AALIANCE

THE EUROPEAN AMBIENT ASSISTED LIVING INNOVATION ALLIANCE

Ambient Assisted Living Roadmap

COOPERATION

AALIANCE is funded within the specific programme Cooperation and the research theme ICT of the 7th European Framework Programme

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Ambient Assisted Living Roadmap

AALIANCE – The European Ambient Assisted Living innovation Platform
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The Coordination Action AALIANCE – funded by the European Commission, DG Information Society and Media, within the 7th Framework Programme – focuses on Ambient Assisted Living (AAL) solutions based on advanced ICT technologies for the areas of ageing at work, ageing at home and ageing in the society. AALIANCE will

- provide a framework for stakeholders, led by industry, to define research and development priorities, timeframes and action plans on strategically important issues in the field of Ambient Assisted Living
- play a key role in ensuring an adequate focus of research funding for AAL, in fostering effective public-private partnerships and in developing a European research policy, in particular in focusing on FP7 and on current activities launched by EU member states (AAL Joint Programme).

Therefore the immediate objectives of AALIANCE consist of:

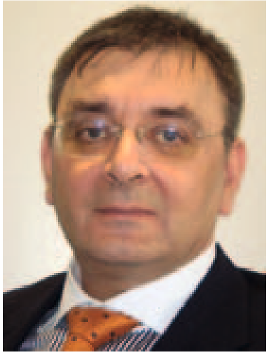
- setting-up a sustainable network – starting with 14 partners to be extended to approx. 35 – involving companies as technology providers and systems integrators, service providers, research organisations and user associations
- coordinating the various activities of European industry and research institutions in the field of Ambient Assisted Living,
- preparing and maintaining a R&D roadmap and strategic research agenda (SRA) for AAL with a mid to long perspective
- defining standardisation requirements
- providing recommendations for a European RTD policy on Ambient Assisted Living, and
- supporting European and national entities to increase political awareness and intensify activities for the enhancement of new AAL technologies.

From these activities it is expected to strengthen the Ambient Assisted Living value chain in Europe, to reinforce the position of providers of Ambient Assisted Living solutions in Europe and address one of the most promising markets of industrialised countries.

Partners:

VDI/VDE Innovation + Technik GmbH (Germany), AGE – the European Older People's Platform (Belgium), Bosch GmbH (Germany), Deutsche Telekom Laboratories (Germany), Fraunhofer-Gesellschaft (Germany), Fundación Vodafone España (Spain), Institute for Microelectronics and Microsystems – CNR (Italy), Luleå University of Technology (Sweden), Philips Electronics (The Netherlands), Scuola Superiore S. Anna (Italy), Sorin Group (France), University of Newcastle (UK), Vermon SA (France), VTI Technologies Oy (Finland)

Foreword



The emerging demographic change towards an ageing population is introducing drastic changes in our society.

We therefore need to find ways to motivate and assist older people to stay active for longer in the labour market, to prevent social isolation and promote societal inclusion and finally to help people stay independent for as long as possible.

Information and Communication Technologies (ICT) can play a major role in order to help achieve the above goals. ICT can help elderly individuals to improve their quality of life, stay healthier, live independently for longer, and counteract reduced capabilities which are more prevalent with age. ICT can enable them to remain active at work or in their community.

To achieve these goals, we need appropriate policies that will help promote introduction of such solutions for improved quality of life for elderly people and their carers, strongly increased efficiency of our care systems while creating fantastic new global market opportunities for European industry.

In response to these challenges and opportunities, the European Commission has launched an Action Plan for Ageing Well in the Information Society which includes measures to: Raising awareness and sharing of good practice; Building consensus via stakeholder cooperation; Promoting policies to stimulate innovation in the public sector and to overcome technical and regulatory barriers to market development; Accelerating take-up and innovation; Boosting research and innovation. As a result, between now and 2013, the EU and Member States, and the private sector

will invest more than €1 billion in research and innovation for ageing well: some €600m in the Ambient Assisted Living Joint Programme, an expected €400m in the EU's 7th framework programme and so far more than €60m on large scale pilot projects in the EU's ICT Policy Support Programme.

I therefore welcome very much this initiative of the ALLIANCE innovation platform on ICT for Ageing Well. A strong common vision and a corresponding roadmap and Strategic Research and Innovation agenda across all relevant stakeholders is essential to ensure that the investments will bring forward relevant ICT solutions for Ageing Well.

The European Commission will use this document and further AALIANCE developments as a key input to help define future strategies and direction of EU funding schemes that can provide support to the stakeholders in this domain.

I strongly encourage the whole community to contribute to make this vision come through for the benefit of Europe.

Florin Lupescu
Director,
ICT addressing Societal Challenges,
DG Information Society and Media,
European Commission

Executive Summary

New European population projections for 2008–2060, published by the European Office for Statistics, has recently underlined that the number of elderly persons will quickly increase. From 2015 on, deaths are projected to outnumber births in the EU27 and almost three times as many people will be aged 80 or more in 2060[1]. This demographic development and the ageing of European populations will lead to a growing number of older people living alone and in need of (intensive) care, to an ageing workforce in general and to more financially well-appointed and wealthy senior citizens ready to enjoy their third age and to spend money on products securing and enhancing wealth, safety, security and not forgetting entertainment and communications needs. Considering that this trend will also be correlated to a rapid growth in the number of persons with physical disabilities, it is clear that the problem of care and assistance to these persons are becoming more and more important both from social and economical points of view. These societal trends will bring dramatic challenges for healthcare and care systems, state pensions schemes and employers alike and at the same time offer innovation and business opportunities for technology providers in the field of innovative ICT-enabled assisted living or "ambient assisted living" (AAL). AAL relates to intelligent systems of assistance for a better, healthier and safer life in the preferred living environment and covers concepts, products and services that interlink and improve new technologies and the social environment, with the aim of enhancing the quality of life (related to physical, mental and social well-being) to for all people (with a focus on older persons) in all stages of their life. AAL can help older individuals to improve their quality of life, to stay healthier and to live longer, thus extending one's active and creative participation in the community.

Currently there is a vast number of (more or less linked) European and national research activities in the field of AAL involving various technology areas and innovative technology approaches. What is missing however is a common vision of AAL providing and defining the necessary future R&D steps and projects on the way to Ambient Assisted Living. In order to close this gap the AALIANCE project – "The European Ambient Assisted Living Innovation Alliance" – was funded within the specific programme "Cooperation" and the research theme "ICT" of the 7th European Framework Programme. Its aim is to develop such a roadmap and strategic guidance for short-, mid- and long-term R&D approaches in the AAL context.

In this document the roadmap for AAL and its main related concepts are presented.

The first part of this document firstly includes main trends for AAL, analyzed by demographical, economical and technological point of view; and secondly barriers for deployment, identified for each stakeholder of AAL, i. e. users and caregivers (primary stakeholders), organizations offering services (secondary stakeholders), organizations supplying goods and services (tertiary stakeholders), and organizations analysing the economical and legal context of AAL (quaternary stakeholders). Starting from the identification of needs of elderly people to live independently in different contexts and of relative technological support, the field of AAL is grouped in three principal application domains.

These argumentations are widely and in detail described in the second part of the roadmap. More precisely, AAL has to be firstly distinguished from more traditional forms of (ICT enabled) assistive technologies by emphasizing the important role of ambient intelligence in AAL technologies. These technologies have to be embedded, (non invasive or invisible devices, distributed throughout the environment or directly integrated into appliances or furniture), personalized (tailored to users' needs), adaptive (responsive to the user and the user's environment), and anticipatory (anticipating users' desires as far as possible without conscious mediation). Ambient intelligence therefore refers to electronic environments that are sensitive and responsive to the presence of people: Ambient intelligence covers together the concept of ubiquitous computing and Intelligent social user interface. It accommodate the following needs: offer a secure environment and peace of mind, select food

[1] http://europa.eu/rapid/pressReleasesAction.do?reference=STAT/08/119&format=HTML&aged=0&language=EN&guiLanguage=en

and drink I like within the constraints of my diet, stay in touch with friends and family which also gives me reassurance, and organize and receive healthcare in my home. In conclusion, ambient assisted living is the utilization of ambient intelligence in the respective social domains of ageing at home and on the move, ageing in society, ageing at work[2]. However, taking the aspect of ambient intelligence seriously in AAL, one has to be aware that in reality a person using AAL traverses multiple physical spaces (room, home, car, working location, shop, out-of-door) and virtual spaces (e-shopping, gaming, chatting, searching or planning activity) throughout the day, depending on current activity or focus. Therefore, the distinction between different domains can only be a logical, not a practical one.

The third part of the document is also a wide and detailed descriptions of technologies, which applications and functionalities of the previous domains are based on. They are grouped in:

- Sensing: anything and anywhere: in-body or on-body, in-appliance or on-appliance, or in the environment (home, outdoor, vehicles, public spaces, etc.).
- Reasoning: aggregating, processing and analysing data, transforming into knowledge within different and often cross-connected spaces (body, home, vehicle, public spaces).
- Acting: automatic control through actuators, feedback (e.g. information, suggestions, guidance) – local or remote (e.g. call centre), instantaneous (e.g. in the case of alarms) or delayed (e.g. in the case of trend information and lifestyle recommendations) to relevant participants using personalized multi-modal interfaces, possibly across multiple spaces.
- Communication: Sensors and actuators are connected to one or more reasoning systems that in turn might be connected (even dynamically, e.g. a person moving from home to vehicle to some public space) to other reasoning systems, possibly with their own sensors and actuators.
- Interaction: intelligent interaction with systems and services is an very important aspect for applications and will have specific requirements to cope with the abilities of users.

Finally this document revolves around the system integration and interoperability, i.e. the way to compose an AAL system. In AAL these different functions, provided by a heterogeneous set of disciplines (e.g. advanced human/machine interfaces, sensors, microelectronics, software, web & network technologies, energy generation or harvesting and control technologies, new materials and robotics), have to be integrated in a system that offers applications and services in a user-centric way. While ICT-enabled products in the field of walking aids or telemonitoring could be developed following already existing technological paths in the field of gerontechnology, more ambitious AAL solutions raise specific challenges regarding system integration and design hierarchy. In AAL, system integration is dependent not only on technical and functional integration factors, but has to take into account user needs and user knowledge. This could lead to a situation that the systems design cannot be fully defined as long as the applications have not been defined on a basic level by the users themselves. This emphasises the importance of user involvement and user perspective in AAL-related research and innovation activities that has already been tackled by a number of R&D projects. On the other hand, a common AAL platform based on selected standards to allow interoperability of applications and services could be the basis for 3rd party service development and provision, and could stimulate the development of products at an early stage and the establishment of value chains that put into effect the business opportunities within AAL. The contradiction between a user-centric system design and the need for a common application platform approach might turn out to be the central contradiction and challenge in AAL in the years ahead.

[2] Following the terminology used in the European action plan for "Aging well in the Information Society".

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1 Introduction

During recent research conducted it has become clear that there is no common view as to the precise definition of Ambient Assisted Living (AAL). In this introduction, we will sketch a view on AAL as it has developed within the project during its first year.

In the AAL program, the scope is defined as "cultivating the development of innovative ICT-based products, services and systems for the process of ageing well at home, in the community and at work, so improving the quality of life, autonomy, participation in social life, skills and the employability of older people and reducing the costs of health and social care." This may be based e. g. on innovative applications of ICT, new methods of customer interaction or new types of value chains for independent living services. The resulting technologies could also be used by other groups of people, e. g. people with disabilities.

From our view of AAL, we wish to present a more detailed and holistic view, which is inspired by the NeAT project in the UK (especially by the presentation on NeAT by Charles Lowe) (Lowe 2008). The essence of this holistic approach is presented in the following table, which describes the top-level needs, the electronic support that can accommodate these needs and the challenges that need to be tackled:

To allow for this possibility the following issues should be taken into account:

- always-on broadband communication facilities;
- unobtrusive easy recording, with access to the relevant data by all key agencies involved (electronic records) (problems: deficient standards, no single integral approach);
- supportive inter-disciplinary care teams (problems: technical interoperability, organizational incompatibility, spread of responsibilities, accountability of actions);
- case-management software (problem: cross-organizational approach);
- stable knowledge base and clear decision support for all care givers (professional and informal) as well as the client (reliable information, algorithms and rules);
- functions (e. g. coping with cognitive limitations, safety, disease management or medication management), implemented by intelligent applications and services that rely on specific types of sensors and actuators (in a generic view interaction devices can be considered as sensors and actuators);
- important issues are configuration (static or dynamic), installation and management;

Table 1: AAL Needs – Support – Challenges (Lowe 2008)

To live independently I need :	**electronic support can help a lot in the form of:**	**but there are challenges:**
a secure environment, peace of mind	proactive environmental sensors and assistive technology	currently too expensive, reimbursement issues
food and drink I like	monitoring of meals, dietary help, Internet shopping	need for standards for smart labelling and packaging
contacts with friends and family, including giving reassurance	user-friendly communications	
physical, social and mental stimulation	local media, local activities, employment/occupation, voluntary work	little local and personalized content available
healthcare in my home, comfort, peace of mind	tele-health sensors, medication reminders, medication management	presently tele-care and health systems incompatible
certainty that my carers will come	electronic carer monitoring and communication	
appropriate response when things go wrong, peace of mind	appropriate response team, proactive calling	how?, can one team deliver?, cross-organizational issues with respect to business models and responsibilities

- decisions on issues such as level of control by users, security and privacy management;
- AAL should concentrate on applications and services and integration of these to present them in a user-centred way (to all users), using enabling technologies that will delivered by other programs.

All this should be adapted to individual needs, which will change over time due to specific episodes like rehabilitation after hospital treatment or degeneration, and made available to clients in an easy-to-use way.

The users of the systems can be divided into different target groups. The primary target group is of course older or disabled people but it should also be remembered that the people who care for them (e.g. family, neighbours, home-care nurses, staff from community centres and in special situations also emergency personnel) are important users, who might even use services from their own location. The systems should also support interaction between the prime users and carers as well as the scheduling and if necessary rescheduling of care events.

We should also be aware that the location of assistance will show much variety. Examples are:

- different living locations, varying from the family home, home for seniors, supported or sheltered housing or apartment, and nursing home, depending on the needs of the primary user;
- mobile locations, e.g. walking, cycling, being in a person's own car, being a passenger in a car or taxi, or public transport;
- visiting locations such as family homes, working locations, public spaces e.g. shops or museums;
- location from people who are involved in caring for people who belong to the primary target group.

Such factors lead to considering the need to support clients in a person-centred way (geared towards the primary user, at the different locations and taking the situation into account, e.g. with respect to environmental sensors at various locations) and to support care givers in a more task-oriented way.

This AAL support can be grouped in various application domains, and the following have been selected for this document:

- Ageing well at work or "active ageing at work": remaining active and productive for a longer time, with an improved quality of work and a better work-life balance with the help of easy-to-access ICT, innovative practices for adaptable workplaces, ICT skills and competencies and ICT-enhanced learning (e.g. e-skills and e-learning).

- Ageing well in the community: staying socially active and creative, through ICT solutions that are geared toward social networking, as well as good access to public and commercial services, so improving the quality of life and reducing social isolation, which is one of the main problems of older people in rural areas with a low population, as well as in urban areas with little family support.

- Ageing well at home: enjoying a healthier and higher quality of daily life for longer, assisted by technology, while maintaining a high degree of independence, autonomy and dignity.

Based on the observation that a person (with in-body or on-body sensors) traverses many physical spaces (room, home, car, working location, shop, outdoors, each with a collection of environmental sensors, either physically placed in the physical space or built in in furniture or appliances) and virtual spaces (e-shopping, gaming, chatting, searching or planning activity) and depending on the current activity or focus, we would like to focus on the area "Ageing well at home". The current definition is strongly related to location. In our context it might be more practical to replace this area by another one "Ageing well for the person" and adding to the definition "either at home or on the move".

This would give us the following three areas: AAL4persons (consisting of AAL@home and AALon_the_move), AAL@community and AAL@work.

To bring about application in these domains, the following enabling technologies are defined:

- Sensing: anything and anywhere: in- body or on-body, in-appliance or on-appliance, or in the environment (home, outdoor, vehicles, public spaces, etc.).
- Reasoning: collecting, processing and analysing data, transforming it into knowledge in different, and often across, connected spaces (e.g. body, home, vehicle, public spaces). Reasoning engines could be implemented on a dedicated device together with one or more sensors, on an on-body device for mobile situations, on a home device, or on a server connected to a network.
- Acting: automatic control through actuators, feedback (e.g. information, suggestions, or guidance) which can be local or remote (e.g. to a call centre) instantaneous (e.g. in the case of alarms) or delayed (e.g. in the case of trend information and lifestyle recommendations) to relevant participants using personalized multi-modal interfaces, possible across multiple spaces.
- Communication: Sensors and actuators are connected to one or more reasoning systems which in turn might be connected to other reasoning systems with optional additional actuators. These could include dynamic communication systems, e.g. a person moving from home to vehicle to some public space).
- Interaction: intelligent interaction for people with systems and services, which is a very important aspect of the applications and will have specific requirements to cope with the people's abilities.

1.1 Structure

Following this introduction, some trends in AAL are presented from different perspectives, to which are added some observation of barriers for deployment. This is followed by a detailed discussion of the application domains (AAL4persons, AAL@community and AAL@work) and a detailed presentation of the enabling technologies (sensing, reasoning, acting, interaction and communication). The final chapter presents a way to set up an AAL system.

2 Mega-trends in AAL

2.1 Demographic trends

In the next few years, European communities will have to face up to significant demographic changes. As in other industrialized countries, the average age of the population will increase dramatically. The "ageing society" is becoming not only a clear challenge for social-security systems but also for society as a whole. Recent European population projections for 2008–2060 published by the European Office for Statistics underlined these demographic developments. From 2015 onwards, deaths are projected to outnumber births in the 27 countries of the EU. Almost three times as many people will be aged 80 or more in 2060 (Eurostat 2008).

The social behaviour and lifestyles, as well as the identity of the individual older person, will change if current trends continue. Their requirements and consumer behaviour will change both in quantitative and qualitative terms. With higher expectancies of life and rising retirement ages in European countries, the proportion of older people at work will increase, as will the number of elderly people participating actively in social life. It is significant also to note that the number of elderly people living alone and those who live below the average subsistence level will increase.

Although older people in future will remain self-sufficient for a longer time, more people will need high-intensity care in the end-of-life period and more people will need support in daily life operations before this phase due to more or less severe disabilities (European Commision 2005). Increasing life expectancy is accompanied by an increasing prevalence of health impairments and mental-health problems as well as dementia, e.g. Alzheimer's disease. The number of people who report they cannot properly fulfil ordinary daily activities will also increase. As for the labour markets, pension systems and social schemes in general, we also have to remember that demographic ageing means that the number of older people is increasing while the participation made by those of working age is decreasing. Not only will the income side of social schemes be affected but expenditures will be too: health-care systems will be affected as an ageing population will lead to an increase in the proportion of people with disabilities or chronic illnesses. Thus, health-care systems and social care in general – which is typically organized on a national level and characterized by national differences as regards institutional design – will have to cope with increasing requirements both in quality and quantity and so lead to increasing expenses.

As a result of demographic and socioeconomic developments, the ageing European population will lead to:

- a growing number of older people living by themselves and in need of care, especially intensive care;
- a growing number of older people lacking basic financial and social resources, who will have difficulties obtaining a minimum of health and care services;
- a higher number of financially stable and wealthier senior citizens who are able to enjoy their retirement and spend their money on products that secure and enhance not only their wealth, safety, security but also their entertainment and communications needs;
- changing family relationships and living situations (e.g. larger geographic distances between relatives) affecting the level of support that family members can give;
- an ageing workforce in general and the need to keep older people active in society and at work.

At the same time, these developments will be accompanied by changes in how healthcare and care is organized in society in some countries – e.g. the trend towards a more decentralized care system in local-care centres and at home and the greater importance of self-managed care.

As we tackle these challenges and opportunities of ageing societies in Europe, we also see opportunities for technological and socioeconomic innovation to enhance the quality of life for older and disabled people, to mitigate the economic problems of an ageing population and to create new economic and business opportunities in Europe. It is assumed that Ambient Assisted Living (AAL) technologies and services for elderly people will play an important role in solving some of the increasing problems in the future. The European action plan "Ageing well in the Information Society" addresses ICT in the context of aging. ICT can help older individuals improve their quality of life, lead healthier lives and live longer, so extending their active and creative participation in the community. In some cases, a wider adoption and massive use of these technologies will be necessary to guarantee at least a minimum level of service for older citizens in the future.

2.2 Economic trends

In the information society, companies try to offer a more individualized service in order to address new customer groups. Often, one company integrates the services of several suppliers, so reducing the complexity for end users and creating customized or tailored services. Ways in which services for AAL need to be individualized and flexible include:

- Hospitals – which play a significant role in the health system – are increasingly trying to differentiate their offerings from competitors. They offer a broader portfolio that is more tailored to individual customer needs. This trend is strong especially in private hospitals and hospital chains but is also starting to be evident in publicly owned hospitals.
- Tele-medicine companies are developing to complement existing stationary and ambulant treatment – a gap is being filled. Many European countries are currently restricting tele-medicine to a minimum. However, with the significant arguments of greatly lower costs and high quality, it is only a matter of time until tele-medicine plays an important part in every country's health system.
- Services offered by care-delivery organizations in the broadest sense: – e.g. home-care organizations, security firms, community centres – are becoming more important than equipment and they result in a b2b business model.
- Integration of services at the site of care delivery organizations will become an important differentiator.

