagnose different health problems.

4 Associated Issues and Case Studies

In the third and final part of the book, cross-cutting issues of AAL systems are tackled, which go beyond technology and applications and affect an AAL system's whole lifetime from design to result evaluation. These issues, such as the design of AAL services, accessibility, and privacy, have come up several times in this book, and it can be seen clearly how challenging and wide-scoped these subjects are when targeting in-home technology and health care services. In *Smart, Age-friendly Cities and Communities: the Emergence of Socio-technological Solutions in the Central and Eastern Europe*, smart cities and age-friendly communities are studied, focusing mainly on universal design, usability and accessibility. *Klimczuk & Tomczyk* present examples of such cities and communities and the concepts and premises that grounded these developments. Then, a closer look is taken to Central and Eastern Europe analysing the local needs of older adults, and how the challenge of a rapidly ageing population is handled along an often deficient existing infrastructure.

With all the analysed technologies and applications AAL compromises, one could ask the question of how a really accessible environment would look like that enables seamless multimodal interaction for older adults and impaired inhabitants, with both existing and emerging assistive technology solutions. *Stephanidis* attempts to answer this ambitious question in the chapter *Towards accessible Ambient Assisted Living environments*. By presenting such an accessible AAL environment, the emerging requirements are analysed, along the existing work of the state of the art and open challenges.

Perhaps one of the most clear issues associated with the adoption of AAL systems in private and semi-private environments is how the right to privacy can be protected without decreasing the quality of the service and, in particular, the recall of monitoring systems that detect situations of risk, such as falls. In *Privacy and ethical issues*, *Florez-Revuelta et al.* introduce privacy, ethical and legal issues related to healthcare technologies. With this context, design principles for privacy-aware technologies are presented. One particular case of technology is studied in further depth. This is visual monitoring with cameras, since this is one of the most intrusive technologies seen throughout this book. Different methods for visual privacy protection are reviewed, and an approach to offer different visualisations based on the user's context is presented.

End-users of AAL services have to be involved from very early design stages to avoid unexpected user experience conflicts. However, even when this is done, older or impaired adults are extremely heterogeneous, which makes it very difficult to find the right target group and approach the design stage appropriately. In *Human-centred design with older adults: examples and recommendations for research, ideation and testing*, *Correia de Barros & Vasconcelos* go through the principles and practice of human-centred design with older adults reviewing existent literature and defining recommendations for the phases of ideation, testing and refinement. As a result, this chapter is very useful for both researchers and practitioners to support human-centred design processes.

Finally, the last chapter of this third part of the book presents a case study that goes from the initial design of a specific home platform to the final evaluation of experimental results obtained on an implemented proof of concept. In *Design and Implementation of a Smart Home Technological Platform for the Delivery of AAL Services: from Requirements to Field Experience*, *Spinsante et al.* first provide an overview of existing technology platforms used in research projects, and then introduce their platform for AAL service provisioning. Due to the close collaboration with several small medium enterprises which contributed their own technology, special attention is given to interoperability and product integration. During the evaluation of the experimental results, several aspects are addressed, not only limited to technology and the successful use of AAL services, but including also data management and analysis, and user interaction.

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References

[1] European Union, *The 2015 Ageing Report. Underlying Assumptions and Pro-*

jection Methodologies, 2014.

[2] S. L. Colby and J. M. Ortman, *Projections of the Size and Composition of the US Population: 2014 to 2060*, 2015.

[3] N. McCall, *Who Will Pay for Long Term Care? Insights from the Partnership Programs*. Health Administration Press, 2001.

[4] F. Colombo, A. Llena-Nozal, J. Mercier, and F. Tjadens, *Help Wanted? Providing and Paying for Long-Term Care: Providing and Paying for Long-Term Care*, ser. OECD Health Policy Studies. OECD Publishing, 2011.

[5] OECD, *Pensions at a Glance 2015. OECD and G20 indicators*. OECD Publishing, 2015.

[6] European Commission, *Active Ageing Special Eurobarometer 378*, 2012.

[7] ——, *Growing the European Silver Economy*, 2015.

[8] Euromonitor, *Boomers as Consumers*, 2012.

[9] AAL Association, "Objectives - Active and Assisted Living Joint Programme," http://www.aal-europe.eu/about/objectives, (Accessed in March 2016).

[10] AALIANCE2 Consortium, "AALIANCE2 AAL Roadmap 2014," http://www.aaliance2.eu/system/files/drafts/AALIANCE2_Roadmap2014.pdf, (Accessed in March 2016).

[11] A. M. Cook and J. M. Polgar, *Assistive technologies: Principles and practice*. Elsevier Health Sciences, 2014.

[12] M. Law, B. Cooper, S. Strong, D. Stewart, P. Rigby, and L. Letts, "The person-environment-occupation model: A transactive approach to occupational performance," *Canadian Journal of Occupational Therapy*, vol. 63, no. 1, pp. 9–23, 1996.