2.3 Technology trends

General technological trends in the next decades will foster and shape future AAL applications. These include:

- The Internet, which will be available in every device – the Internet of Things will enable internal and external support systems in the home.
- RFID capable devices (including Near Field Communication (NFC), Electronic Product Code (EPC), etc.), which will penetrate daily life.
- Concepts of context Awareness. The Assisted living (AL) system may in future have awareness of the presence of a user, location, devices and date/time, etc. This requires presence-detection capabilities.
- The integration of services: devices that can be directly connected even to external services.
- Networking capacity, which is increasing, enabling video and multimedia communication between homes and the outside world.
- Broadband communication is becoming more and more available at home, but also on portable equipment. (There are however large differences in the availability of broadband in different countries or regions and in the usage of different age groups.)
- The rise of robotics, i.e. self moving devices in care.
- Advance recognition of user states, i.e. susceptibilities, feeling, faces.
- Integration of entertainment devices. The trend towards standardization (UPnP, DLNA, etc.) and entertainment devices that are capable of communicating with other such devices.
- Easy authentication systems: advanced authentication systems may develop in future the are easier to use.
- Communication capabilities in home artefacts – inside devices and – beyond that – embedded in the house.

3 Barriers for deployment of AAL

Besides the trends discussed in chapter 2, it is also important to recognize that there are also barriers that hinder the deployment of AAL. These obstacles can be identified for each stakeholder of AAL: users and caregivers (primary stakeholders); organizations offering services (secondary stakeholders); organizations supplying goods and services (tertiary stakeholders); organizations analysing the economical and legal context of AAL (quaternary stakeholders).

3.1 Barriers related to primary stakeholders

The main users who can benefit from AAL technology are the elderly and people lacking in certain abilities and their caregivers. Even though AAL solutions and services are conceived of as offering help to these users, the application of AAL has until now been limited among these users because of:

- a general reluctance to use technology;
- unclear evidence of real benefits of AAL;
- an inability to use the appropriate technologies.

The main barriers in applying AAL technologies to older people and caregivers originate from psychological factors, especially the perception of quality of life, prejudices, habits and education.

Many elderly people are very attached to their memories and their previous lifestyle and so strongly reject anything that could ask them to change their life or habits. Often these people are not aware of the possibility that they could have an improved quality of life

According to this negative view, technology is an element that could interfere with real habits and could require changes in their lifestyle and so technological solutions are considered invasive and troubling. The consequence is that people remain wary of technology, and they do not understand the real benefits that these devices can give them and they have prejudices about their usefulness and ease of use.

The way to overcome such problems is to spread knowledge among end users of AAL about the benefits that AAL technology and services can provide.

Besides the prejudices of older people, sometimes this reluctance is well-founded because technologies do not properly satisfy the needs of the end users. In most cases this is caused by wrongly designed technologies, ones that have been developed by not thinking about the real needs and capabilities of the end users. Often such tools are so complex that people prefer not to use them. For this reason, a design approach based on the analysis and the direct involvement of users in identifying their requirements that need to be satisfied is fundamental in order to develop technological solutions and services that really are perceived of as useful by the end users and are accepted by them.

Furthermore, the economic expenses of these systems have until now been unsustainable from the point of view of the purchasing power of the final users and the benefits related to their use are not well understood to justify the high costs. According to this economic obstacle, studying political and economical strategies to fund and facilitate the wider application of this kind of technology and service is fundamental.

3.2 Barriers related to secondary and tertiary stakeholders

The role of secondary stakeholders is taken by organizations that provide services to the main target group (i. e. security-service providers, care-service organizations, shopping services, transport services, delivery services, social services, community centres, etc.). The tertiary stakeholders are all industries and companies that supply goods and services to the secondary stakeholders (see AALIANCE 2009).

The main barriers to AAL related to both kinds of stakeholders are:

1) a misunderstanding of the requirements and objectives of devices and services;
2) the lack of standards and references for technological design;
3) the partial broadband coverage in various European geographical areas.

1) Sometimes devices and services related to AAL do not reflect the real needs of the end users and for this reason they are considered useless and unsatisfactory. In most cases, this is caused by a misunderstanding of the aims and requirements of the systems and services. This phenomenon can be avoided by studying in depth the reality of elderly and people who are not self-sufficient and by directly involving end users in every stage of the design. What is needed are adaptable and personalized user-friendly interfaces integrated into real-life environments. All stakeholders should be aware that user involvement is key for technological, innovative and business success in AAL – from initial concept through systems design and integration to the prototypes and business models. Questions of design and usability are of similar importance to AAL products and the involvement of design and usability experts is also essential for developments that seek a more than minor survival chance in the real world outside the laboratory. Design and usability concepts should not become substitutes for real-user involvement. Only a few R&D projects in Europe have tackled this issue in depth and secured the involvement of users to a full extent (Best Practices in Europe on ICT enabled living for elderly 2008). Living laboratories are one way of developing and implementing user-driven approaches in product and service development. Moreover, during every stage in the development of their products, systems and services designers should remember that their end users have characteristics and skills that can also vary over time. Every person and his or her conditions are different and constantly changing. Systems therefore need to be highly configurable and flexible in terms of the evolution of the person, changing conditions and multiple diseases, and diversity in (care) organization. Approaches in general should be people-centred and life-course based. Such a holistic approach also means that other scientific disciplines must be involved in research, such as:
- science-based gerontechnology, for the knowledge of age-related changes in human functions;
- social, environmental and technological innovations and support in a community-based setting ("integrated community"), for moving from older people as care customers to older people as members of a community.

2) From a more technological point of view, organizations that develop devices and services suffer in their work from a lack of standards and references for designing the systems. These include:
- domain models that are concepts, functions and qualities for AAL systems to make explicit the demands and contributions;
- open-reference architecture that facilitates the efficient integration of diverse assistance devices and services into personalized, trusted and manageable assistance solutions;
- standardized solutions for unobtrusive, affordable sensing of context (location, activity, vital data);
- advanced user-interfaces that can be adapted to the changing needs of users;
- guidelines for privacy and security of data management;
- system management and interoperability of heterogeneous components.

Moreover, a generic AAL service platform based on certain standards as the basis for third party application development is also missing. This would stimulate the products and service market development tremendously.

3) Another technological problem that limits the wider application of AAL services is the spread of broadband facilities across different geographical areas. Broadband is a fundamental technological element for the development of AAL that allows the remote monitoring of the environments and elderly or non-autonomous people and the connection of users with other subjects and services. Unfortunately, broadband is not available throughout Europe: many rural areas and some south-eastern European countries are not covered by a broadband network. People who live in country areas far from a town or city often do not make good use of all public services and in particular elderly people remain isolated from such application. AAL technology can allow such people to be included in the social and services network and to get in touch easily with others. To enable these users to use this kind of technology, it is fundamental that broadband should cover these country areas in every part of Europe.

3.3 Barriers related to quaternary stakeholders

Quaternary stakeholders of AAL are organizations and institutions that work in the economical and legal context of AAL.

These agents of AAL deal with the following problems:

1) diversity of social, welfare and healthcare systems in Europe;
2) lack of visible value chains;
3) heterogeneous target groups (user/buyer);
4) lack of standards and certification;
5) funding and reimbursement of AAL services.

1) In Europe, the level of national-health care and social-security systems varies from one country to another. This hinders the development of common European business models and a common market for AAL solutions. Currently, reimbursement schemes do not encourage the adoption of technological innovations in these systems and provide no clear perspective to link investments and revenues/savings for those who adopt the applications. At the same time, investors and developers have to deal with a wide variety of welfare, healthcare and care systems in European countries. Each of these systems has a complex legal and regulatory basis that restricts or encourages the use of AAL technology in the public healthcare and care services in specific ways. Some countries have established welfare structures that are more open to technological change (e. g. tele-monitoring in the National Health Service UK), others – despite huge social reforms in the past – still lack basic prerequisites to handle the upcoming demographic change (e. g. lack of care insurance in the Eastern European states) which could also benefit the wider adoption of AAL. This is seen by most experts as the main barrier for the wide adoption of AAL technology in the public sector. Since social policy in the European Union is coordinated relatively loosely (i. e. by the Open Method of Coordination [OMC]), this diverse welfare structure will not disappear overnight, and a common European Social model seems to be out of reach in the coming decades. In this sense R&D policy deals with problems beyond its reach – but it could nevertheless raise awareness of the issue. Another barrier relates to the different national regulations of medical and care-related services. In almost every country there are clear standards and professional and educational obligations imposed on providers and suppliers of services in the healthcare sector. On one hand, these standards secure quality and reliability of these vital services. On the other hand, they only slowly keep pace with the rapid developments in ICT in the health sector and could raise barriers for market entry for innovative services and products. The same applies to privacy and data-security issues and regulations. Nowadays, public opinion is greatly concerned with privacy and data-security issues. Governments are therefore reluctant to promote solutions that tackle the common understanding of privacy in the home and could lead to a fear of "surveillance" and a negative view of these applications.

2) In both the more regulated markets of healthcare/care and the consumer-oriented private markets, the lack of visible value chains is obvious. This might been seen as an indicator of the nascent state of the AAL industry. At this present time, AAL activities seem to be limited to the R&D sector – business models are only discussed cursorily. A vicious circle is in place: no products are available on the market, there is no experience and data of user acceptance and the cost-saving/health-promoting effects of products and service which leads to lack of commitment and engagement on the part of industry and health-care and care-service providers, and no business models are being developed and tested.

3) Moreover, there are a number of possible value networks with different types of agency. Several stakeholders – healthcare and care providers, the IT industry, insurers, real-estate developers, patients and relatives and governments/local authorities – have different sets of interests. It is clear that each of these groups is itself heterogeneous and that the various subgroups could be further described in terms of size, legal status, potential needs/demands and expectations towards AAL products and services – not to mention national and regional differentiations in the target groups.

4) There is also very limited knowledge about the potential target groups for AAL solutions. In principle, we can distinguish the following user groups: healthy elderly (independent users), partially disabled (physical and/or mentally) elderly, (dependent users), 2nd level users like careers and relatives. Potential buyers of products and service are the elderly, healthcare and care organizations (private and public), insurers (private and public), real-estate companies, relatives and other informal carers in the community, etc. It is clear that each of these groups is itself heterogeneous and that the various subgroups could be further described in terms of size, legal status, potential needs/demands and expectations towards AAL products and services – not to mention national and regional differentiations in the target groups. Older people for example, are to some extent very demanding (elite) users, with increasing personal wealth and an ability to pay for articles at the right price and quality. Further, there is a lot of diversity in terms of needs and changes during the lives of older people. Any products targeted to this market need to aim at the right segments. Stigmatization is also an issue – future product packaging and marketing needs to be appropriate. In some cases, it would be best to avoid "niche products" and look for products and services that are adaptable to the needs and demands of a wide range of potential customers.

5) In the long run, established AAL-related standards and certification procedures are necessary to provide reliability and trust in buyers and users. This is a crucial topic since developing, negotiating and implementing technical standards is a time-consuming process. Global industry players and consortia (Continua Alliance) are already active and marking out the playing field. It might be that the opportunity for a European approach in AAL standards is closing – although the demand for "open standards" in the AAL R&D domain (in contrast to incremental standards imposed by transnational industry incumbents) might provide further opportunities for an independent European strategy in this field. In addition to technical standardization, the need for new AAL-related standards might also arise in the formerly non-technical domains of healthcare and care services. Here, standards for quality management and service quality and reliability have been discussed for some time. The emerging AAL sector could bring out the need for completely new standards and professional regulations in this area when new products and services – combining ICT and human care – need to fulfil privacy and ethical standards and have to secure quality and reliability in the critical domains of healthcare and care for the elderly. It should also be mentioned that the combination of innovative technology with healthcare and care sciences typically for AAL might raise the demand for a specialized and educated workforce in this area – both on the developer and user sides of AAL. Professional education, training and qualifications might be necessary to fulfil the workforce demand of this new industry. In the field of gerontology it took several decades to establish separate education and training for the significant field of gerontechnology – it is likely that the same will occur for the even more innovative and complex field of AAL. Potential users in the care and healthcare sector need to be trained in order to benefit from AAL applications to the fullest extent.

6) The economic problem of public funding and reimbursement of AAL services needs to be faced up to. AAL services and technologies remain very expensive and therefore few elderly and not self-sufficient people are able to privately buy AAL devices and services. Because of the ignorance of politicians about the social and functional benefits provided by AAL to individual users and also to society generally, social and health politicians are reluctant to provide financing for AAL-related services or to put them on the list of accepted treatments of statutory insurances. This is a great barrier for the greater application of AAL in society. For this reason, it is vital that the benefits of AAL for society in general are communicated effectively to members of governments and the wider population, so leading public institutes to fund this kind of service.

4 AAL4persons (AAL@home, AAL@mobile)

4.1 AAL for health, rehabilitation and care

Individualized therapies and care lead to high success rates, which results in a better quality of life for those people accessing the service. The Swiss online pharmacy "Mediservice" offers a new "pharma care" program that supports patients with heavy chronic diseases (MediService (2007). In addition, the demand for home care is increasing. Future care will become more flexible and interconnected, i.e. home care, stationary care and acute medical treatment will be strongly interlinked and combined. This involves individual care services but also requires the use of new technology to enable the complex orchestration of the different players. New technologies are therefore the enablers of a future care and rehabilitation system. However, new processes and business models also need to be implemented to bring the new possibilities to the market.

The following sections describe how care and therapy can become more individual, i.e. person-centred and how health-care professionals can benefit from new technologies.

4.1.1 Person-centred health management (at home and away from home)

While the scenario described below is a long-term view, parts of it are already technically feasible, e.g. an elementary set of sensors for vital signs, electronic readable emergency data on eHealth card or USB stick and dedicated decision support systems. A lot of work still needs to be undertaken, however, to achieve the full array in an easy-to-use fully interoperable environment. Further, many barriers have to be overcome, which are not only technical but also are related to business models, reimbursement, regulations, and cultural changes in medical professions with new roles and redistribution of responsibilities.

Obviously, the application is not a one-size-fits-all system but one that will adapt itself to the needs of the person during his or her life and related to their conditions using their personal health profile. In a person's life, the application could start as a coach for health-conscious people who want to avoid becoming ill: it will help them to follow a healthy lifestyle. It could then develop into a disease-management application for a chronically ill person who needs extensive monitoring, guidance and help to maintain medication compliance.

4.1.2 Tele-monitoring and self-management of chronic diseases

Tele-monitoring of patient status and self-management of chronic pathological conditions (e.g. COPD and chronic cardiovascular diseases) represents the most evident, short-term outcome of Research and Technology Development (RTD) in the domains of Ambient Assisted Health-care, rehabilitation and long-term care.

The combination of wearable or implantable multi-sensor platforms with sensors mounted in the environment, using low-power and reliable technologies, is being explored and the first prototypes are now being developed. Clearly, patients might well have difficulties using large and/or obtrusive wearable sensors or large implants. One of the main short-term challenges therefore lies in the development of small and unobtrusive sensor systems that can, for example, be embedded in clothes or are so small that they can be easily inserted under the skin on ambulatory medical care. Thanks to new low-power wireless technologies, low-bandwidth networks can be used for the exchange of data.

A distance of up to 1 metre power transmission or energy scavenger will be required in order to recharge the battery for wearable or implanted devices without asking the patient to do this, as it is too much to ask patients to perform this task regularly.

A relevant application in this field relates to the recognition of a patient's patterns of activity, and on the subsequent suggestion of specific behaviour and exercises for self-management of the health condition.

Physical activity is not typically measured in clinical care. Health-care professionals usually focus on the disability that is experienced rather than on the potential rest ability. Furthermore, physical activity is assessed mostly subjectively by means of questionnaires. An objective measurement of physical activity is possible with accelerometers, for instance. Triaxial accelerometers can be used to measure daily activities, such as standing, walking, ascending and descending stairs and cycling.

To give older adults who suffer from chronic problems (e. g. respiratory difficulties) a better insight into how and how often they may perform their activity of daily living (ADL) activities and specific rehabilitation exercises, additional ambient sensors are necessary.

In terms of motivating users to undertake exercise, research is needed on user interface design, to build

Scenario 1: **Person-Centred Health Management**

At some time in the future, a person (if he or she so desires and their conditions demand it) will be surrounded by virtual, real-time, around-the-clock health and medical assistance through various wearable, mobile, and implanted sensor devices. These devices will be connected to an intelligent software virtual agent (Personal Health Application [PCA]) that is designed to support optimum health and acute/chronic treatment and will probably be implemented on some mobile constantly connected device. This mobile device contains a summary of the person's medical records, containing e. g. current treatment, chronic diseases, allergies, current medication, which is easily accessible in emergency situations and can easily connect to: in-body, on-body, stationary and environmental sensors giving an up-to-date status of health and potential risks based on physiological processes, biological processes and environmental situation within and surrounding the person; medical databases with historical patient information as well as current diseases and treatments, which include genetic profiles, clinical information; non-medical databases with current as well as historical information about e. g. level of activity, performance information from fitness equipment and eating habits; analysis services, which use patient information and information from certified medical knowledge from the different databases to give personalized advice.

The application empowers the person with the relevant knowledge and with online support allowing him or her to take more responsibility for their own health. Their full state of health (including historical information) consisting of genetic, biological, physiological and environmental information as well as the information stored at systems from pro fessional care givers will be available and combined with access to the relevant medical knowledge, personalized advice will be given for self-treatment or referral to proper professional support with the adequate relevant information at hand, using decision-support tools based on an ongoing analysis and synthesis of medical evidence. An important part of self-management is related to the prevention of diseases which can be based on the genetic and molecular warning signs before a disease exposes itself and also on the data collected by non-medical services such as activity management, fitness equipment, eating habits, supporting a person in keeping to a healthy lifestyle. Monitoring medication intake and e. g. exercise programs allows checks of adherence to treatment (and react when this is not so), combined with monitoring their status, which provides indications on whether the treatment needs to be adapted.

The application also acts a virtual nurse-doctor who knows the person's status and needs and is on call at any time and in any place, to guide and support the person. This application acts as a knowledge source, a personal decision-support system, health and fitness coach, personal dietician, and much more, giving instantaneous feedback to the user, raising an alarm or informing professional or informal care givers when needed. This is. important for managing people suffering from e. g. chronic diseases, detecting relapses, before they become dangerous, based on monitoring, trend analysis, and raising the alarm and initiating appropriate action like calling a person, or visiting when needed. This will also include the possibility for action related to behaviour management by giving relevant education information and checking adherence to treatment programs (medication or exercise).

If a real emergency happens, it will be detected by the application automatically: it informs the emergency service of all the relevant medical and the exact location of the patient because one of the environmental sensors is of course a GPS sensor. Knowing that this will be done when necessary also increases the self-confidence of the patients.

The application also communicates with the person's network of medical professionals who are involved in current treatment plans and link the person to diagnostic and treatment services. All care providers and their supporting facilities like radiology, laboratories and pharmacies use electronic health-record systems that are connected to a secure health-information-exchange network which enables easy access to the relevant data using a role- and task-based access-control system that is in line with the consent rules controlled by the patient. In this way, they all have constant access to up-to-date patient information, which is of course important in emergencies.

Roadmap 1: Tele-monitoring and self-management of chronic diseases

Roadmap	Short term (2013)	Mid term (2018)	Long term (2025)
tele-monitoring of patient status transmitted parameters	ECG, EEG, acceleration, movements, weight, pressure, temperature, heart sounds, respiration body worn and subcutaneous Ingestible capsule for pH, temperature, pressure, heart sounds, blood flows, respiration Cellular phone wireless connected to sensors body worn or ingestible or subcutaneous	Biomarkers external	Wireless biomarkers implanted
wearable multi-sensor platforms	Sensors power supplied by rechargeable batteries Leadless ECG and respiration	Sensors power supplied by energy scavengers Sensors wireless powered	
implantable multi-sensor platforms	Sensors power supplied by batteries or rechargeable batteries	Sensors wireless powered	Sensors power supplied by energy scavengers
Self- management of chronic diseases	Intervention of the patient for powering and management of chronic diseases		No patient intervention for powering and management of chronic diseases

on strategies that are known to motivate behaviour change using just-in-time information.

Context-detection algorithms combined with fixed and wearable sensors can provide information that can trigger messages at an appropriate time, and a mobile device can allow a message to be presented at the appropriate place. A history of the user in terms of physical activity recorded on a mobile device should be developed to create personalized feedback based upon past experiences and current context.

The most common chronic cardiovascular disease is congestive heart failure. In 2015, according to the European Society of Cardiology (ESC), it is expected that 12 million Europeans will have a heart failure (Cleland JG, Swedberg K, Follath F et al., *The EuroHeart Failure Survey Programme – A Survey of the Quality of Care Among Patients with Heart Failure in Europe*. Part 1: Patient Characteristics and Diagnosis. *Eur Heart J* 2003; 24:442–463).

Heart-failure patients need tele-monitoring to adjust treatment with drugs or electrotherapy, to avoid hospitalization.

The *Washington Post* published the following on May 1, 2008:

"Remote monitoring can improve the condition of mobile heart failure patients and may reduce hospital readmissions, according to a pilot study that included 150 patients admitted to Massachusetts General Hospital in Boston.

"The patients, average age 70, were randomly selected to receive usual care for heart failure (68 patients) or remote monitoring (42 patients). Forty of the patients declined to participate. The study was conducted by the Center for Connected Health, a division of Partners HealthCare.

The patients in the remote monitoring group received telemonitoring equipment to track vital signs such as heart rate, pulse and blood pressure. They weighed themselves daily and answered a set of questions about symptoms every day. The information was transmitted via the telemonitoring device to a nurse, who would call weekly or more often if a patient's vital signs were outside normal parameters.

"After three months, patients in the remote monitoring group had lower average hospital readmission rates (31 percent) compared to patients in usual care (38 percent) and those who refused to participate (45 percent). The patients in the remote monitoring group also had fewer heart failure-related readmissions and emergency room visits than patients in the other two groups.

"'The goal of our Connected Cardiac Care program for this group of patients is to reduce hospital readmissions, provide timely intervention and help them understand their condition using home telemonitoring,' lead author Dr. Ambar Kulshreshtha, a research fellow at Harvard Medical School and Massachusetts General Hospital, said in a prepared statement.

"'Participating physicians are pleased with the program and consider it a success,' said Kulshreshtha, who added that the initial data suggests that 'Connected Cardiac Care is a win-win for our patients and health-care providers,' and has the potential to have 'a dramatic impact on improving the lives of heart failure patients and reducing hospital admissions.'

The findings were expected to be presented Thursday at the American Heart Association's Scientific Forum on Quality of Care and Outcomes Research in Cardiovascular Disease and Stroke, in Baltimore.

The researchers plan to expand the Connected Cardiac Care program to target 350 mobile heart failure patients by this summer.

An estimated 5.3 million Americans have heart failure, and hospital discharges for the condition increased from 400,000 in 1979 to 1.08 million in 2005, an increase of 171 percent, according to background information in a news release about the study."

A relevant application for tele-monitoring of congestive heart-failure patients is the monitoring and processing of heart vibrations with a 1D or 3D accelerometer implanted under the skin which allows detection of atrial and ventricle contractions, aortic and mitral flows which gives an hemodynamic status of the patient.

4.1.3 Support for care givers and care organizations

A vital part of home care is the use of highly trained personnel and experts. Since they are alone at the home of the client, they must cope with any situation that arises on their own. This responsibility and solitary decision making is a major strain on care givers as expert interviews have shown[1]. A support system for

Scenario 2: ***Mobile Support for Care Givers***

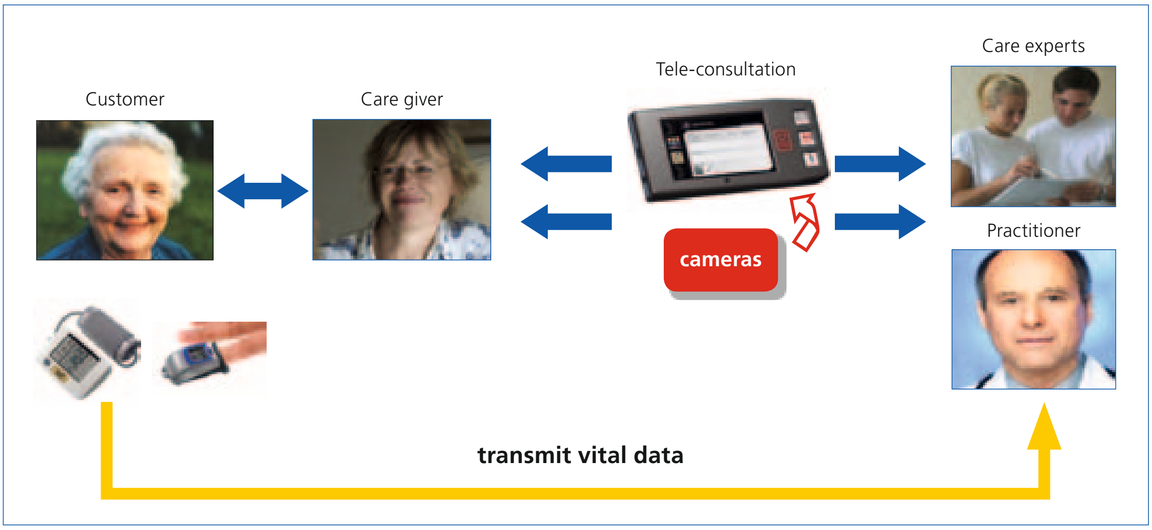
If a situation arises where a care giver is unsure about what to do, an expert can be consulted. For instance, a care giver is not sure if a wound needs further treatment by medication or if a change of bandage is sufficient. He taps on his mobile device and selects "expert consultation" and "general practitioner". An audio and video connection to a general practitioner in a tele-medicine centre is established. The use of a tele-medicine centre ensures that an expert is immediately available – which will mostly be impossible when calling the patient's practitioner. The care giver has two cameras in his mobile device: one pointing at himself so the expert sees who is calling. More important is the camera on the other side of the care giver to point at the wound, so that the expert can see the patient or wound in this case. After a brief consultation, the general practitioner can confirm that the wound shows a stronger inflammation, but the medication with antibiotics already in place is sufficient.

The tele-consultation can also significantly reduce the number of experts needed. Nowadays most communities need their own, cost-intensive experts for e. g. psychiatry and paediatrics. That is simply because a local supply has to be ensured, but these specialists have a much higher capacity for special assignments than occurs in a small region. Thus, their efficiency is low. With the remote consultation system, a single specialist for psychiatry can offer support to an unlimited region and be utilized to his or her full capacity.

Finally, a tele-consultation has a significant impact on training. With such a system in place, less experienced care givers can undertake any assignment and request advice if they are unsure what to do.

[1] The interviews referred to were conducted with experts from the Swiss care organization "Spitex", which is responsible for all care in Switzerland.

Figure 1: Tele-consultation for home care



care personnel that allows remote consultation with experts can significantly reduce stress for care givers and increase the quality of care and allow a better use of specialists. Scenario 2 sketches the most important features of such a support system.

By using vital data transmission together with tele-consultation and tele-medicine, completely new ways of home care are possible, where also complex medical treatments can be undertaken by care givers under the supervision of a remote professional.

Such a draft mobile system has already been developed for a different application area, for service technicians at the German railway company Deutsche Bahn. It was due to be evaluated in 2008 in a small series of about 10 devices.

4.1.3.1 Organizing care (professional and informal)

When organizing care, it needs to be realized that the task cannot be undertaken without giving time and thought to the elements of best practice and efficiency. It is vital to ensure best practice when many different services are offered to help older people to continue to live independently at home. There are many ways in which best practice can be defined but the point of view of the older person and his or her helpers must be considered most of all.

The primary question to ask when defining best practice when a variety of services is on the market is: "What answer do we have to meet the needs of care and inequality?" Respect needs to be given to the balance between the means of local authorities and the State on the one hand and that of the means of the users who are able to purchase on the private market on the other. Furthermore, inequalities between individuals do not only exist in the economic field; they can also exist in the means of their offspring or by the environment of the **n**eighbourhood. It also needs to be remembered that the organization of professional help is by no means automatic. The user's choice, the opinions and arguments of relatives must also be taken into account. However, the need for professional help is also the solution chosen in a crisis, when informal care is perhaps no longer possible.

Another aspect of best practice is seen in organizing professional help for older people is the quality of the availability of information that identify the tasks offered by service providers. Information on care services must be not only available, but also fully descriptive and understandable.

In the face of parameters including increased needs, cost control, different options for residential care, interaction of different levels of service, the organization of professional care-at-home systems is a complex task. Those involved in putting into place institutional care by professionals must include the viewpoint of users, which is after all taking into account the satisfaction of the older people themselves.

4.1.3.2 Supporting information exchange among care givers

Care givers in a domiciliary home-care organization have the special task of carrying out their function independently in contrast to care givers who work in a residential or nursing institution. Reliable solutions for ensuring the exchange of information is a vital part of care-service organization. The role of the care-service organizer is therefore of crucial importance: first and foremost in choosing the most appropriate technological system to put into place. Among other tasks, it must ensure that the exchange of information between the care givers of the service, between the care givers and all other external agencies that are concerned with the user-patient, and through very reliable systems between the network of carers, helpers, cleaners, and the case manager.

An important and very demanding part of a carer's job is related to transport, the amount of time spent driving from one home to another. Patient surveillance through new technology will reduce the number of calls to each home and the exchange of information between the multiple levels of care givers will ensure that each patient is attentively monitored.

Finally, meeting the need for ongoing training and for the professionalization of helpers, carers, cleaners, nurses can be provided by new information devices. For the service provider, these may help to professionalize, i.e. give greater respect to the identity of the care giver to older people, and enable them to use the technologies that will be in place in future.

4.2 Personal and home safety and security

4.2.1 General requirements of feeling secure at home

Staying well and comfortable, and feeling safe and secure within a person's own home is an important part of life and plays a central role especially in societies that have an increasing proportion of older people. It is therefore essential to enable and extend autonomous daily living in a person's own home also when that person reaches an advanced age. As human beings we need both a sense of satisfaction of personal security at home and also the need for personal communication. Technologies may offer an enhanced sense of security, prolonged independence and an improved perceived quality of life for seniors. Informal care givers experience less strain and an improved quality of service is expected from the service provider. For society in general and those paying, a reduced bill for care should result.

Roadmap 2: Support to care givers and care organizations

	Very short term (2010)	Short term (2015)	Mid term (2020)	Long-term (2025)
Video consultation	High-resolution video & audio	Augmented Reality Video, mostly 2D	Some 3D; Augmented Reality Video, mostly 2D	3D Augmented Reality communication
Vital data acquisition & transmission	Cardio, pulmonary and some blood data	Capabilities of a medical praxis		Distributed systems with capabilities of hospitals in some areas and direct data links to laboratories for dedicated pattern analyses
Remotely operated actuators	Complex & stationary actuators, only in clinical trials		More mobile actuators, first trials for home care	

4.2.1.1 Integration

Special attention must be paid to the integration of solutions and components that are already available on the market into a coherent and conclusive system which is easy to use for those living at home.

Further, innovative solutions for recognizing emergencies in the home are needed. Here, a combination of monitoring vital parameters of the person living at home as well as supervising the conditions of domestic appliances lead to new paradigms of ambient assistance.

Personal safety can be improved if vital data measures are combined with the monitoring and control of devices in the household. Additionally, remote monitoring of devices of potential sources of danger increases the individual sense of security and can make life much easier and more comfortable (e. g. checking whether the stove or the coffee machine has been switched off and to be able to turn it off remotely if necessary).

4.2.1.2 Intelligent sensors

Sensors positioned at electrical devices and at doors and windows may be integrated into an easy-to-use house-control system which also provides improved personal safety and security. An intelligent system may issue a reminder to switch off devices and/or lights in an apartment or not to forget medicines or the mobile terminal needed to inform friends or neighbours where necessary.

4.2.1.3 Open issues

Although many solutions and products are already available on the market, a number of open issues remain that need attention and careful research and development in order to meet central user requirements. Issues that need to be addressed include:

- technical solutions should be suited to individual requirements, personal preferences and habits;
- ease of use is essential for user acceptance;
- support of users through the complete supply chain: implementation, configurations and adjustments, during operation, coping with system errors, malfunctioning of components etc.;
- privacy, data integrity and reliability of sensors and systems are essential for acceptance of the technical solutions;

Furthermore, mechanisms and processes for third-party-service provisioning are clearly needed for a wide and sustainable market penetration.

4.2.1.4 Safety in the face of specific threats

Older people, especially those who are elderly and frail, are one of the groups of a population that is most vulnerable to accidents, particularly in and around the home.

In the UK every year about one in eight of those attending hospital following a home accident are aged 65 and over. Many of the fatal and non-fatal accidents to older people are attributable wholly or in part to frailty and failing health (RoSPA).

Poor mobility, a poor sense of smell and a reduced tolerance of smoke and burns contribute to fire-related accidents. Medicines and gases, mainly carbon monoxide and pipeline gas, are the main causes of accidental poisoning of people aged over 65.

Older people are at greatest risk of fatal injuries from burns and scalds – four to five times greater than the population as a whole. Pre-existing conditions often contribute to their death. Contact burns to those over 65 can prove fatal. The frail and poor health of victims are often contributing factors. The main sources of heat include radiators, electric fires and cookers. Many are scald injuries, involving the use of kettles.

The great majority of both fatal and non-fatal accidents involving older people are falls. Almost three-quarters of falls among those aged 65 and over result in arm, leg and shoulder injuries. Older people are also more likely to injure more than one part of their body, with 25 % of falls causing injury to more than one part of the body, compared with an average 16 % among all age groups. One in every five falls among women aged 55 and over results in a fracture or fractures requiring hospital treatment. The most serious accidents involving older people usually happen on the stairs or in the kitchen. The bedroom and

Table 2: Security against personal integrity

Situation	Technical solution	Current state of technical solution
Intrusion by burglar through front door, door to garden, windows	Intrusion alarm systems	Door locks available but mainly for professional use
Intrusion by front door by unauthorized persons without personal contact	Video communication from bed to front door; identification of visitors and comparison with stored list of authorised visitors; link to centre which can check unknown visitors	Video communication systems available; identification under development for professional use
Intrusion with personal contact (front door)	Identification of visitors; video link between front door camera and security centre; database containing authorized visitors	Available for professional use
Phone call by annoying people	Identification of person calling (name, image)	Identification of cooperative persons by phone number available; identification of other people not possible due to privacy
Attack in the road	Mobile phone with positioning sensor and emergency switch; cameras for public survey	Available but efficiency is limited
Attack in public transport (while entering, leaving, travelling)	Mobile phone with positioning sensor and emergency button; cameras in trains and vehicles	Available, but efficiency is limited
Attack in own car on the road/while parking/ in own garage	Automatic door lock with accident opening function; "goodbye" and "welcome" lighting function	Available

Table 3: Safety against external physical threats

Situation	Technical solution	Current state of technical solution
Traffic accident	As driver of a private car see separate section 5.3.2	
Traffic accident as vulnerable user (bicycle, pedestrian)	Clothes with integrated reflectors/blinking LEDs; cooperative design of vehicles and trucks	Frontal Protection Systems for cars are available and partially mandatory; active systems for detection, tracking and initiating collision avoidance measures are under development
Electric shock	Residual current device	Mandatory in most countries in EU but often not installed in old houses
Hot surfaces (stove, oven, plate)	Sensor and warning device	Warning lights available; induction cookers do not have a surface but potential biological effects of HF magnetic field have to be considered
Hot water (bath/shower)	Temperature mixing valve	Available and in common use (except in the UK)
Fire, smoke	Smoke detector; automatic extinguisher; sprinkler system; nonflammable clothes and fabric, stove use detector	Sensors available; mandatory in several states in Germany; in the USA more than 90 % of houses equipped
Gas, carbon monoxide, radioactivity	Gas detector; dosimeter	Sensors for carbon monoxide and other gases available
Flood	Flood sensor	Sensors available; included in modern appliances; missing in water-taps in kitchens and bathrooms
Storm	Air-speed meter; actuators at windows and marquees	
Missing or poor illumination	Light sensor; emergency light smoke sensor with integrated emergency illumination	Photoelectric lighting controller available
Window/door unintentionally open		Sensors available

Table 4: Safety against falls and cuts

Situation	Technical solution	Current state of technical solution
Falls	Fall detector; fall-prophylaxis device	Wearable detectors available, separate or integrated in clothing, shoes, walking sticks. Detectors embedded in the environment also available. Intelligent mobility aids available (CAST) but restricted performance on rough terrain, on stairs and doorsteps
Cuts, straining or twisting	Good illumination; sensors	Packaging of goods that can be opened easily without using knives, etc.
Hip fractures	Fall-prophylaxis device	Devices available but problems are comfort and user compliance
Hypothermia	Falls detector	See falls

the living room are the most common locations for accidents in general. The largest proportion of accidents is falls from stairs or steps, with over 60 % of deaths resulting from accidents on stairs. 15 % of falls are from a chair or out of bed (on two levels) and a similar number are caused by a slip or trip on the same level, e. g. falling over a mat or a rug. Although most falls do not result in a serious injury, being unable to get up exposes the faller to the risk of hypothermia and pressure sores.

The main factors in falls are:

- physical ability and lack of mobility, balance and gait disorders;
- nutritional status – deficiency in vitamin D and calcium;
- medication – analgesics, antidepressants etc.;
- acute and chronic diseases and disorders including stroke and heart disease;
- environmental hazards;
- a history of previous falls.

Fractures, particularly hip fractures, are one of the most debilitating results of an accidental fall. 90 % of hip fractures occur among those aged 50 and over. Hip fracture is a major cause of morbidity and mortality. It can result in medical complications, infections, a blood clot in the leg or a failure to regain mobility. The increased popularity of hip protectors has been very useful in preventing the severity of injuries related to falls.

Other main injuries suffered are bruising or crushing, cuts, wounds resulting from piercing and straining or twisting part of the body.

Hypothermia occurs when the body temperature falls below 35° C. It is the main contributing factor in the cause of death for over 400 people in the over-65 age group each year in the UK.

Food poisoning is another threat which could be prevented by measures that are part of a proper "Food Chain management". It might use the packaging of food with information about its origin, ingredients, nutritive value, transport conditions, minimum durability. The packaging could communicate via RF (radio frequency) transceiver with the refrigerator or another (mobile) device which might contain data about standard and limit values of the relevant parameters of specific foods. It might also include information on individual diet plans of the user or his or her intolerances to certain ingredients. Another component is a small portable analytical apparatus that will give information on the status of the food via a remote scanning system.

"Intelligent" clothing might be a tool to detect an emergency in situations in which the user is not within reach of stationary sensors and/or is not able to activate an emergency call. This clothing contains a sensor-system that will detect an emergency on the basis of missing or abnormal motion and physiological parameters of the user. It also contains a

RF transceiver to automatically call an emergency service and provides an communication link to the centre.

Another system which might improve the safety of older users is a so-called "emergency recognition system", which learns the "normal" behaviour and activities of the individual user and compares it with his or her actual activities. It uses a range of common sensors that are installed in the flat or house. In the case of missing activities compared with a prediction of the usual behaviour, the system would give a warning to the user and in the case of continuing missing activities would give an alarm to relevant people or an emergency centre.

Table 5: Safety against other personal fatalities

Situation	Technical solution	Current state of technical solution
Missing activities due to an medical emergency case or a fall etc.	Emergency recognition system	Intelligent activity analysis under development
Loss of geographic orientation	Personal navigator; navigation device with speech output; file of tracked course; tracker with access by family/care provider	Pervasive positioning under development; privacy might be a problem
Hot food/drinks	Plate/cup with temperature sensor	Prototypes presented
Wrong drugs/wrong dosage/detrimental interaction between different drugs	Intelligent drug dispenser	Monitoring and reminding drug dispenser systems available. More intelligence and cooperation with drug producers seems necessary. Software to evaluate knowledge of detrimental effects of drug combinations needed. Information in database is available
Medical emergency situation (heart attack, hypoglycaemia etc.)	Mobile phone with positioning sensor and emergency button; „Intelligent" clothing	Systems available
Food poisoning	Packaging with specific information and RF trans-ceiver; portable analytical apparatus	Prototypes presented

Table 6: Safety while performing specific activities

Situation	Technical solution	Current state of technical solution
Moving at home	Automatic door opening; lift; automatic walker	Door opening and lift available but expensive due to performance and safety requirements; automatic walker under development
Transport of goods at home	Service robot	Service robot in research state; systems with limited performance on the market
Checking state of home devices/appliances from external	Remote access by mobile phone or other device	Available
Withdrawing money from a bank or cashpoint	Home banking	Available and popular
Transferring money	Home banking, easy and usable	Available; problems are security und usability

Table 7: Security and privacy of information and data

Situation	Technical solution	Current state of technical solution
Data storage (at home/carrying data with me/ at doctors practice/at the help-centre)	Safety against physical damage; data backup mechanism	Storage devices available but basic computer knowledge is necessary; introduction of electronic patient records will be introduced but still under discussion
Data transmission between sensor, home station, to the help centre	Authentication, encryption mechanism	Important area of innovation; technical and standardization problems to be solved
Authentication for data usage	Biometric identification	Available but expensive and security still not acceptable

Roadmap 3: Personal safety and security

User demand	Short term (2013)	Mid term (2018)	Long term (2025)
Safety and security against personal integrity and external physical threats	Distributed sensors with RF network to home station and phone link to alarm control centre	Sensors “plug-and-play” network with automatic configuring capability	Sensors with energy harvesting
Safety against falls and cuts	Fall sensor	Motion monitor including fall sensor functionality; home station capable of situation interpretation	Integration into false teeth, into implants or other body devices
Safety against other personal fatalities	Outdoor localization via Navstar-GPS	Usage of other GPS like Galileo: indoor inertia navigation supported by stationary beacons	Pervasive navigation with centralized storage of position and track; merged with outdoor and building maps; personalized and secure access of data
Safety while performing specific activities	“All terrain” mechanical walker in which individual devices like illumination, navigation system can be installed	Walker can be docked to personal private car	Walker is able to enter public transport vehicles, escalators, stairs and cross doorsteps. It will carry its loads into the car and into the flat/house. It will avoid collisions and knows about routes and potential conflicts

4.3 Personal activity management

The following scenario describes a possible AAL-based approach to personal activity management for an older person suffering from a mild form of dementia.

Scenario 3: ***Personal Activity Management***

Jim is 87, and suffers from a relatively mild form of Alzheimer's disease. The effects of the dementia on his behaviour are kept under control by drugs, and drugs also allow a fairly good functioning of mnesic functions.

Nevertheless, quite often Jim is not able to correctly develop and fully carry out plans for his tasks, so his ability to successfully conclude many activities of his daily life would be seriously compromised without a good cognitive support system.

But his home knows what he is doing, at any moment in the day:

> *The home knows Jim's world, his habits, his preferences, the way he usually does things; it has been learning this through observation and recording for years, even since before Jim developed Alzheimer's.*
>
> *The home knows what Jim is doing right now: it know where he is, if he's standing or sitting, if the TV – or any appliance – is on or off, if he's using it or not, what objects he is handling. By comparing observation and stored information, the home is able to recognize – with some likelihood – which activity Jim is performing, and subsequently the expected outcomes, the risk factors associated to that activity etc.*
>
> *The home is thus also able to actively support the correct execution of the activity, by seamlessly comparing the execution flow with a "normal" one (a "model" stored as a result of past observation), and by guiding Jim through a safe and effective sequence of steps, by means of ubiquitous audiovisual support.*

Jim is usually alone during the day, while a care giver stays at his home for the night: his children don't live in the same area of the town, and they are at work almost all day long. But they worry about Jim's wellbeing and safety and are always ready to intervene in case of need. They know that they can rely on Jim's AAL system and on its capability to keep the situation under control, and to inform them when something goes wrong.

Jim likes to go out for a walk in the neighbourhood, to the park, to the main square, or to the nearby grocery to buy some food. When he does this, the system automatically sends a message to Jim's relatives and/or to the care giver. This message is nothing alarming; it is a normal event, but it is good that they know that he's gone out. The same kind of message is sent when Jim comes back home.

But two hours is probably a little too long. A new message, telling them that he hasn't come back, could help. Just to let them know, so that they can try and contact him to see if everything's OK.

Similarly, the assisted-cognition system is able to detect other critical situations (e.g. panic or delirium), by interpreting a number of distinct pieces of information related for example to activity and/or to physiological parameters. When such a situation is detected, three distinct groups of action can be taken:

- *reinforcement of the safety measures inside the home (e.g. lock of the exit door and of the windows; lock of the pieces of furniture where dangerous items and substances are stored);*
- *calls to relatives or to care givers;*
- *targeted stimulation with stimuli that are known to capture Jim's attention and to calm him down (e.g. pictures of family members or other images, or music).*

Summary of technologies for Personal activity management

- sensors and systems for indoor localization and monitoring;
- ontologies and user models – activity models for activity recognition and monitoring and for cognitive support;
- ubiquitous audio-video-data communication;
- multi-channel stimulation;
- ubiquitous/pervasive sensing and computing + pervasive communication = Internet of Things;
- event streams processing and probabilistic reasoning.

4.4 Biorobotic systems and AAL

Biorobotic systems can provide useful solutions in order to address different issues raised by the ageing of the population.

Biorobotic solutions can represent a key technology to improve the quality of life of older people. It is important to point out that only a deep understanding of basic issues will allow the development of effective assistive and rehabilitation devices.

4.4.1 R&D state-of-the-art

4.4.1.1 Biorobotics for personal autonomy and for care

The OMNI semi-autonomous omnidirectional powered wheelchair (Hoyer 1995, S. 26–29) was one of the first attempts to develop an assistive device for indoor mobility including navigational intelligence. The wheelchair prototype was equipped with four omnidirectional Mecanum wheels and with an array of composite proximity sensors, each composed of an in-air ultrasonic rangefinder and an infrared detector, with dynamic local-map- building capability. In later versions of the prototype, new and more usable user interfaces were added, together with modules for local navigation based on path storage as splines from odometry data and path retrieval, featuring playback and backtracing of stored paths.

PAMM (Personal Aids for Mobility and Monitoring) is the acronym for a series of test-beds under development and demonstration at the Department of Mechanical Engineering of the MIT since 2000. Two prototypes in particular have been described, namely the SmartCane and the SmartWalker.

The SmartCane (Dubowsky 2000) was designed for older people with mobility difficulty due to physical frailty and/or disorientation due to ageing and sickness.

The SmartCane was aimed at operating in known structured indoor, single-floor environments with random obstacles such as furniture and people, and at providing equal or better stability than that of a standard four-point cane, while at the same time providing guidance to destinations, continuous health monitoring and two-way communication with a caretaker computer. It basically consisted of a small mobile robotic platform endowed with: 1) a CCD camera pointed vertically along the Z axis to detect markers on the ceiling, allowing localization; 2) acoustic rangefinder sensors for obstacle detection; 3) a 6-channel force-torque sensor mounted on the cane shaft, to measure the user's interaction with the cane itself. The SmartCane mobility-control system allowed direct user control on path and speed as well as system-driven path following, with the possibility for the user to adjust the speed and/or the path itself.

The SmartWalker (Spenko 2006) was developed to meet the needs of users who require the support of a walker, and it used several of the same features as the SmartCane; additional features included longer power autonomy, added physical support, health monitoring capabilities (activity levels in terms of speed and applied forces, and ECG-based pulse monitor), and omnidirectional movement by means of a couple of active split offset castors (ASOC).

The MOVEMENT system (Modular Versatile Mobility Enhancement System) (Huntemann 2007) (Mayer 2007) was developed by a consortium of European research and industrial partners in the framework of an EU-funded project to address the mobility needs of impaired individuals in a number of ways, ranging from a larger group of users who do not need or want to use a wheelchair permanently, but could benefit from motorization in various mobility-related activities, to a smaller group of much more severely disabled users, who normally would not be able to control existing powered wheelchairs (e. g. because of spasm or other multiple impairments). The MOVEMENT system core was formed by an intelligent mobile (robotic) platform, which could dock itself to a user-definable set of application modules (e. g. a simple chair or a multifunctional chair for severely disabled users, a device actively supporting deambulation and postural transitions, an information terminal or a simple height-adjustable table).

An innovative approach to in-home service robotics for care and autonomy has been presented recently by the MATS Project (Balaguer 2006, S. 51–58). With the aim of introducing a robotic manipulator in the environment of a person needing it, the researchers abandoned the "traditional" scenarios (i. e. a manipulator fixed in the environment, on a mobile base or on a wheelchair) and developed a robot able to move from one room to another or from the static environment (walls, tables, etc.) to the wheelchairs or vice versa by climbing. The MATS robot was developed as a 5-DOF robotic arm, equipped at its extremities with a conical connector that could also serve as a gripper, allowing total symmetry in the use of the robot extremities as a docking device, or as an end-effector for manipulation. The climbing process was performed by letting the robot move between very simple docking stations (DSs) placed in the environment. Experimental tests were performed with users, related to tasks like eating (the MATS robot, attached to a Docking Station, could take food from a special plate and bring it to the user's mouth and shaving/ making up (Balaguer 2005).

4.4.1.2 Cognitive and companion robots

An increasing number of pilot experiences, in which animaloids and other companion robots were investigated as potentially useful agents for the care of older people, has been documented in the scientific literature during the last five years. It is in fact a wide and articulated domain of application for robotics, as demonstrated by the large number of different projects and pilots developed by researchers, mostly in Japan and in the USA.

Two different paradigms play an important role in this domain: Ubiquitous Robotics (Jong-Hwan 2005) (Jong-Hwan 2007) and Relational Artefacts (also named Sociable Robots) (Turkle 2006, S. 247–61) , the first one concerning especially the investigation of companion robots as agents of an intelligent living environment, aimed at providing older people with a mix of physical and cognitive support in their everyday life, while the second one relates more specifically to the investigation of the non-verbal, emotional and affective component of human-robot interaction.

An interesting research area within cognitive/companion robotics focuses on how robotic creatures can be used with patients suffering from Alzheimer's disease and other types of dementia, not only as "emotional activators", but also as cognitive stimulators, by fully exploiting their interactivity and their (although limited) processing capability. Following this approach, after exploring the effectiveness of using animal-shaped toys for pet-therapy, a group of researchers from Japan (Yonemitsu 2002) described the beneficial effects of interaction with the AIBO robotic dog on older subjects with dementia, with a special focus on the results in terms of increased communication patterns.

The AIBO robot by Sony has also been used in a recent preliminary study (Odetti 2007), aimed at a preliminary evaluation on how acceptable robot-mediated pet-therapy is for older people with light-cognitive deficits (MCI or other kinds of dementia diseases in early stage).

The described study involved 24 older subjects with light-cognitive deficit and allowed gathering some basic preliminary user-centred information, in order to develop in the near future a new suite of more acceptable relational artefacts.

Some researchers are defining the new concepts of robotic psychology and of robotherapy, which focus on "interactive stimulation robots" (Libin 2004, S. 1789–803), and to develop new unified assessment tools like the Person-Robot Complex Interaction Scale (PRCIS).

Cognitive and emotional interaction between older people with cognitive deficits and animal-shaped robots is also being investigated at the National Institute of Advanced Industrial Science and Technology (AIST) in Japan (the PARO robotic baby seal) (Wada 2008, S. 53–60), as well as at the MIT MediaLab, where the Robotic Life Research Group aims at studying the mechanisms that underlie this human and animal competence and at developing a science of human-robot collaboration through multidisciplinary research. In this framework, a Teddy Bear-like companion robot is being developed to investigate the recognition of affective contents of touch in human-animaloid interaction (Stiehl 2006).

4.4.2 The SRA on robotics in Europe

The Intermediate Strategic Research Agenda on Robotics produced by the CARE project provides an interesting overview on the high-level research roadmaps in this field.

The CARE taxonomy is intended to cover all the branches of robotics research; the most relevant category for the AAL universe is that of Robotic co-workers.

Co-workers are robots designed to help humans in some way; identified application examples range from cleaning and gardening to assisting a user or a patient, and co-workers usually co-exist with human beings in the same environment (or they act on behalf of human beings in dangerous environments, which is not the case in AAL).

Close interaction between human and robot is one of the most relevant aspects of this type of robot, and interfaces assume a crucial role in this context.

The following example of co-worker robots, and of their evolution in the short/mid/long term, is extracted from the CARE Intermediate SRA (Roadmap 4).

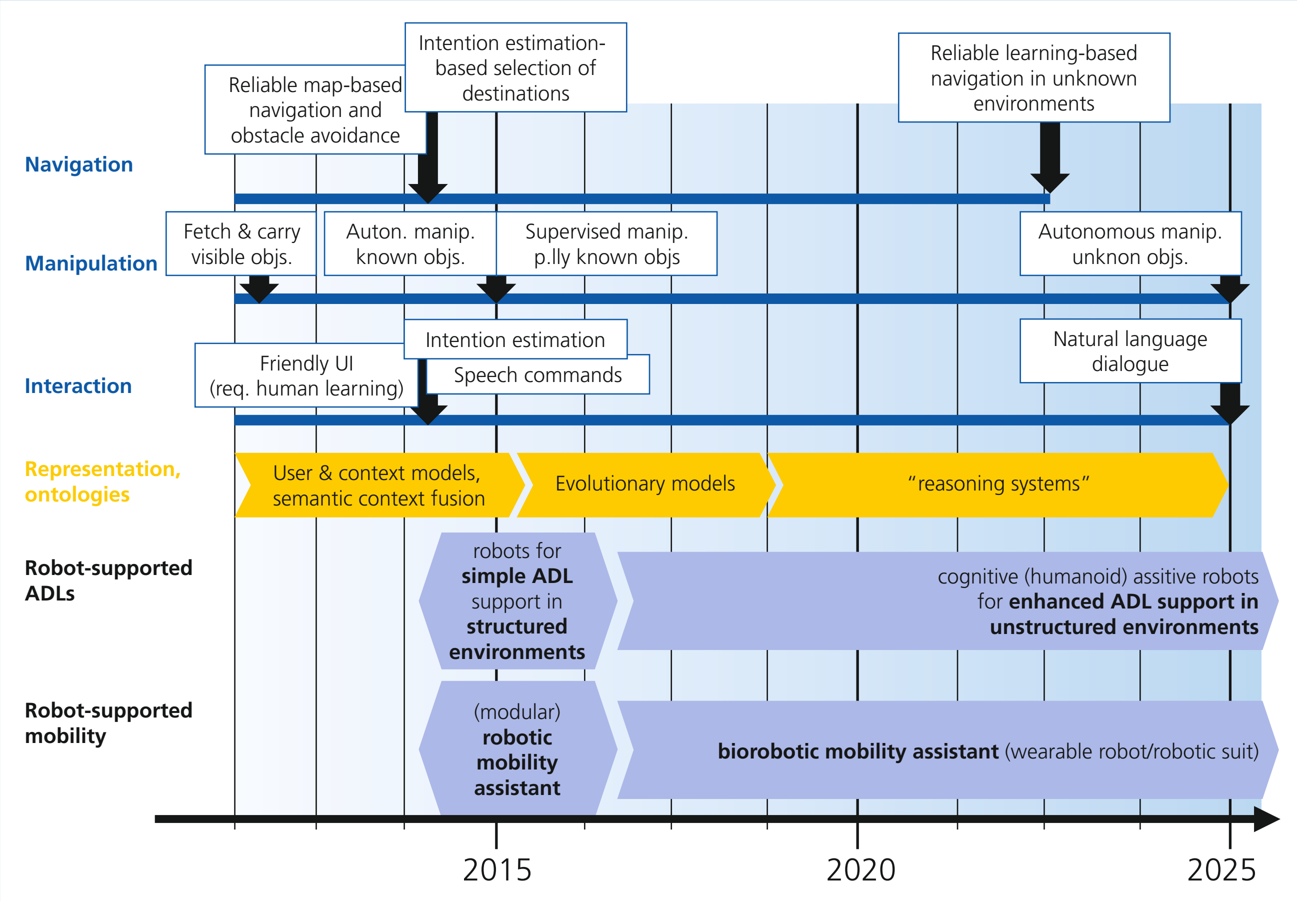
With a stronger focus on biorobotics in AAL, and in particular on biorobotic solutions for autonomy and care, three outcomes can be envisaged in the mid- and long-term period, namely:

- Assistant/companion robots for simple activity of daily living (ADL) support in structured environments (2015). Such robotic systems will show the following features:
  - reliable map-based navigation with obstacle-avoidance capability;
  - fetch and carry visible objects;
  - autonomous manipulation of well-known objects;
  - supervised manipulation of partially known objects;

Roadmap 4: Assistivite robotics

	SHORT TERM (2010)	MID TERM (2015)	LONG TERM (2020+)
Professional Co-Worker Robot	auton. topologic learning of environment; one hand manipulation of known rigid objects: symbolic gestures	auton. semantic learning of environment; two hand manipulation of unknown objects; natural language	learning tasks by watching & asking; manipulation of sliding, non-rigid objects; brain computer interface
Professional Cleaning Robot	task learning by graphical description on a map; one hand picking-up of simple shaped rigid objects	task learning by manual driving, two hand collection of complex shaped rigid objects	autonomous learning based example or semantic information; two hand collection of soft objects
Personal Robot (e.g. tidy)	greedy collector unable to sort objects	basic manipulation of limited range of known household objects within in a defined work scenario	handling of unknown objects within a defined work scenario
Personal Robot (e.g. floor cleaning)	room to room navigation	room coverage guarantee; reactive cleaning, regularly cleans without request from user	location awareness; common cognitive context with user about location; whole house cleaning

Roadmap 5: Biorobotics for Autonomy and Care



- classification of ADLs (based mainly on user localization and on limited information about involved objects);
- interaction with user-friendly interfaces (requiring human learning);
- limited speech recognition.

- Robotic support to in-home mobility (2015)
  - reliable map-based navigation with obstacle-avoidance capability;
  - intention-estimation based selection of destinations;
  - features of sitting mobility (wheelchair), support to postural transitions and walking (combined lifter/walker);
  - modularity: moves user to places and objects to user with one mobile base.

- Cognitive assistive robots for enhanced ADL support in unstructured environments (2025)
  - reliable learning-based navigation in unknown environments;
  - autonomous manipulation of unknown objects;
  - activity recognition;
  - fully compliant physical interaction with user;
  - natural language dialogue;
  - non-verbal communication (emotions, gestures).

4.4.3 Biorobotics for neuro-rehabilitation

Looking at the effects of different intensities of physical-therapy treatment, a significant improvement in activities of daily living as a result of higher intensities of treatment has been reported. Unfortunately, when traditional therapy is provided in a hospital or rehabilitation centre, the patient is usually seen for one-hour sessions once or twice a day. For this reason, the possibility of increasing the effectiveness of the rehabilitation by exploiting the potentialities of robot-mediated therapies is becoming more and more popular around the world. In this case, the physiotherapist must programme and control a mechatronic device able to replicate (and when possible improve) the traditional therapeutic strategies, possibly enabling a quantitative, intensive and repeatable "dosage" of the therapy and a quantitative evaluation of the outcome for each patient.

In the recent past, several robotic and mechatronic systems have therefore been developed to achieve this important goal. In particular, two different types of devices can be defined:

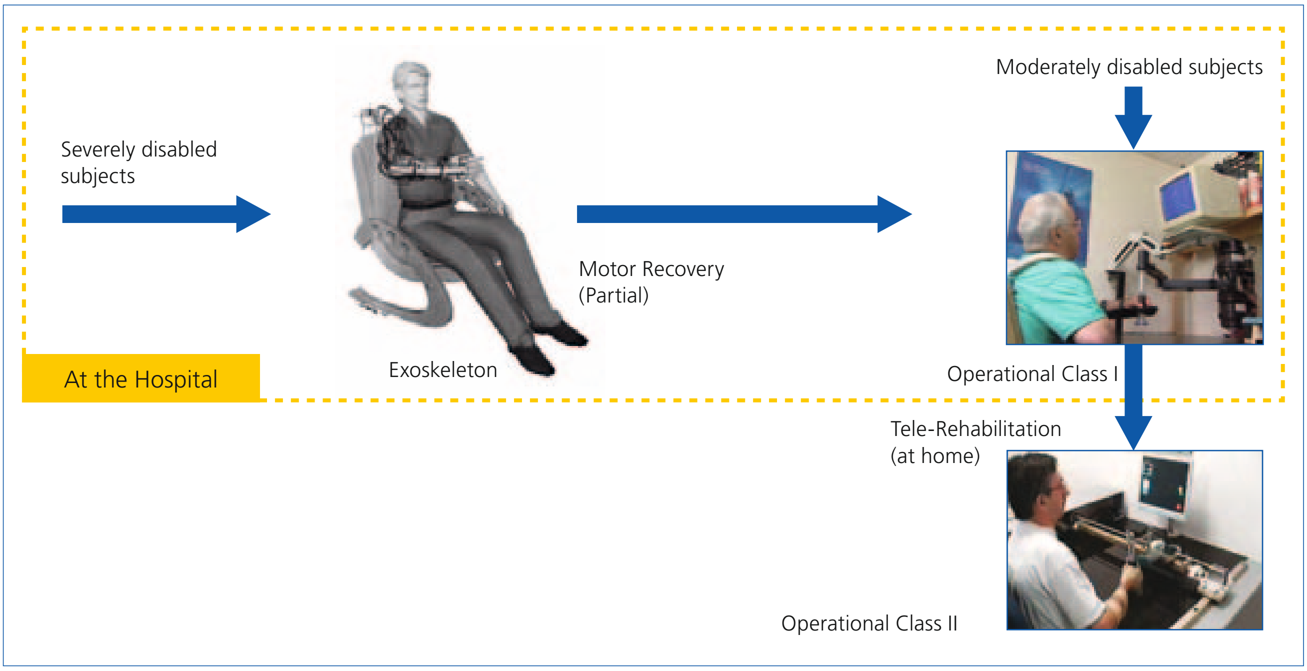
- Operational Machine for upper/lower limbs A.A.Rehabilitation
  - compliant physical interaction at the end-effector;
  - neuromotor/biomechanical monitoring;
  - real-time remote monitoring of motor performance;
  - remote calibration of rehabilitation protocol parameters.
- Exoskeletons for upper/lower limbs A.A. Rehabilitation
  - compliant physical interaction along the whole limb kinematic chain;
  - neural control and biofeedback.

4.4.3.1 Operational machines

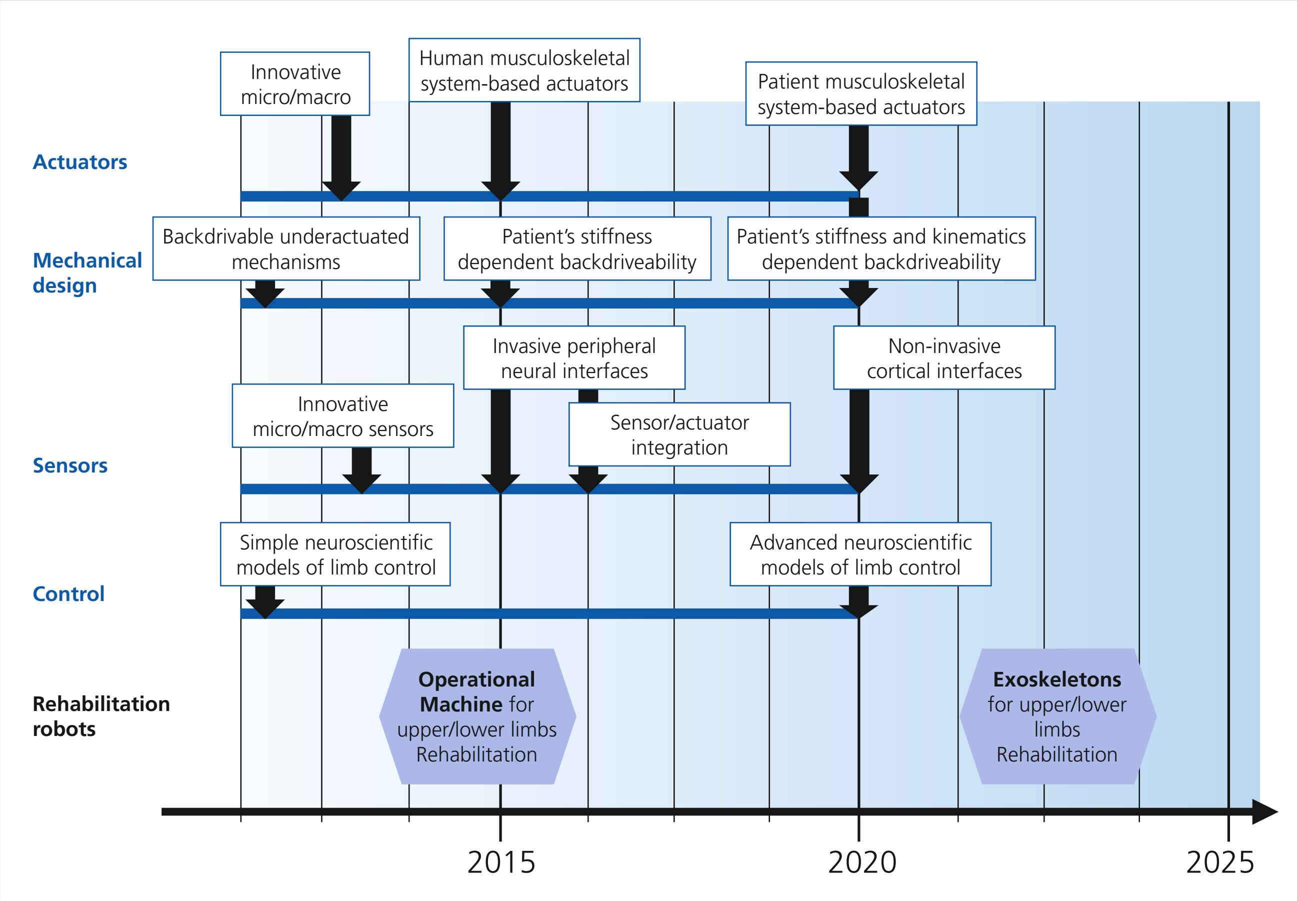
In the case of operational machines, the contact between the patient and the machine is only at the end-effector, through a purposive mechanical interface (e.g. pedal or handle). The movements can be programmed in the robot-operational space and the patient is expected to exploit his or her own synergies at a joint level to follow a trajectory in operational space. This means that these machines can be used with patients with moderate disabilities (when the patients feature a sufficient level of natural motor synergies).

Moreover, among the operational machines, two different classes of devices can be identified: 1) Class I systems characterized by a low mechanical inertia/friction, a high back-driveability, fine tuning of viscoelastic properties for force fields generation and

Figure 2: An example of the application of the robotic gym paradigm at ARTS Lab of Scuola Superiore Sant'Anna, Pisa



Roadmap 6: Biorobotics for Rehabilitation



measurement of the impedance of the human arm, and high cost; 2) Class II systems characterized by a simple mechanical structure, no back-driveability, (in some cases) an active compensation of inertia/friction and a low cost. Even if Class II operational machines present some limitations, they are interesting because of the low cost and the simplicity of functioning can make them more acceptable in clinical practice and even for tele-rehabilitation.

The characteristics of the machines belonging to the different types will be described, showing their potential and limitations while addressing the different levels of disability.

In particular, we believe that these different devices must be seen as different tools that clinicians can combine according to their experience and to the motor abilities of the subjects as a "robotic gym" (see Figure 2). For example – and note that this is not the only possibility – it could be possible to use exoskeletons during the first phase with severely disabled subjects helping them to restore motor-control strategies lost after an accident (e. g. natural upper-arm synergies while "Operational Class I" devices can be used for moderately disabled people who still retain some levels of correct control strategies in order to use force fields to improve the smoothness of upper-arm motor control. Finally, "Operational Class II" devices can be used for example for tele-rehabilitation, increasing the time of rehabilitation exercises carried out.

4.4.3.2 Exoskeleton-like machines

Exoskeletons are wearable biomechatronic systems that follow the limb movement of the subject. In this case the human-machine interface is extended all along the limb (or its part of interest) and the number of degrees of freedom (DOFs) of the machine is at least the same as that of the joints on which the therapy is expected to produce an effect. The motor exercise can be directly defined in the joint space and for this reason these machines are very complex. However, they seem to be useful for severely disabled people whose natural synergies have been significantly altered and there is a need for separate control of the different joints in order to restore the natural motor-control strategies.

A major challenge in the practical use of exoskeletons for daily activities is related to the coupled control of the human-exoskeleton system. Some researchers have addressed this problem, in simulations, by relegation of the human control and exoskeleton control to two control subsystems: one for the voluntary control of commands generated from the Central Nervous System, and the other one responsible for joint-level accommodation of all gravitational, static and certain reactive forces.

Another important problem for active orthoses is related to power consumption and to the need for powerful batteries or supply units to perform their work.

A further significant issue for this kind of device is related to the need for a close match between the exoskeleton structure and the wearer's limb structure, and in particular for close alignment between artificial and natural joints in order for the user to perceive the system as "transparent" for his or her mobility, and for the system to act on the user's limb and support daily activities or prevent incorrect movements or fall risks.

In conclusion, power suits could be useful to contribute in reducing age-related causes of risk of falls, but at present the results need to be improved in order to make a controller as easy as possible and to significantly reduce the weight and size of the required power supply.

4.5 Person-centred services

This section recognizes that the key features and the future strategic researches related to AAL and person services can be identified only by analysing the problem of person services following the Human-Activity Technology (HAT) model. This approach helps to study all the agencies and contexts that are related to the services and aims at highlighting the most important features that these services should provide in the near future.

The Human
The agents related to personal services are the beneficiaries (the users) and the suppliers.

Among all possible users of the services, a specific kind of beneficiary should be considered, elderly and not self-sufficient people. These subjects have reduced physical and cognitive abilities which have negative repercussions on carrying out the activities of daily life. Even though they have problems, these people have the right to lead lives with as much dignity and, as far as possible, independence as healthy people. Public and social services should guarantee this right and so should be conceived and aimed at overcoming the main problems related to this typology of users: reduced mobility (related to upper and lower limbs), cognitive deficits, sensorial deficiencies, cultural differences and poor health.

The suppliers of public and social services should satisfy the needs of a large number of users and often this demand is so high that it cannot be effectively fulfilled by service providers. For this reason, services should be restated and supported by technological solutions which can offer them strong support to carry out their work.

The Context
Public and social services should be planned to reach users at home or be easily reached by them. Moreover, it is fundamental that people should have human contact with those supplying the services, for example public workers, shop assistants, traders or socio-medical staff.

Technology
Technology is the means that allows people also are not self-sufficient to benefit from services. The technological solutions should be used both by non- autonomous subjects and by services suppliers; for this reason these systems should be conceived and de-

signed to be effective, efficient and easy to use and not perceived as being “invasive”. They should be easily integrated into the users’ context related to environments and habits.

Activities

The services should reflect the necessities of users and be related to the activities of daily life (ADL). In particular, the services that are to be provided to subjects should be related to the following activities: *shopping*, *feeding*, *personal care*, *socialization*, *communication*.

4.5.1 Shopping

Going shopping for food, clothes, etc. is an important activity that is carried out to satisfy daily needs and this task is also strongly related to the expression of personality and autonomy of a subject. To maintain this service to elderly and people who are not self-sufficient, the following three shopping services should be developed:

1) Remote shopping services

Remote shopping is carried out by linking the shops of an urban network (or in a rural context) and integrating the information related to their products and costs in a real-time database.

Each person who stays at home can consult the database using a tablet computer or a standard PC. Thanks to a user-friendly interface, subjects can log onto a database that recognizes the specific user and his or her personal data, the database being conceived to guarantee privacy to subjects and to protect their personal information from external interference.

After having identified the desired products, consumers look them up in the database:

– to verify the presence of the items and their costs in reliable shops;
– to identify the shops where the products are sold at cheaper prices.

Users then send their order to shops and, within 15 minutes, they receive confirmation or refusal of their request. Where shops have the required goods, the shops inform the users of the approximate time of delivery of the articles.

Thanks to this approach, products are chosen by people at home and are delivered directly there.

This method of shopping can be adopted to deal with public services, e. g. register office, post office or health department. An easy to use and reliable electronic payment service is needed in such a context. An example is the iDeal service offered by the major banks in the Netherlands.

2) “Missing products” services

Technological solutions could be used to help people to recognize the lack of specific items. Such solutions should identify missing products, alert users to this fact and, where necessary, send the order for articles to specific shops.

An example of this service and system is seen in a smart dispenser of drugs.

A smart dispenser is a system that contains the drugs that a user needs, in specific doses, and reminds the user to take the medicine. This device is able to recognize if the person is taking the drugs and if the drugs are running out. In such cases, the system alerts the user and members of his or her family and the doctor. If the doctor confirms the continuing need for these drugs for the user’s health, an order for the medicines is sent directly to the chemist’s which prepares the items and, as necessary, delivers them directly to the user’s home.

This method could be adopted in other cases, too, for example, the renewal of insurance.

3) Services for moving in shop environment

Going shopping is a sign of independence and is a way of communicating with other people and of socializing. For this reason, it is important to support people who find it difficult to move around for a long time, to stand up for a long time or to carry loads for a long time, to carry out the shopping autonomously. Technological solutions can support such users with shopping, to help them reach the shops and move around inside them.

A possible solution is a smart shopping trolley. This is a motorized trolley with a seat. It should be designed as being able to recognize its user and to follow him or her without needing to be pushed. Furthermore, when the subject feels tired, he or she can sit down on the device and the system will moves him or her to the part of the shop that the user has selected on the maps shown on the interface. Because the system knows the map of the shop and its location in the environment, it is able to plan its the way to reach the desired point and move autonomously to it, avoiding obstacles, because of its in-built sensors.

4.5.2 Feeding

The welfare and the health of a person are strongly related to his or her nutrition. Often people with deficiencies have difficulty in carrying out feeding. Supplying these subjects with appropriate technological services can help overcome this problem.

4) Services for the preparation of meals
In many cases, preparation of the meal is a complex and dangerous activity to carry out. Two solutions can be adopted to solve this problem: delivering the meal direct to the user's home and using sensorized pots and pans in cooking.
- **Meals delivery service**. Delivering the meal direct to the user's home is a service that can be provided by connecting restaurants and canteens set in an urban area in a virtual network that are part of a common database that contains information about the dishes to be prepared. Restaurant managers should update the database every day with data related to the kinds of foods, ingredients, calories and costs. People who stay at home can look up meals in the database and can order the food they want. The restaurant receives the request in real time and delivers the dishes direct to the subject's home as soon as possible. Moreover, the information related to the foods supplied can be consulted by the family of the person and his or her doctor: in this way, the diet of the subject is constantly monitored and modified as necessary.
- **Cooking service**. The use of technology and sensors can support the activity of cooking. Smart cookers, lids and pots and pans, with sensors, can control the cooking and baking parts of meals and, when necessary, alert the user to potentially dangerous conditions (e.g. foods burning, the flames on cookers needing to be extinguished, the cooker being switched on but with no pan on it, an inadequate quantity of water).

5) Feeding services
Because of motor problems and disorders, elderly and disabled people sometimes have difficulty in eating and drinking autonomously and normally they are helped to undertake these functions by other people. A support service as part of the task of feeding can be supplied by a technological solution. Systems should help people to carry out the following activities:
- cutting the food in the plate safely, avoiding the user having to handle knives, which would be risky for himself or herself and others;
- feeding the subject taking the food from the dish to the user's mouth, avoiding the possibility of hurting himself or herself by using cutlery;
- helping the person to drink, in case the user has problems in sucking liquids.

By means of technological solutions, people with certain deficiencies can autonomously carry out activities concerned with eating their meal. For systems to be accepted by users, they should be easy to use, easy to clean, transportable, not invasive and also usable in various conditions, e.g. with a wheelchair, on a normal table, on a bed.

4.5.3 Personal care

Taking personal care of ourselves is the result of various activities that help preserve our welfare. Such tasks are perceived as be being natural and easy to carry out by health persons, but for subjects with motor inabilities, even if they are only slight, this statement is not valid. Technological services can support people in carrying out tasks like monitoring health, taking drugs, dressing and undressing and personal hygiene.

1) Health monitoring services
Wearable sensors, advanced signal processing techniques and networking are solutions that monitor the physiological parameters of people and control their health, but not in an invasive manner. This

information should be provided remotely to users, their families and clinicians in order to make known constantly the health condition of the subject, to make an exact diagnosis, to identify the correct therapies and to intervene at the right time.

2) Rehabilitation and drugs services
Undergoing treatments of drugs or rehabilitation that are properly prescribed by clinicians is fundamental in preserving and improving health. To maintain this, technology can be used to carry out certain therapies.

- **Memory services**. Smart dispensers can remind users of the times to take drugs, also including the correct doses. The systems can also recognize when the medicines are running out and alert patients, their families and clinicians. If clinicians confirm the need to continue that treatment, the system sends an order for the drugs to the chemist's, which can than deliver the medicine directly to the patients' home.
- **Rehabilitation services**. Technological rehabilitation services can help patients effectively and frequently carry out rehabilitation tasks in clinical rehabilitation centres and also at home. Patients can perform the rehabilitation exercises autonomously but medical staff can remotely monitor the patients and correct possible errors as necessary. In this way, clinicians also have quantitative information about improvements in patients' health. Finally, these systems can result in positive effects on patients' life because they can regain their sensor and motor abilities more quickly and effectively or can maintain them in the best condition.

3) Services for dressing and undressing
Dressing and undressing are two tasks that we carry out naturally and easily but they conceal complex movements that people with reduced motor abilities in their upper and/or lower limbs cannot perform. Technological solutions should support these subjects in carrying out these activities. Robotic platforms with multi-joints arms and specific control strategies can help people dress and undress by performing complex movements that people are unable to carry out, at the same time guaranteeing compliance and safe interaction with subjects.

4) Services for personal hygiene
Personal hygiene is a basic necessity in maintaining a person's health. Although this is self-evident, access to a bathroom and the use of sanitary fixtures are not tasks that are easily performed. Statistics bear this out: the bathroom is the environment in the house where the second highest number of accidents happen. Technological services can be used to support people who are not self-sufficient in tasks relating to personal hygiene e.g. using the toilet, having a wash, taking a bath, shaving, and to save people from possible accidents. The main requirements of these systems are the ability to work in a wet environment, safety in interacting with users, the ability to carry out complex movements and the capability to support the weight of a person.

4.5.4 Social interaction and communication

Social interaction and communication are two elements that strongly influence the quality of life perceived by subjects. Everyone is entitled to enjoy interacting with other people and in taking part in the social activities of a community. Technological applications can help people with physical and/or cognitive problems to communicate and to socialize with others. Advanced vision, haptic feedbacks and virtual reality are valid starting points in developing new technological solutions that aim at facilitating and increasing the quality of social tasks for people who are not self-sufficient.

1) Services to help communication and social interaction
Technological applications can be used to provide services that support users in communicating with members of their family, friends and clinicians.
Sociomedical staff should monitor the physiological parameters of the patient and should also have the possibility of contacting and interacting with patients staying in a health centre.

Through 3D special calls (telephone calls with a 3D interface, e.g. a hologram, for communication), they can communicate with subjects and can verify their physical and psychical health state. These calls, in addition to periodic physical inspections at patient's home, can guarantee continual monitoring and timely and appropriate interventions where necessary.
3D calls can also be used to help people cultivate relationships with friends and members of their own families. Thanks to this kind of calls, subjects can perceive more closely the important people in their life and this can have a positive effect on their quality of life and health.

2) Services for remote social activities
Technological applications can make it possible for people with disabilities to interact with other subjects while remaining at home. To clarify the idea of remote social services, here is an example applied to the activity of playing cards:
A woman who is confined to bed at home plays cards with three of her friends who are seated in a recreational centre. To play with their friend, they use a special platform that has touch screens and monitors with webcams that are remotely and wirelessly connected between them. In the recreational centre, each friend has their own touch screen showing their own cards and on the table stands a monitor that shows the cards at stake. The subject at home has a touch screen showing her cards and a monitor that displays both the cards at stake and her friends. Thanks to the real-time communication between the different components, the four friends can talk to one another, see their friends' gestures and interact positively.

3) Services for physical participation in social activities
Robotics can help people with a disability to join in activities carried out in recreational centres, houses of friends, cinemas, restaurants, theatres, churches, etc. Innovative systems, smart and with reduced dimensions, can move users from their house in the urban environment and then reach the other environment where they can meet other people and socialise. The most important feature that should characterize these systems is the ability to move indoors and outdoors. The devices should be able to overcome obstacles like steps, to be able to move on different kinds of ground and to have reduced dimensions for moving around easily in closed environments.

5 AAL in the community

Social participation decreases with age, fundamentally because of three factors: intrapersonal, interpersonal and structural factors.

The first category includes all personal factors, attitudes and other variables that are inherent to the individual person and make the participation in, and enjoyment of, leisure activities more difficult. Such factors include health, financial circumstances, individual aspirations or disillusionment for life.

The second group includes all circumstances derived from contact with family, friends, neighbourhoods that condition the practice of leisure activities. Examples of such circumstances are the loss of loved ones, distance from children or the fact that an elderly person often cannot find someone to share an activity with.

The third group represents external or environmental factors that influence leisure activities.

Any activities aimed at minimizing any of these factors will promote the social interaction of elderly within their community

Despite all these factors, participation levels can be significantly increased with adequate **motivation and support**. Thus, elderly people can be supported in finding and carrying out work, establishing and maintaining contacts with other people, and, in general, can be helped to spend time participating in different leisure activities.

Promotion of social participation of elderly people can be undertaken in many ways. First of all, **communication** services should provide new and easy-to-use facilities so as to help seniors enhance their social relationships. This is a way of raising self-esteem and increasing the sense of control and autonomy. A second way is that the elderly should be provided with necessary **information** about leisure activities that are adapted to the needs of the person and able to attract his or her attention and create interest. This can include outdoor activities and volunteering activities. Finally, **mobility** is essential for general independence and to ensure good health and quality of life. For older people, mobility represents more than having a means of transport, but is also a symbol of freedom, independence and self-reliance, and retaining some control over their life.

Communication

Human beings are social beings by nature, from the time of our birth to our death. We need other people to live. A person's fragile condition makes him or her in need of support and fosters communication with others not only to maintain an interest in living, but also in developing a deeper sense of personal fulfilment and identity. Loneliness is a subjective experience that results when interpersonal relationships are not fulfilled.

Elderly people tend to feel isolated. Old age is a stage in life that comes with a series of losses such as work, social status, physical capacities and friends that all relieve a sense of loneliness. In fact, for example, in Spain 13 % of the elderly feel loneliness often or very often, this percentage rising to 38 % if they live alone.

An easy way to prevent such loneliness is friendship and family relationships.

The elderly should be provided with tools that enable them to communicate better with others and foster the fulfilment of relationships with new friends, so stimulating their sense of belonging in a social environment and reducing a sense of isolation and exclusion.

Such an improvement can be carried out for example by introducing videoconferencing systems, since image is a key factor in communicating with others. Videoconferencing has the immediate benefit that elderly people can have enhanced communication with others. There are also important positive side effects: through a videoconference, not only will the elderly be able to see other people, but since other people will also be able to see them, it will also be an incentive to greater personal self-care.

Active citizenship and cultural participation

There is an inverse correlation between age and the realization of leisure activities, except for passive leisure activities such as watching television, which is the only social activity that increases with age. This tendency shows that cultural activities are not extended to include old people. However, participation in active leisure increases the quality of life, as it leads to a better adjustment to real living circumstances. It is also an opportunity to create and develop new abilities, knowledge and feelings. More developed activities should allow seniors to be informed, understand their environment, organize themselves and play a positive role in activities.

Elderly people should be engaged in activities that interest them and are suited to their needs. They should increase the levels of awareness of the need to learn, change and discover new experiences. In this way, attitudes towards participating in activities would change, reinforcing the role of the elderly in the community.

Activities in this area should be aimed at promoting voluntary activities, virtual communities that motivates elderly to get together sociably to be informed about, and involved in, the leisure activities of a city or town, etc.

Going outdoors

Mobility is essential for general independence and ensuring good health and quality of life. For older people, mobility represents more than having a means of transport, but it is also a symbol of freedom, independence, self-reliance and having some control of their life.

Mobility is more than merely moving from one place to another; it can benefit elderly people in several ways. It provides the elderly with the possibility of travelling to achieve access to desired people or places. Psychologically, movement in itself or "getting out" induces feelings of independence and increased self-esteem. Finally, it can help elderly people become involved in more local community activities.

Although there is a tendency for seniors to move around in their own car, there are numerous reasons to maintain and improve public-transport systems and raise the awareness of alternative transport options among older people. However, using public transport can be stressful for older people: ticket machines are often complicated to use and there is an vast amount of customer information to take in.

Activities aimed at improving the mobility of the elderly can make public transport more accessible:

- physically, by making it easier for elderly people to actually get on a bus;
- practically, by providing the right information for moving around a city by public transport and by providing the means of finding the way through a city using for example a GPS-based system.

5.1 Social inclusion

Social interaction is one of the most important characteristics and needs of human beings. Social interaction is a natural event that happens between people in everyday activities, e. g. during shopping, at work or in spare time, and allows individuals to express their personality and their ideas and also to become fuller more rounded in character and experience. Human social interaction is the basis of all communities: both on a personal level and also on the level of a community or society: good social interaction helps increase the general welfare and quality of life of all members of the community.

Unfortunately, motor, cognitive and health deficiencies are often barriers to social interaction and communities face up to and deal with these difficulties inadequately in the support given to those who are older, disabled or sick. The result is that most people with deficiencies are excluded from society and often feel marginalized; this causes damage not only to the life of the individual but also the whole community is weaker, because it has missed the opportunity of becoming enriched with many people's experiences, ideas and skills Most countries have understood the importance of overcoming barriers to social interaction experienced by elderly, disabled or sick people and support the study and development of new strategies, services and means of supporting social interaction and work towards greater inclusion of these individuals in community activities.

Research that considers social inclusion of people who are elderly and not self-sufficient in communities should deal with various aspects of social interaction, including the expression of creativity, the mobility of individuals, access to social networks, learning and participation in community activities.

5.1.1 Participation in community activities

In most cases, elderly and disabled people do not participate actively in activities in their community because society does not put them in the position of being able to take part in such activities.

Elderly and disabled people are individuals in their own right in a community and, for this reason, supporting them fully to enable them to participate in social and community events is important.

This aim concerns both the information and also physical access to public services and buildings. European communities are already working on these aspects but more needs to be done, including the wider use of technological applications.

In many cities, local newspapers are the means of informing citizens about local news, events and political decisions. New technologies can provide fresh solutions to facilitate access to news and to allow active interaction in a community's events and decisions.

Accessing information – a scenario
Each older person can use his or her digital television or a facilitated computer to choose the kind of information he or she is interested in, e. g. politics, sport, news or cultural events, and also the geographical area of interest, local, national, continental, or intercontinental. Such information is described using a comprehensible language – primary and secondary education should be sufficient to understand the news – and should be expressed with video (using large characters) and audio tracks (with variable volume). For each item of information, the user can express judgements, remarks and opinions by means of both a facilitated keyboard or voice-recognition software, and such judgements are sent directly to the main subjects that manage the information or event.

Access to local services and buildings is an objective to which all countries are working towards. It is possible to design or modify public buildings to facilitate access to people with motor deficiencies. Moreover, other possible ways for guaranteeing that elderly and disabled people benefit from public services and activities should be adopted:

- increasing remote access to events and services;
- developing local mobility networks of minibuses which move the elderly and disabled from their homes to the location of services and events;
- designing systems that move individuals autonomously to the desired location.

Physical access to services and activities – a scenario
People who have motor deficiencies cannot move from their house but can remotely access services or events. Using digital television or a facilitated computer connected to biometrical recognition systems (fingerprints, voice, optical) they can recognize and gain remote access to a specific service, e. g. a post office or a register office) and talk with employees and workers. They can also use the same system to buy tickets for particular events and watch them on the television or computer screen.

5.1.2 Creativity, hobbies and sports

Sports and hobbies are ways of expressing a person's creativity and personality and are a means of social interaction with other people. Older and disabled people often have difficulties in carrying out this kind of activity because of sensory, cognitive or motor deficiencies and also because of other people's prejudices and ignorance.

Sports and hobbies can help improve an individual's health in maintaining motor, sensory and cognitive abilities and so increase the quality of life. In most cases these are also the means of creating relationships with other people and to become more fulfilled people.

Communities should work towards improving inclusion of disabled and older people in participating in hobbies and sports, so enabling richer self-expression.

Possible ways of increasing such inclusion:

- developing buildings, e.g. gymnasiums, community centres, that are well equipped and accessible to healthy users and also elderly and disabled people;
- organizing courses and activities that are given and delivered by experts and qualified people, in which subjects of different ages and with various abilities can interact. Examples are team games, theatrical activities, language courses, computer courses, mixed-games tournaments;
- planning alternative solutions to ensure the participation of elderly and disabled people in these activities, e.g. by providing buses that pick old people up and take them to the location of the activities;
- organizing final events, e.g. exhibitions or tournaments, that show and inform the general population about the results of the courses or activities.

Stimulating and facilitating old and disabled people to undertake such activities is basic to increasing the integration of such individuals in society, in awakening public opinion about problems related to everyday life of these people, in overcoming general prejudices about the elderly and disabled people and in improving the sense of fulfilment and quality of life of every member of the community.

5.1.3 Cultural and experience exchanges

Elderly people in AAL environments have the possibility of actively participating in cultural and experience exchanges. The following are examples of the different activities that could be arranged and supported:

- Formative activities:
  - improving education, learning how to use new technologies for communication with family and friends, entertainment;
  - Internet-based mass media, chats and forums where people from different countries and with different religions and ideologies could meet and discuss, read local and national newspapers, etc.
- Creative activities:
  - interest in painting and drawing, music, theatre, films, literature;
  - contact with different generations;
  - knowledge of Internet magazines;
  - teaching, instruction or the sharing of skills (e.g. artistic) by some elderly people,

5.2 Entertainment and leisure

Training the brain

Some elderly people are looking for new ways to keep active and alert. They are responding to the advice to take care of their brain and are involved in special activities such as doing jigsaw puzzles, playing music, learning foreign languages, juggling, dancing and playing table tennis. Nowadays, games that have been specially designed to stimulate and train the brain are also available. Such games are now entertaining a new generation of computer users: elderly people who up to this time have not been interested in computer games.

A clear and growing market – a business opportunity – of older adults has opened up for the computer game industry. This has created a major challenge to game companies in designing games and applications that are attractive and interesting to older adults. Although there is not yet any direct evidence that increased mental activity can slow down the age-related decline in the brain, millions of brain games have already been sold in Japan, the USA and Europe. A growing number of companies are marketing computer programs and games that they say will help older people stay mentally sharp and perhaps delay the inevitable decline and possible dementia. These applications are targeted at one of the fastest growing segments of the game market: people over 40 years old who are worried about losing their mental edge.

Empirical studies of ageing and memory show that older people maintain their ability to acquire new information and strategies. Several studies of elderly people suggest that cognitive-restructuring techniques may help older adults improve their memory functioning and gain control over their beliefs about memory, so enhancing performance of their memory.

It would be worthwhile to study the possibility of developing such applications as brain games for rehabilitation purposes for e.g. people with dyslexia, memory disorders or difficulties in perceptive skills. It would also be interesting to consider using a brain game as an assessment tool for e.g. memory tests.

Exercise and gaming

Maintaining good health and physical condition in old age is important, but there are not yet inspiring ways for the elderly to keep fit. Solutions of ambient intelligence have the potential of delivering motivating concepts for exercising and keeping fit with the help of the seamless integration of technologies such as wireless and mobile networks, tagging technologies, context-aware solutions, locating technologies and media-rich wireless sensors. In order to be effective in the design of such applications, information is needed about the needs of elderly users and different types of technology solution and their consequences for older people.

Game-like applications and play-service concepts can be one solution when challenging people to practise physical exercise. The key research question in the concept development is how to motivate people to take part in physical exercise, to receive and share information related to their overall health and wellbeing and to change their health-related behaviour patterns.

The positive effects of physical exercise are commonly known. Even small amounts of daily physical activity can strengthen a sense of good physical health. Physical exercise affects also mental health. It results in a heightened sense of wellbeing, with or without a relationship with characteristics of physical fitness. In addition to mental forces, it also increases social capabilities.

Depression among older people, which is often an unfortunate consequence of isolation, has already become a significant problem in Europe. It can sometimes lead to institutionalized care. Investigations show that physical exercise strengthens the essential components of a mentally healthy human being: self-confidence, self-appreciation and self-assertion. Depression has also been both prevented and treated with physical exercise.

Various service concepts have been developed for mobile applications that encourage people to "exergame", to practise physical exercise whilst using an entertaining application, e.g. a game. "Exergaming" means combining physical activity and instrumental playing. This kind of playing is also called physical playing, body gaming, technically supported physical activity and fitness gaming. Examples of exergaming are dance games, camera-controlled games, simulator games, and location-information mobile games.

The key research questions in the concept development are how to motivate people to take part in physical exercise, to receive and share information related to their overall wellbeing and to change their health-related behaviour patterns.

Motivation plays a significant role in continuing to exercise. Rather than being a spontaneous behaviour carried out for fun and challenge, exercise is often accomplished for extrinsic reasons such as improved fitness or appearance. However, such extrinsic motives often fail to sustain exercise activity over a longer period of time. Furthermore, intrinsic motivation (such as enjoyment and competence) remains a critical factor in sustained physical activity. In this respect, the exercise undertaken must be enjoyable and possibly even fun if the person is to continue with it for any length of time. As people form a harmonic unity of physical, psychological and social elements, social interaction is also a strong motive to take part in an activity.

Our world is becoming more and more technical. At workplaces and even during leisure time, basic computer skills are frequently needed. Along with this development, the threshold of including technological solutions also to regular physical activity is becoming lower all the time. Mobile phones and personal digital assistants (PDAs) are small enough to be carried personally when e.g. walking or running, and the new features of mobile phones that include always-on online access can be used to enrich different fitness applications.

Wearable technology is developing rapidly and will definitely lead to new aspects in physical exercise and also entertainment. Along with general pedometers, cyclometers and pulse meters, new generation sportswear will be designed to measure and give feedback on the user's heart rate, skin temperature and breathing frequency. In a game, the clothing could change its colour, form or temperature according to user action in a game. Game manufacturers have noticed the potential of physical gaming and are constantly bringing new kinds of equipment onto the market. The thought of combining entertainment and exercise is generally approved and it is one of the most important aspects that will determine the popularity of these games. To become popular, this kind of exercise game needs to be a good idea and to be a combination of the right price and user's knowledge of the usefulness of exercise gaming. It also needs to respond to players' consumer habits.

Different research studies have been carried out related to exercise and wellbeing solutions to develop:

- An interactive, stimulating and social-play environment for children and their grandparents. Through games and play, the future play environment supports creativity, learning, and physical development. The goal is to combine elements of traditional playground, modern technology, and innovative and interactive applications.
- New interfaces for playing computer games, using users' gestures and touch as input, enabling users to move around and continue to interact with the game and with each other.
- Multiplayer games based on wireless communication and mobile-phone technology. The players play the game using their mobile phones and at the same time follow the game events from a public display.
- A combined fitness service and body-controlled user interface with the help of a new kind of fitness game – one which reacts to physiological stress and allows a person to practise in a group or on his or her own. The interface can be created, e.g. between the PC and the exercise cycle, giving a rich and motivating experience for the user.

It is commonly known that daily exercise should be regularly practised to increase personal efficiency. There is therefore a clear need for motivating solutions that would encourage people to practise regular physical activity. Fortunately, older people are becoming more aware of the need for regular physical activity. In order to succeed in fulfilling this need, they seek professional help in terms of counselling and advice. Health-care professionals should respond to this need.

5.3 Mobility

5.3.1 Supporting individual physical mobility

Walking is sometimes overlooked as a means of transport, despite the fact that it is fundamental to any journey. Everyone has to walk, even if it is just from the front door to the car or bus stop, around the house, or around a museum. As people become older, or if they develop impairments, they become at greater risk in pedestrian environments, finding them increasingly difficult to negotiate. There are often design conflicts involving street furniture, signage, lighting, rest areas, amenities, vehicles and road-crossing to consider, but also information about location (positioning), finding the right way and accessible routes. Geo-referencing and route guidance using satellite, wireless or mobile-phone technology can help pedestrians, not only by providing relevant and useful information, but also by giving reassurance in complex, busy or unfamiliar surroundings.

5.3.1.1 Summary of technologies for pedestrians

- Localization/positioning (i.e. where am I? what is near me?):
- outdoors, this can usually be achieved by satellite- (currently GPS, perhaps in future Galileo) technology combined with a suitable receiving device;
- wireless technologies are also widely available (e.g. WLAN, Bluetooth, RFID);

Scenario 4: **Supporting Individual Physical Mobility**

Angela is 72 and very active. She has many friends and likes to go out regularly. As she lives in the city centre, she finds it convenient to walk, as she always has. She is, however, suffering from angina and asthma which makes walking, although beneficial for both conditions, more of a challenge. This makes her planned trip to meet her friend Rosemary at the Science Museum more of a challenge than it was five years ago.

But in those five years a single piece of technology has revolutionized Angela's life: the "smart" mobile phone. She has used a mobile phone for some years but found the previous model difficult to use due to the small size of the keys. Recently she purchased a new-generation phone with larger keys, a larger display, and comprehensive functionality including adjustable colour contrast, adjustable text size, zoom functions, digital maps, GPS, wireless and near-field communication (NFC), and different methods of output (text, pictograms and audio).

It has been many years since Angela visited the Science Museum (Galileo was still a scientist and astronomer rather than a satellite system at that time), so she does some pre-trip research about its location using the Internet. Then she pre-sets the location of the Science Museum into her smart phone. Once she leaves her house, she is able to consult her satellite-based positioning and route guidance system. She is informed audibly of the directions to take via an earpiece, which means she can leave the phone (and digital map) in her pocket. This is more reassuring to her as it enables her to focus on the route ahead rather than a device in her hand. Because the digital map is highly detailed and regularly updated to take account of things like road works or re-modelled pedestrian crossings, or even re-sited street furniture, she is able to rely on the audible output.

Halfway through her journey she receives an audible warning that the presence of ozone is above the recommended level in that area. To avoid a possible asthma attack, she accesses a web-based journey planner on her smart phone to adjust her route to avoid the environmental problem.

Soon Angela arrives at the museum. Upon entering, her smart phone switches seamlessly from satellite-based navigation to wireless-based, as the museum is equipped with a dense wireless network. As the phone is NFC-enabled, she is able to pay her concessionary entry fee by swiping the phone a few centimetres from a reader, with the fee automatically deducted from her credit.

She has arranged to meet her friend Rosemary in the café on the third floor. To find the café she consults the map of the museum on her phone display and plots out an appropriate route based on her personal profile. This route will include some stairs to provide beneficial physical exertion. The map is able to display multi-floor visual representations of the museum and alternative routes between amenities and exhibits when required; Angela is able to click on features of interest, and in this way soon locates the café. She is also able to access information about the café's menu and services. Within a few minutes she has met up with her friend. Angela is happy that the powerful functionality of her smart phone combined with satellite and mobile technologies, and the wireless and sensor networks deployed in the city, have helped her enjoy a hassle-free and health-beneficial trip.

  - information delivered in a variety of formats to suit the individual;
  - indoor positioning requires wireless technology or dead reckoning (working out a current location based on a previously determined location) as satellite is not effective. Applications in complex buildings, e.g. airports or museums, may be especially effective.

- Navigation support (how do I get where I want to go?):
  - information delivered in a variety of formats to suit the individual;
  - indoor navigation requires wireless technology and enhanced accuracy technologies e.g. dead reckoning;
  - outdoor-to-indoor transition involving a seamless switch between technologies (e.g. satellite to wireless);
  - digital mapping for pedestrians.

5.3.1.2 Brief description of technologies

Mobile phone technology

GPRS and 3G mobile communications are now commonplace. It is likely that 4G (fourth- generation) systems, which integrate wireless and mobile communication technologies, will be available in the near future, with much more emphasis on appropriate design and functionality for older and disabled users. Facilities like synthetic speech output, more accurate positioning, high-quality digital maps, and location-based information will become widely available through new generation devices. Phone technology can be important for obtaining additional services such as arranging personal assistance.

Satellite systems

Satellite systems are a core technology for providing positional information and location-based services. GPS is the best-known example, but the Russian GLONASS system and the European system Galileo are also likely to become important in the future. These systems require a line of sight from their satellites to the receiving device and so are largely unsuitable for indoor locations or dense urban areas. Modifications can be implemented (assisted-GPS) and combinations with other technology (e.g. wireless) can enhance accuracy.

Digital mapping for pedestrians

Until recently most mapping has been aimed at motorists. There is now great interest in developing pedestrian systems, but the level of detail and maintenance of up-to-date maps is a major challenge, as for example there are daily changes to the location of street furniture, while road works, extreme weather conditions and building activities often disrupt regular routes.

Web-based technologies

Web-based journey planners are commonplace and offer increasingly sophisticated multi-modal planning options. It is becoming more common for such systems to include walking (e.g. Google maps and http://www.walkit.com which both provide walking directions in several UK cities). Personalized services are becoming available whereby only relevant information is supplied and in an appropriate and accessible format.

Near-field communications (NFC)

NFC is an innovative technology that enables the exchange of information simply by two devices being brought adjacent to each other. In that respect it is similar to Radio Frequency Identification (RFID) and smartcards. A range of 10 cm initiates communication, with longer-range communication possible via Bluetooth or WiFi. It operates at the same frequency as contactless smartcards. The real advantage of NFC is that an existing phone can be used to link to another device; it therefore does not require extra technical knowledge or the need to purchase an additional device. Potential applications include ticket downloads, and access (e.g. to railway stations) by touching the phone onto an NFC-enabled ticket barrier. It could also be used to obtain audible information through a phone speaker, simply by touching the mobile adjacent to an NFC-enabled sign.

Wireless networks

Although wireless technologies such as Bluetooth and WiFi are widely available and used, it is the ability to interact within a wireless network deployed as part of a pervasive computing system that is set to really open up this technology to exciting new applications. As with pervasive computing, a powerful intelligent infrastructure will exist to support travel and transport services, including pedestrian movements. Vehicles, pedestrians and the infrastructure will communicate with each other: an example of how this could work is the automatic communication of a warning to car drivers that older people are in the area and are trying to cross the road. Personalized services and location-based information could also be provided, for example extra time to cross a road or keep lift doors open. This technology is largely proven, but networks need to be constructed.

Sensor networks

A variety of sensors can be deployed, often as part of a wireless network, to monitor pollutants or perform some other task. This information can then be processed and supplied to policy makers and individuals to help them make more informed policy or travel decisions based on health risks. Sensors are available and in use, but tend to be high cost and deployed in low densities. Low cost "ubiquitous" sensors should be commonly deployed in three to five years. Weara-

Roadmap 7: Supporting individual physical mobility

Innovative technology	Short term (2010)	Mid term (2015)	Long term (2020)
4G mobile technology	Mobile devices designed with older people in mind e. g. simplified layout, large keypad and screen, availability of alternative output modes		
Satellite technology	Improvements to accuracy of GPS GLONASS available	Galileo available. Seamless switch between satellite, mobile and wireless technologies	
Digital maps for pedestrians			Comprehensive coverage of urban areas with detailed, regularly updated digital maps Delivery to hand-held devices via range of suitable outputs
Web-services	More personalized services available	Distributed computing systems linking different content providers	
Near-field communication	Technology mature by 2010	Widespread deployment in transport applications	
Wireless networks	Technology mature and reliable	Deployment of systems, indoor and outdoor. Systems and people communicate via personal wearable devices (PWD), e. g. smart jewellery, or smart phone/hand-held devices	
Sensor networks		Deployment of systems. Systems and people communicate via personal wearable devices (PWD) or smart phone/hand-held devices	

ble sensors, e. g. accelerometers and pedometers, are also available for pedestrians. New data processing and storage techniques are required. The size of sensors is decreasing, and their capabilities are increasing. It is possible that they could become nano-scale technologies, whilst the range and design of personal wearable devices will undoubtedly increase.

5.3.2 AA-driving (cars/private vehicles)

The need for personal mobility

Personal mobility is a key factor in independent living of older people. This includes participation in the social life in the community, leisure activities, visits and also activities where older people take social responsibility. In rural areas where public transport is not available or is not provided in an acceptable quality, driving with a private (or rented) car is essential for independent living. Driving in a private car is often considered as more comfortable and safer and faster than public transport.

Systems found originally in high-priced cars

Most car manufacturers consider the demands of older people in their specifications due to the increasing number of older customers and their contribution to the market segment of high-priced cars. In this segment, new systems of comfort and safety can be realized due to their cost. Later, these systems will also be available in medium-priced cars and especially safety systems also will migrate into the low-priced market segment.

The specific situation of older drivers

Systems for younger or older drivers are not distinguished here because both groups will benefit from them. Older drivers often show decreasing motoric, sensorial and mental capabilities, as shown in figure 3, but they use specific strategies to reduce the load caused by the driving process such as avoiding unknown areas or driving at night or in bad weather conditions. On the other hand, it is also well known that older drivers have an increased rate of fatal accidents compared with middle-aged drivers.

The involvement of older drivers in fatal accidents

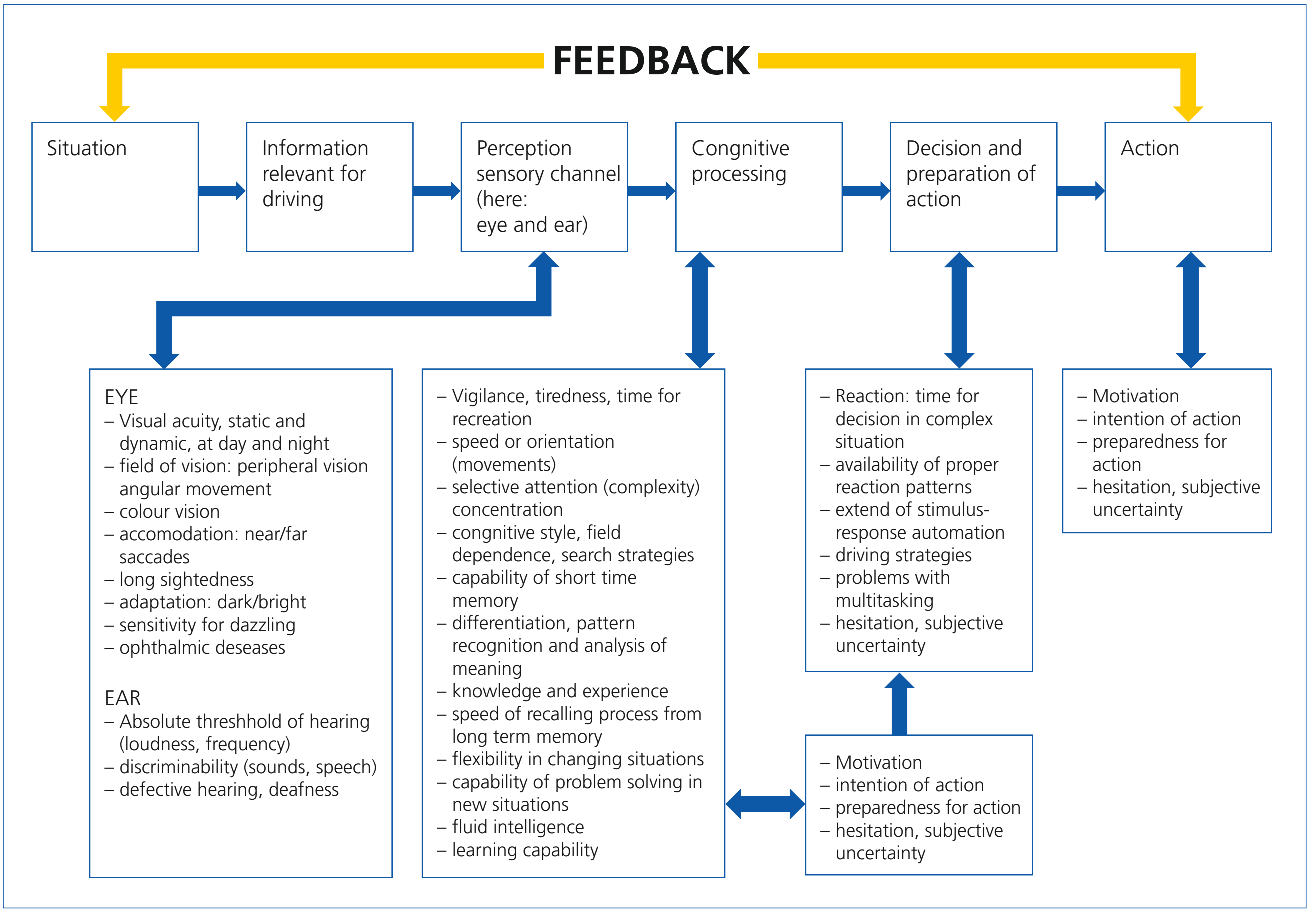
The decrease of capabilities of older drivers also contributes to the fact that older drivers are more often involved in traffic accidents then middle-aged drivers if their number of accidents is related to their traffic exposure. In Germany in 2006, the number of fatalities in the group of >65 years was 7.3 per 100,000 inhabitants compared with 6.2 in the whole population but it was still much lower than 18.4 in the group 18–20 years.

Another fact is that older drivers suffer more from accidents than younger persons due to their decreased muscular strength, the reduced stability of their organs and body structure and the longer time they need to recover.

EU goal of 50 % reduction of fatal accidents

For many years, European governments, private organizations and motor industries have been working hard to make driving more comfortable and, especially, safer. This includes measures concerning infrastructure,

Figure 3: Problems of older drivers in perception, cognition and action (Schlag 2008)



legislation and education and in particular technical improvements to vehicles. This has been reflected in the number of fatalities: in Germany the number reduced from 19.193 in 1970 to 5.091 in 2006. Now the 27 EU states have published the goal of reducing the number of fatal accidents in their countries by 50 % by 2010. Starting from a different base of the number of fatal accidents in different countries, considerable reductions have already been received. But it seems that the goal of <50 % which means about 25,000 fatalities in total in the EU27 will be difficult to reach, especially if only passive safety systems are applied.

Passive measures to reduce fatal accidents

Previously, mainly so-called passive measures have been provided in cars, such as having a body structure containing a safety cell and a crash zone for the driver and passengers, safety belts, head rests, airbags, side-impact protection, and a body structure which is compatible with the structure of potential crash objects including pedestrians.

Active systems benefits of ESC

In future, additional active systems will be introduced. It is expected that they will have a great potential of avoiding accidents or mitigating the impact of an accident. For example, several car manufacturers have found that by introducing electronic stability control systems (ESC), the number of accidents caused by loss of vehicle stability was reduced by 40–50 %.

The goal: an Integrated Safety System

Many other active safety systems are now under development, mainly concerning the longitudinal and lateral control of the vehicle. Communication between one car and another car and from car to infrastructure to exchange information which might not be available in a single car will play a prominent role. These systems will be introduced step by step and in the future they will grow together to form an Integrated Safety System. As a private car is only one participant in traffic, many developments aim at reducing the risk to so-called "vulnerable road users" like cyclists and pedestrians.

Reliability and performance

It should be pointed out that these systems must be highly reliable and must be able to function in even difficult situations. It is unacceptable that drivers have to control their activities generally but have to take over manually if the task becomes difficult. This situation could be even worse than if there were no such assistance system because the driver might be unused to the reality of the present situation while previously driving in assisted mode.

Products and services

The following products were rated by experts on behalf of the EU regarding their potential impact on traffic safety. Their functionality is explained in the appendix (see pages 46f.).

Priority of vehicle-based autonomous systems:

- ESP (Electronic Stability Program);
- blind-spot monitoring;
- adaptive head lights;
- obstacle & collision warning;
- lane-departure warning.

Priority of infrastructure-related systems:

- eCall;
- extended environmental information;
- RTTI (Real-time Travel and Traffic Information);
- dynamic traffic management;
- local danger warning;
- speed alert.

Enabling technologies

The following sensors or systems are crucial for many of the assistance systems referred to in the previous section. Some of them like wheel-speed sensors or steering sensor are available in nearly every car and some of them are available in high-priced cars or will be available also in low-cost cars as soon as an interface between OEM and aftersales systems is established (GPS, Digital Map, GSM):

- Long Range Radar/LIDAR;
- camera with object detection, classification and recognition;
- short-range radar with narrow/wide angle;
- vehicle-to-vehicle communication;
- Wheel speed sensors
- Steering Sensor
- GPS

- GSM
- Digital Map
- traffic detection;
- road weather detection;
- incident detection.

Critical functionalities

The main technical problems are:

- sensor performance and cost;
- fusion of sensor information;
- understanding of situations;
- the provision and maintenance of the infrastructure and business model.

The main human-machine interaction problems are:

- perception of driver state and his or her mental model of the systems and the driving situation;
- perception of driver's intention like overriding the systems action;
- the learning process of the driver;
- the adaptability and adaptiveness of the systems versus stability of the interaction scheme;
- general problems with increasing automation like cooperative/divided action;
- keeping the driver informed: situation awareness, motoric capabilities;
- legislation: clarification of the responsibility of driver, supplier, manufacturer, data provider, sales organization, public authorities.

Legislative problems include:

- the need for clarification of the responsibilities of driver, supplier, manufacturer, data provider, sales organizations and public authorities.

Estimation of market penetration of the safety systems in new cars

The market penetration of these systems varies a lot between different car segments and also between countries. It will also differ if the driver purchases a system on a voluntary basis ("Without implementation support by insurance companies or government")

Table 8: Vehicle-based systems in the "Without implementation support by insurance companies or government" and "implementation support" scenarios

Without implementation support by insurance companies or government	% new cars equipped		
	Short term (2005)	Mid term (2010)	Long term (2020)
ESP	medium	high	high
Blind-spot monitoring	very low	low	high
Adaptive headlights	very low	medium	high
Obstacle & collision warning	very low	low	medium
Lane-departure warning	very low	low	medium

With Implementation support	% new cars equipped		
	Short term (2005)	Mid term (2010)	Long term (2020)
ESP	medium	high	very high
Blind-spot monitoring	very low	medium	high
Adaptive headlights	very low	medium	high
Obstacle & collision warning	very low	medium	high
Lane-departure warning	very low	medium	high

Table 9: Infrastructure-related systems in the "Without implementation support by insurance companies or government" and "implementation support" scenarios

Support by insurance companies or government	% new cars equipped		
	Short term (2005)	**Mid term (2010)**	**Long term (2020)**
eCall	very low	very low	medium
Extended environment info	very low	low	medium
RTTI (Real-time Travel and Traffic Information)	low	medium	high
Dynamic traffic man-agement	low	low	medium
Local danger warning	not applicable	not applicable	not applicable
Speed alert	very low	low	medium

Implementation support	% new cars equipped		
	Short-term (2005)	**Mid-term (2010)**	**Long-term (2020)**
eCall	very low	high	very high
Extended environment info	very low	medium	high
RTTI	low	medium	high
Dynamic traffic management	low	medium	high
Local danger warning	not applicable	not applicable	not applicable
Speed alert	very low	medium	high

or if insurance companies or legislation support the acquisition by benefit schemes or if legislation forces the owner to buy it ("Implementation support").

The level of market penetration or deployment is estimated in the following categories:

- Very high 80 to 100 %
- High 50 to 80 %
- Medium 20 to 50 %
- Low 5 to 20 %
- Very low 0 to 5 %

Additional systems improving comfort and safety

The precise date of market introduction is not given because simple versions of these systems are in most cases already available but only in high-priced cars with limited performance. The introduction of systems with further functionality depends on technical problems – most of them included in the listing above – cost problems or the undefined attribution of responsibility between stakeholders.

Systems with special benefits for older drivers

Older drivers will have the same benefit from these passive and active safety systems as other drivers or other road users. There are also several products or systems which are especially useful for them as they are aimed directly at the deficiencies of this older user group.

Such systems are improving safety, vision and driver-system-interaction:

- tyres with flat running capability (available);
- night-vision systems. Available systems extend the range of vision at night. Advanced versions provide object classification and can therefore warn of relevant objects like pedestrians and cyclists;

- advanced front light (available; systems with extended functionality under development);
- blind-spot detection (available; performance will be improved);
- head-up displays show driving relevant information as a virtual image several metres in front of the car, making it easier for the driver to keep his or her eyes on the road and to see the information that is displayed faster (available; systems with extended field of view and luminance range under development);
- speech input for operation of suitable functions (available; natural dialogue under development);
- improved navigation (matching of navigation hints and external world).

Systems improving driving activities:

- cruise control with extended range (urban area, stop & go, traffic jams);
- detection of driver impairment due to health or drug problems;
- detection of driver inattention (gaze direction) and potentially mental distraction;
- obstacle & collision warning;
- crash mitigation/avoidance systems;
- lane-detection/lane-departure warning/lane-keeping support (available for standard situations; extended functionality under development);
- parking assistance which support or even perform the parking process (informing systems on the market in large quantities; systems with lateral control available by leading OEMs; with lateral and longitudinal control in research vehicles available but still problems with detection of all kinds of obstacles and with legislation/responsibility).

Systems improving comfort and wellbeing:

- identification of driver and passenger for adaptive functions;
- improvement of thermal comfort (individual, faster reaction);
- improvement of acoustic comfort (active noise reduction, intercom between front/back seats);
- physical-training devices;
- in-car illumination adaptable or adaptive to driver/passenger mood.

Description of vehicle-based systems

Active Body Control (ABC)

Active damping and suspension system minimizing car-body roll and pitch motion, adjusting ground clearance according to speed, allowing for a two-stage ride height including load-independent all-round self-levelling.

Adaptive Brake Lights

Triggered by the strengths of brake activation, the rear-brake lights are illuminated in different kinds to indicate emergency braking manoeuvres to the following vehicles.

Adaptive Headlights

The system consists of electromechanical controlled headlights to ensure optimum illumination of the lane on bends. The headlight are directed into the bend as soon as the vehicle begins cornering. A reduction of the glare to the upcoming vehicles is possible. Vehicle speed, yaw-rate and steering wheel angle can be used as input data for the controller of the system.

Alcohol (inter)lock

The system checks the alcohol intoxication of the driver (breath test) when starting the vehicle and prevents the start of the vehicle when the driver is intoxicated. During driving, the system also checks intoxication at specific intervals and takes preventive actions with prewarning.

Automatic Headlight Activation

When activated, the system switches on the headlights automatically when major environmental conditions for the use of headlights are present. The system detects the darkness and the light conditions in the environment.

Blind-spot monitoring

On both sides of a vehicle there are normally some blind spots, if using a mirror for backward view. Different systems can either provide better vision into the blind-spot area or supplemental information regarding an obstacle being there, e.g. by warning signals. Wide-angle side mirrors reduce the blind-spot area. If the mirrors are heated, the vision in bad weather conditions is optimized further. Camera techniques with image processing or radar sensors can give additional information about the situation in the blind spot. An adequate HMI solution is generally a prerequisite for an effective system.

Driver Condition Monitoring
The system monitors the condition of the driver. Parameters being discussed are drowsiness, distraction and inattention.

Dynamic control systems (ESP etc.)
Active Front Steering: The AFS allows – electronically controlled – variable steering transmission and steering force support. Two different inputs overlap, the steering angle from the steering wheel and a correction angle given by a controller through a special gearbox.

Electronic Stability Program (ESP)
Stabilizes the vehicle under all driving conditions and driving situations within the physical limits. Helps to stabilize the vehicle and prevent skidding when cornering or driving off through active brake intervention on one or more wheels and intelligent engine-torque management.

Lane-Departure Warning
Warning given to the driver in order to avoid unintentionally leaving the lane. Video- image processing is the most important technology.

Lane-Keeping Assistant
Active lane-keeping support through additional and perceptible force e. g. in the steering wheel.

Obstacle & Collision Warning
System detects obstacles and gives warnings when collision is imminent. Current solutions with limited performance are a separate feature of Adaptive Cruise Control systems which use information obtained from radar sensors to give visual and acoustic warnings. Future systems will use long-range/near-range radar sensors or LIDAR and video-image processing.

Runflat Indicator/Tyre Pressure Monitoring System
In case of an air loss in a tyre, the systems gives a warning to the driver. With the runflat indicator the system detects the different rotation speed of the tyre which is under-inflated. In case of a tyre-pressure monitoring system, the air pressure in each tyre is directly measured and displayed if necessary.

Vision enhancement Assistance function
With camera techniques like infrared which enhances the perception of pedestrians and other relevant objects at night or in otherwise bad vision conditions.

Description of infrastructure-related systems

Dynamic traffic Management
Influencing traffic flow by influencing speeds, lane use, route choice, merging operations by employing variable message signs (VMS) in order to improve safety and network utilization. Applications include also e. g. ramp control, access control, tunnel control and closure. Three categories of VMS are identified: “regulatory messages”, “danger-warning messages” and “informative messages”. Uses for motorway links, for network situations and for rerouting are also recognized as functionally separate domains.

eCall
The emergency-call gives precise coordinates of the location of an accident to the emergency services which are responsible for providing help. The service is a multi- stakeholder function of public organizations, telecom companies and service providers and car manufacturers.

Event data recorder On-board EDR
Collects certain vehicle parameters to be stored in case of an accident. Those data, before, during and after the event can be used for scientific, technical and legal purposes. Driver awareness of such a system might reduce the number of crashes.

Extended environmental information
Data from different sources of the vehicle e. g. switched-on lights, windscreen wipers on, fog lights on, information from ABS, stability-control systems can be used to create useful information about the environment where the vehicle is driving. They are called extended floating car data, which can – after filtering – provide information about potentially dangerous situations at certain locations. These data are handled like floating car data.

High quality Congestion/Traffic Information/ RTTI (Real Time Travel and Traffic Information)
Information to the driver about traffic congestion and the weather conditions for choosing the most effective route or for preparing to cope with the foreseeable situation ahead on the route. It is vital that traffic information is correct to the time of driving to maintain the credibility of the function. The information is transmitted to in-vehicle and nomadic devices. Short-term forecasting is essential for these systems. Information can be personalized.

Infrastructure-based Warning Systems/Local Danger Warning
Warning systems about dangerous locations or situations do not necessarily have to rely on vehicle-based technology. There are solutions which are only based on the infrastructure to warn the drivers. Local warnings can be given via variable message signs, flashing or electronic beacons or radar-based excessive speed information.

Inter-vehicle hazard warning
To transmit warnings about hazards and extended data to other vehicles in the vicinity, the function uses technologies of wireless local area networks between cars. Vehicles can be used as sender, receiver and relay stations for that information. Other technologies using communication infrastructure can provide local hazard warnings with the help of extended floating car data too.

Speed Alert
The system alerts the driver with audio, visual and/or haptic feedback when the speed exceeds a limit set by the driver or the legal fixed speed limit. The speed limit information is either received from transponders in speed-limit signs or from a digital road map, requiring reliable positioning information.

Traffic sign recognition and alert
The function uses camera technologies and image processing to perceive the traffic signs and give an alert about the content of the sign to the driver. The HMI is an important aspect for the information process.

5.3.3 Public transport

Transport – the ability to get from A to B – is fundamental to independent living. Public transport must be accessible and easy to use, especially for older people, many of whom do not have access to – or do not want to drive – a car. This refers not only to the vehicles, but also to the transport infrastructure such as stations, airports and ticket machines and on-street approaches. Pre-trip planning should be quick and simple, and on-trip planning should be available so that people can make adjustments to their journey for whatever reason (social, emergency or change of plan).

There are many different modes of public transport (bus, train, metro/subway, air, taxi, ferry), and it is vital that integration of the services (usually a political issue) and integration of information (usually a business issue) takes place where possible. Such measures enhance the convenience and simplicity of using public transport, which in turn (and in combination with measures such as travel training) increases user confidence.

The aim is to provide a seamless journey, with full information about facilities, travel times, and any potential barriers to accessibility. Provision of a comprehensive multi-modal public-transport system that is easy and reliable to use is a great aid to social cohesion as it provides better access to services and better support for local communities.

Summary of travel information technologies

Travel information (e. g. timetables, amenity information and physical access information):

- use of web-based technologies to supply on-trip information to mobile devices;
- improved information in vehicles, at stations, etc.;
- information delivered in a variety of formats to suit the individual;
- information delivered at home;
- real-time information with a short response time.

Scenario 5: ***Public Transport***

Pete is 70 years old. Due to a worsening eye condition, he finally gave up driving two years ago, but since then has found it difficult to maintain his previous social life. After several decades of relying on the car, he feels he has "forgotten" how to use public transport. Moreover, he has been put off by stories of complex fare structures, unreliability and anti-social behaviour. He has lost his confidence in public transport. However, tonight Pete is due to attend a concert at the SAGE venue in Newcastle, and he decides to set himself a challenge: to attend by public transport.

First of all, Pete carries out some pre-trip planning. Using the Internet he accesses details of the railway timetable; he needs to take the train in order to travel from his suburban town to the city centre (Central station). He knows that Central Station isn't very close to his final destination, but from his research he discovers that the "Quaylink"' bus departs from just outside the Central station and takes him to the quayside area and so within walking distance of the SAGE venue.

Reassured by this pre-trip planning, Pete sets off for his local station. His first step is to purchase his ticket using the smart card that he originally obtained for use in his local library, but which also has a transport application through an arrangement with the local transport operator. The smart card automatically deducts the cost of the ticket from Pete's smart card balance. By swiping his NFC-enabled mobile phone against an information point, he receives an audio message that informs him of the time of the first available train and its time of arrival at Central station, plus additional information about the frequency of the train service.

On his journey, Pete realizes he will travel through the village where his friend Graham lives. Having not seen Graham for over a year he decides it would be a great idea to stop off briefly for a cup of tea. He calls Graham on his mobile and arranges to meet at the station café.

After an engrossing conversation, Pete realizes he risks being late for the concert. His fear is worsened by an automatic alarm on his mobile phone that is triggered when he misses the next train. Because the system knows Pete's current location and the time, it notifies him that there is not another train for half an hour, but the number X11 bus runs from the adjacent bus station in ten minutes. This service will arrive at the main railway station in time for him to connect to the Quaylink service. All this information is relayed to him in audio form because of his poor eyesight. On boarding the bus, Pete uses his smart card to pay the fare. Meanwhile the onboard information system informs him that his bus will arrive at bus stop R, whilst the Quaylink service will depart from bus stop T within five minutes of his arrival. He is advised that the walk between the two stops should take only two minutes. Pete discovers that his train ticket will also be valid on the Quaylink bus due to an arrangement between the operators.

Suddenly aware that he has never visited the SAGE before, he remembers comments from friends about how large the venue is and how many stairs there are to negotiate. He decides to find out more about the physical access of the building by accessing a point of interest database on his mobile phone. Reassured that there are plenty of lifts – and assistance if required – he goes ahead and books a beer at the bar for the interval using the sms service implemented by the venue.

Pete enjoys the show and feels that he will be much more comfortable using public transport in the future due to the assistance, convenience and reassurance that technology was able to provide for him.

Brief description of technologies

Many of the same technologies that are beneficial to pedestrians (see section 5.3.1.1) are also beneficial to public-transport users, although they might use different functionality and perform different tasks:

Mobile-phone technology

GPRS and 3G mobile communications are now commonplace. It is likely that 4G (fourth generation) systems will be available in the near future, with much more emphasis on design and functionality that is appropriate for older and disabled users. Facilities like synthetic speech output, more accurate positioning, high-quality digital maps and location-based information will become widely available.

Web-based technologies

Much functionality (especially travel information) requires use of web-based technologies. The current focus is on the gradual standardization/harmonization of web-based services so that larger, more complete information databases are made available, transforming web-services from static information to distributed computing systems. The aim is to provide seamless, multi-modal travel information. Journey planners are commonplace today, as are online ticket purchasing opportunities. Personalized services are becoming available whereby only relevant information is supplied and in an appropriate accessible format.

Smart cards

Smart cards have been around for several years now. However, until recently they were not widely used in transport. Smart cards enable customization of service delivery to individuals based on the user's needs, for example how a person prefers to use a ticket machine. They are commonly used to store value (as cash replacements) and are therefore used in ticketing systems e.g. Oyster card in London. Smart-card schemes now exist throughout Europe for transport and other applications (In the Netherlands a nation wide public transport smart card is introduced). Future developments will include wider use of vicinity cards (up to two metres range from the reader), and an increase in the amount of information carried.

Verbal communication with information systems

This future technology will become available when computers are able to translate human speech. In other words, people will be able to communicate verbally with vehicles or information screens.

Intelligent-agent technology

Intelligent-agent technologies can be used to create ambient intelligent infrastructures or environments, in which people are immersed in networks of invisible but powerful communicating technologies that can adapt themselves to the needs of individuals, and can serve them by taking instruction and performing tasks. Agents are embedded in everyday objects e.g. people, vehicles, infrastructure and buildings. The networks can provide personalized services and information based on needs, context, habit, etc. Hand-held devices or personal wearable devices (e.g. watches and bracelets) would communicate with wall-mounted displays. The networks are unobtrusive, personalized, adaptive, anticipatory and most importantly they are designed to respond to the needs of individuals. A "pervasive" intelligent environment can support ageing populations providing independence and easy seamless access to services.

Roadmap 8: Public transport

Innovative technology	Short term (2010)	Mid term (2015)	Long term (2020)
4G mobile technology	Mobile devices designed with older people in mind e.g. simplified layout, large keypad and screen, availability of alternative output modes		
Web services	More personalized services available	Distributed computing systems linking different content providers	
Smart cards	Largely mature technology in 2008. More deployed systems in 2010	Greater use of vicinity cards. More applications on cards. Cards store large amounts of data	
Human-computer verbal interaction		Technology mature	Use in transport domain has begun
Ambient intelligent environments		Deployment of systems. Systems and people communicate via personal wearable devices (PWD) or smart phone/hand-held device	

6 AAL@work

Work is one of the most important activities related to the daily life of each individual. The importance of active participation in life for people is not only related to their earning money in a paid job but also to the expression of their own personality which can also be expressed in voluntary work. Each adult normally spends about six to eight hours working every day (a quarter to a third of the day). To carry out his or her work, each person has to use their physical and cognitive abilities and to interact with other people. The importance of active participation in the lives of other people is demonstrated by the fact that many studies have shown that after retirement, many people decline rapidly in welfare and both physical and cognitive health, which, in most cases, leads to premature death. The significance of these comments shows it is fundamental that all societies should guarantee the right to work to all people, not only to healthy people but also to the elderly and people with disabilities. Unfortunately these rights are not always respected because of the inadequacy of working situations which are often the real barriers to employment of elderly people and people with disabilities. This deficiency has negative effects not only on the lives of these people but also on the richness and welfare of society as a whole, which is unable to benefit from the skills, abilities and experiences of elderly and disabled people.

6.1 Background

Demographic change, the increase in average life expectancy and lower birth rates in the population of Europe have important consequences for the supply of labour in Europe. In the next few years, EU countries will have to face up to the problems of an ageing workforce, while in the long term they will have to face restrictions on the labour supply caused by the shrinking working age population (European Commission 2006). Because of this ageing workforce and in order to reduce the waste of human resources represented by premature retirement, the European Union has already adopted some initiatives to delay the age at which workers leave the labour market and to increase the employment rate of older workers. In particular, the conclusions of the Stockholm and Barcelona European Council, which confirmed the importance of increasing the rate of activity of older people, has been embedded in the European Employment Strategy to "create more and better jobs". The general aim is to increase participation in the labour market for all groups of workers and also to reduce inequalities including those relating to age. The new employment strategy explicitly includes promoting active ageing in the sense of increasing participation in the labour force, working for additional years and remaining at work longer (European Commission 2006).

In some EU Member States, many of those in the 45–54 age group are still very much part of the labour market but, for the majority of them, skills development and support either in the workplace or to help them return to the workplace are needed. From the age of 55 years onwards, the nature of work participation often changes and, for those in pre-retirement years, factors relating to pension provision and to gradual retirement and flexibility in the workplace are more relevant.

6.1.1 Work ability

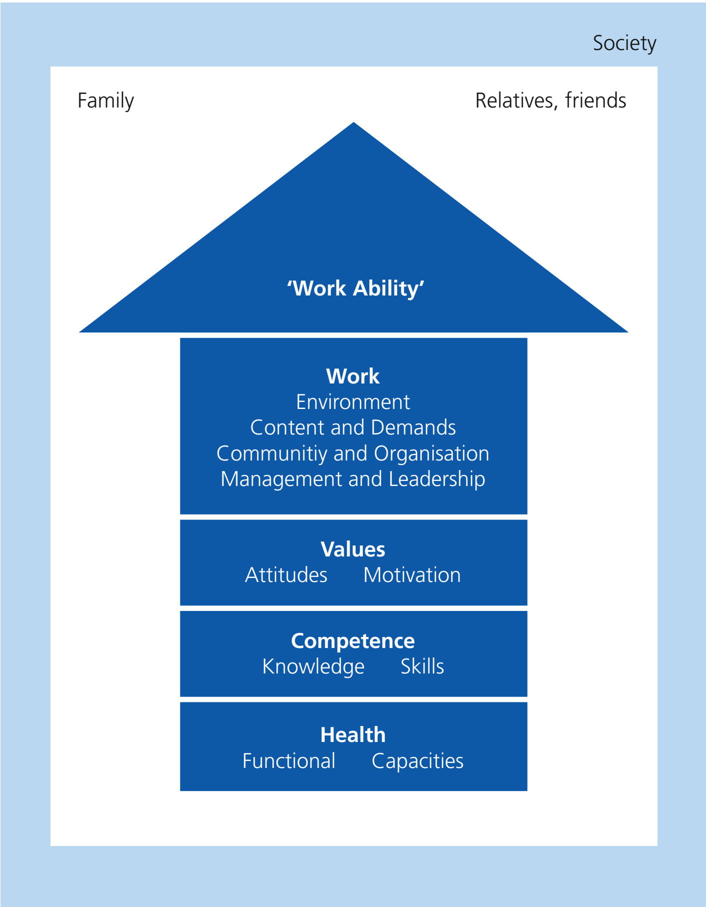
Working conditions and "Work ability" are important factors from the point of view of age, to combine ageing and work successfully. This joint purpose mainly concerns individual workers, but it is also closely connected with the support of enterprises, other organizations and society in general. The health and functional ability of a person at work decline with increasing age, but the mental development nevertheless creates a good basis to succeed and develop in a person's working life. For example, the ability to learn does not depend on age, but learning strategies change with ageing. Thus it is important to promote the health, working ability and wellbeing of ageing workers.

The "work ability" is well explained in different dimensions, using the concept of "the house of work ability". The "house of work ability" has four floors. The three lowest floors depict human resources, and the fourth floor covers all the dimensions of work.

The floors of the house comprise the health and functional capacity (physical, mental, and social functioning), the dimensions of competence, the values, attitudes and motivation, and management, organization and environment. The "work ability" concept suggests that work itself should also be improved for the workers, not only the people improved for work.

In this context, AAL applications and functionality play a fundamental role, above all if they are related to elderly people and employees with disabilities to give support for active ageing, including appropriate working conditions, occupational health status and adequate incentives to work longer, adopting flexible retirement schemes and discouraging early retirement.

Figure 4: The house of work ability (European Commission 2006)



6.1.2 Employers' attitudes to older workers

At a time when populations are ageing, the economic cost of age discrimination is set to grow. Valuable skills in the workplace are also being lost through early retirement or the unemployment of older workers. Employers should seek to reflect the diversity of age in the workplace, so achieving a better mix of younger and older workers.

The main challenge is to change the attitudes of employers and their expectations of their ageing workers. This will require education and the raising of awareness of the needs of older workers as well as the dissemination of models of good practice that have been successfully introduced elsewhere.

6.1.3 Training in and for the workplace

Employers do not always see training as an investment. However, their attitude to the training of older workers is crucially important. As well as developing a more favourable attitude by employers to training, there is a need for workers themselves to view training in a positive light. Workers often exclude themselves from training opportunities because of a lack of confidence in their ability to participate or they see it as something forced on them by management. Special attention needs to be paid to tackling such issues.

Many workers, particularly those in low-skilled jobs, require up-skilling and re-skilling to adapt to changes in the workplace, especially in terms of IT. Equally, those who are currently marginalized need relevant skills to access employment. In addition to the provision of training for those in work, a range of interventions is also required to help those who are at present outside the labour force, to support their re-integration.

6.1.4 Issues of work-life balance

Flexibility is needed to allow workers in mid-life to move from full-time employment to more flexible arrangements, including reduced hours or fewer re-

Scenario 6:	***Marie's Working Day***

Marie, aged 60, is informed via an interactive screen as she was about to leave for the office that her elderly mother has had a fall. The screen also alerts her to the fact that the ambulance has been called and that they are arriving at her home. The emergency services assure her via interactive mobile that she is OK and has minor injuries. The doctor advises that her mother should not be left alone for the following 48 hours. Marie's mother will be monitored with a help of seamless technology and by nurses throughout her recovery.

Marie is now able to go to work without any concerns. Her boss and the transport services had been alerted via mobile messaging service that she was running late. Due to her reduced mobility, an accessible public transport service is now waiting outside to take her to work.

As she walks through her office door, a sensor automatically notes and logs her time of arrival, adjusting the computer, desk and chair according to her ergonomic needs.

As she sits at her desk, the intelligent computer system/software indicates her top priorities for that day. Coffee is brought to her by "robo-rob" at the times that she has pre-set.

Marie has arthritis, so voice recognition, touch screen and an automatic typing system have been installed in her computer to allow her to compose and send email messages. A video-recoding image system is also available should she wish to make more personalized messages. She can communicate with her co-workers via accessible networks on her computer screen.

The window automatically opens and shuts and room temperature is regulated according to Marie's body temperature and her preference for warmth.

As it is now time for lunch, she can choose whether to walk to the office canteen, use an intelligent transport system to take her to the local restaurants or call on the services of "robo-rob" for a sandwich according to her dietary requirements.

The day has now come to an end and as she leaves the office, all the systems are automatically switched off in response to her voice. The office automatically locks behind her and her time of departure is registered by the sensor.

sponsibilities. This is important in a number of respects. Firstly, family obligations may change for some older people who may have responsibilities to care for ageing parents/partners and young grandchildren and who may seek to combine their work and their caring activities more flexibly. Secondly, older workers may be encouraged to remain in the workforce for longer where they have opportunities to work fewer hours or do less strenuous work.

For variations in work-life balance to become a reality for older workers, a shift in attitudes on the part of employers, regulatory authorities, trade unions and indeed workers themselves is required. This could be facilitated through a greater sharing and more dissemination of good practice.

6.2 Needs of older workers in the workplace

Specific issues that need to be considered with regard to older workers are healthy ageing and work, combining work with caring responsibilities and quality of life, e.g. choices regarding free time and working time. Particular areas to be considered include the provision of flexible working arrangements, the provision of gradual retirement options and opportunities for downshifting. Ergonomics, health and safety in the workplace and opportunities for training, including concerning IT, are also key factors to be taken account of when considering the needs of older workers in the workplace.

Employability in old age cannot be maintained by work alone, but demands initiatives in various areas of action:

- health;
- continuous training;
- work design
- leadership style.

The value of the job for each individual is recognized from a legal point of view by all countries in their constitutions and in their legislation. In order to assure the possibility of working to every person, it is necessary to:

- consider appropriate plans of job activities;
- design accessible working environments;
- provide convenient supports and aids to work.

AAL is a perfect approach to adopt in order to enable every person to work. Most solutions related to AAL can:

- facilitate access to workstations;
- assure the right working conditions related to the environment and personal situations;
- support work activities;
- prevent and reduce the prevalence of work-related diseases;
- supply tools for tele-working;
- provide safety and health regulation for employees.

6.3 Access to working space

The working environment should be designed to be accessible by individuals with motor deficiencies and who need to use assistive aids to move (e. g. a stick or wheelchair). This should concern access both to buildings and various rooms and spaces and to workstations.

In fact, international standards and laws of each country define some spatial requirements and conditions that need to be adopted in the design of buildings and of workstations to guarantee access to every kind of employee.

However, some of these rules are dated and do not concern actual needs and requirements. Further, these rules are often not respected and control of these parameters is not always carried out appropriately. Every country should undertake to periodically revise their existing rules and update them according to actual needs and requirements, to seek to source innovative materials and technologies and therefore to see results in the research conducted in this field.

This analysis should hold due consideration for the AAL approach and its innovative vision of working space.

Experts in AAL, design, architecture and occupational medicine should collaborate to study and develop new architectural and technological solutions to increase accessibility for disabled and old people in the working environment and to improve the working conditions of employees in order to reduce the onset of disease attributable to the work and to improve workers' health. They should then define new rules for regulating the design of work spaces and periodi-

Scenario 7: Interaction of Wheelchair with Working Space

Tom is 60 years old, works in a post office and is quadriplegic. He uses a smart wheelchair to move about in his working space. The post office where he works is an AAL environment: the building recognizes the position of each piece of furniture, each object and each person. When Tom arrives at the entrance to the post office, his smart wheelchair shows him the map of the post office on its control screen: Tom specifies to which room he would like to go. Through the wireless system, the wheelchair starts to interact with the control core of the post office to plan the pathway to move along in order to reach the place Tom has selected. The control core sends real-time information about the position of furniture, steps, obstacles and people in the working space to the wheelchair and so it plans the safest and quickest path to follow. Sensors placed in the post office recognize the presence of the wheelchair and sends information to the control core, elaborating the data of the sensors and the pathway planned by the wheelchair, actuating the opening of doors, lifts and other tools. Thanks to the smart environment and interaction with the wheelchair, Tom can arrive at his workstation easily and safely.

Scenario 8:	***Smart Workstation***

Mario is 70 years old and is a skilled worker who works in wood and inlays objects. He is skilled at restoring old small wooden objects. He is restoring a wooden jewel box for a museum. He follows directions given to him by the director of the museum to complete his task.

Mario has a smart workstation at which he carries out his activities. This workstation is made up of a desk with two sections: one with a PC (monitor, case, mouse, keyboard and webcam) and the other with tools to work in wood. Mario's workstation is able to recognize if he is working with the computer or in the other section:

- *if Mario is at the PC, the lighting of the workstation is changed automatically to facilitate Mario's working; he is presbyopic. There is also a set of sensors that recognize the distance between Mario's and the desk (during the day Mario often changes the height of his chair) and the height of the monitor is automatitically varied in order to give Mario the best visibility;*
- *if Mario is working with instruments to inlay the wood, the smart environment recognizes which tool he is using and varies the light accordingly; the change of air is also automatically increased because he works with chemical agents and produces wood shavings and dust.*

With this smart workstation, he can simultaneously work on the old wooden jewel box and follow the directions given to him by the director of the museum. Mario is also able to use his computer with special software and interfaces that facilitate access and control of the PC.

Thanks to this special workstation and easy use of the computer, Mario is able to remain in touch with many international experts who contact him seeking his advice. He is also able to teach remotely some lessons about restoring wooden objects to students at an art school.

cally should verify and update them. To have a clearer idea of the use of AAL in the working environment to increase access to it, some examples of possible scenarios are now described.

6.4 Assuring environmental working conditions

Besides the rules that regulate the architecture of the working environment, many international standards and laws define parameters related to other environmental factors such as temperature, light and change of air, the position of work-tools like monitors, chairs and desks. These elements have a strong impact on the work performance of employees and on the preservation of their health and welfare. Unfortunately, these parameters are often not monitored and optimized and this has negative consequences.

These remarks are even more valid when older and disabled workers are considered. AAL technological solutions can support employees in guaranteeing a constant correspondence of these elements to the levels fixed by international standards and rules. Smart working environments (SWEs) should have sensors that measure ambient parameters such as temperature and humidity, and, according to the measured data, vary the air-conditioning in order to fall within the optimal range of parameters.

SWEs are also able to recognize how many people are present in the environment and which instruments are switched on. The control core of the SWE should apply this information to set the change of air in the surroundings.

Furthermore, AAL solutions can be adopted to regulate the light at the workstation of each employee. To keep workers from developing problems to their sight and tiredness in their eyes, regulating the light of each workstation is essential. SWEs can support this task, based on data of the natural light in the environment, the work activities that need to be carried out and the worker's visual ability. The control core can then modify the brightness of lamps and the covering of windows and skylights by, for example, varying the opening and closing of curtains.

Thanks to AAL technology, the workstation can also be smart and capable of changing the characteristics and positions of its components to improve the quality of working environments and therefore of workers' performances. An example of smart AAL workstation follows.

6.5 Support for working

To allow individuals with disabilities to work and elderly people to extend their employment, technological instruments and working environments should be designed according to the characteristics and needs of these people.

In particular, adopting the AAL approach, working instruments and the workstation environment should be interactive, facilitating the exchange of information about the tasks that need to be undertaken and the user's abilities and the ambient conditions in order to support workers in activities of their job and to improve the quality of their work.

One of the most common problems that elderly people and people who are not self-sufficient have in their jobs is how to use computers. Computers are powerful tools that are now in widespread use in most occupations. They have many applications including typing, defining, organizing, communicating and solving problems. Their use has changed the approach to work activities over the last 20 years. To be able to use computers, however, certain motor skills, abilities and knowledge are required.

These factors are often barriers not only to the use of PC by older people and those who are not self-sufficient but also to their employment. This has a detrimental effect not only on individuals but also on the profitability of the firm that needs to develop the experience and skills of these potential workers.

For this reason, technological and software interfaces should be designed to facilitate the ability of elderly people and non-self-sufficient people to use computers. For example, computers should interact with workers using their language and explaining to them how they could easily carry out work tasks (see Scenario).

Besides the use of a computer, the most common problem faced by elderly people and those not self-sufficient is work concerned with moving objects.

People with limitations and older people often suffer from weaknesses in their upper and lower limbs. They therefore have difficulties in moving objects a long distance, in standing up for long time and in moving and carrying heavy objects. These motor limitations can sometimes cause dismissal from employment or retirement or can be the reason for not employing a potential worker.

Scenario 9: Smart Computer Interface

Helen is 63 years old and is a psychologist. She is a professional and works in her office. She actually works in the Human Resources department of a company. The managers of the firm asked her to create a database of employees' skills, aptitudes and ambitions. She has therefore organized a meeting with workers and she enters the information she obtains onto the database.

- *Normally she doesn't use PC in her work but she uses a special computer workstation for this task.*
- *The smart PC is able to recognize who is using it thanks to its biometrical system: access to the database on the employees is allowed only to Helen and some managers.*

When the workstation identifies Helen, it adopts working conditions suited for Helen. She is unable to use a normal keyboard and suffers from arthritis in her finger joints; she also has carpal-tunnel syndrome. She therefore uses two different interfaces to use the PC: a tablet keyboard and a voice keyboard. When Helen uses the first system, she writes her notes using a special pen directly on the tablet keyboard: the tool recognizes Helen's calligraphy and compiles the words in text files. If Helen feels tired in her hands and she prefers not to grip the special pen, she uses the second system, a voice keyboard. This recognizes her voice and reports the words she pronounces onto text files in the database. The voice keyboard is smart because it recognizes and transcribes only the words spoken by Helen, not by other employees in the Human Resources office; it is also able to distinguish vocal commands from sentences dictated.

Scenario 10: Assistant Robot

José is 62 years old. He is an electronic technician and works in the Repairs Office of a company that makes microwave ovens.

His business has adopted the AAL approach for organizing documents, goods and working activities: its environment is full of sensors that constantly monitor and recognize the positions of workers, documents and objects. A smart assistant robot has also been adopted for moving objects.

José has two workstations available to him: one with a PC and the other with mechanical and electrical tools to work on microwave ovens that are sent to him for repair. The tools include an electric soldering iron, screwdrivers and an oscilloscope

When a broken oven arrives at the warehouse , a message is sent to José and he calls the smart assistant robot to move the system from the warehouse to his office.

Thanks to sensors set on the smart assistant robot and in its surroundings, the robot is able to move safely around in the company space, recognizing the presence of people and avoiding any obstacles in its path.

When the robot arrives in José's office, he sets up a code for the object to be taken <=?>: the robot examines wirelessly the core server of the AAL environment to find out the actual position of the broken oven. With this information, the assistant robot moves to a certain location, and uses its robotic arms to grasp the oven and take it back to José's office with the system to be repaired, leaving it on his workstation.

In order to repair the system, José needs to mend the electric circuits so asks the robot to recover the dossier from the archives (which is at the last set of stairs of the building), setting its code.

The robot moves to the archives; the smart filing cabinet recognizes the presence of the robot, issues the request for the dossier and provides the file to the robot. The robot then comes back to José: he can now work and repair the oven.

When José finishes his work, he instructs the assistant robot to move the microwave oven from his office to the warehouse in order for it to be sent back to its owners.

In order to overcome this problem, automation, mechanization and robotics can suggest effective technological solutions that can support elderly people and extend their employment at their work place. Technological systems can be developed to help in the movement of objects, so aiding elderly workers in their tasks. However, these systems should be safe and not damage the environment or injure employees. For this reason they should be designed to recognize the presence of obstacles and people and to plan the best pathway to avoid such obstacles. This characteristic can be developed not only by setting sensors on a robot but also by setting them in the surrounding environment and designing a constant exchange of information and interaction among them. An example of this idea in described in the next scenario.

6.6 Prevention of diseases and injuries

The preservation of health is one of the most important rights that workers expect to be upheld. Every kind of work has its own set of risk factors that can affect the health of employees and potentially lead to the onset of particular diseases. For example, jobs carried out at video terminal (computer, monitors, etc.) often cause workers to have problems in their sight, arm and hand joints, or back and blood disorders. Manual work that involves the movement of heavy loads can lead to the worsening of hernias, problems to joints and bones, muscular diseases; tasks carried out in noisy environments cause problems to hearing.

To avoid such injuries or disease workers should work in the best and safest conditions, using convenient instruments and carrying out periodical checks to determine their state of health.

Unfortunately, these preventive actions are not always carried out properly (because of costs related to prevention systems and actions, oversight or carelessness) and this causes damages both to employees' health and also to the welfare of the companies and institutions involved.

In order to protect all workers – healthy, elderly people and people with limitations – specific, effective and up-to-date prevention plans should be developed by each firm and office and countries should control the implementation of these plans.

International standards for designing such prevention plans should be defined, developed and maintained by a multidisciplinary team of experts of various fields related to the prevention of diseases and injuries at work. Such a team should include experts in for example occupational medicine, technology, law, economics, sociology and architecture.

New technologies and solutions should also be developed to carry out preventive action.

In particular, adopting the AAL approach, working environments and instruments can be conceived and designed to monitor the state of workers' health, to maintain the best environmental conditions, to recognize potentially dangerous events and to promptly

Scenario 11: Working Environment and Workers' Health Monitoring

Antoine is 64 years old and he is working in the painting sector of a business that produces furniture for offices. He suffers from diabetes mellitus.

His company has adopted an innovative AAL solution to monitor the health status of its workers that is based on various environmental sensors which measure surrounding parameters. These parameters include temperature, humidity, level of foul air and excessive presence of chemical agents in the air. Smart watches are worn by company employees, which measure temperature, pulse and blood oxygenation of the specific subject and identify each worker and his or her position in the working environment.

In Antoine's case, the company has provided him with a specific smart watch that also measures the glucose level present in his blood.

When Antoine starts to paint an office desk, the environmental processor recognizes:

1) the specific tool he is using for painting;
2) his location in the sector;
3) the level of paint particles in the air.

According to the last parameter, the processor directs the activation of the air conditioner to change the air in the sector.

Sometimes, when the level of paint particles in the air is far too high and the air conditioner is not effective enough, the processor alerts the manager of the sector who then directs the employees to stop work, giving them a break so that they can leave that area allowing enough time for the air conditioner to change the air.

Further, in Antoine's case, if his smart watch measures a level of glucose that is beyond the optimal range, the system sends an alert to him and to his manager in order to remind him that he must have a break to take insulin.

The parameters related to temperature, pulse and blood oxygenation of Antoine and his colleagues combined with data about the tasks they are carrying out and the duration of these activities are information that is used to recognize the actual welfare of each worker, agitation states <simplify that?>and reduction of attention level. If any of these events is identified in a worker, his or her manager is alerted to monitor the status of the employee and take any necessary action.

Thanks to this smart working environmental systems, preventive actions to support workers like Antoine are able to preserve their state of health. In this way, the onset of diseases among employees of the company is greatly reduced and the quality and productivity of workers are guaranteed with consequent increase in the company's efficiency and profitability..

alert staff who are responsible in the company or office of cases that need attention.

Smart wireless sensor networks, which monitor instruments, workers andsurrounding environments, and advanced processing algorithms of data events allow the recognition of health status, working tasks being carried out and any potentially detrimental conditions. According to these results, smart systems can take preventive action and advise and support actions and alert the people responsible for workers' welfare.

To clarify this theory, an example of a working scenario based on AAL solutions for the preservation of employees' health is now described.

6.7 Safety and health regulations

The right to work, safety and welfare are principles that are internationally recognized and accepted. Despite this, statistics show that the prevalence of work injuries and occupational disease is very high: every year in the EU alone there are 150,000 deaths caused by work-related accidents (8,900) and occupational diseases (142,000) (*European Agency for Safety and Health at Work,* 2008).

This problem has such high relevance that both individual countries and international organizations and institutions have developed laws, regulations and agencies to control and prevent damage to health of workers.

6.7.1 In Europe

In 1996, the EU set up the *European Agency for Safety and Health at Work* (European Agency for Safety and Health at Work. 2008) which aims to make Europe's workplaces safer, healthier and more productive by bringing together and sharing knowledge and information to promote a culture of risk prevention. The Agency's role is mainly to collect and analyse technical, scientific and economic information on health and safety at work in the Member States, to contribute to the development of Community action programmes and strategies relating to the protection of safety and health at work (without prejudice to the Commission's sphere of competence), and to ensure that the information disseminated is easily understood by the end-users.

The EU has also developed guidelines and directives related to health and safety at work:

- Council Directive 89/391/EEC: introduction of measures to encourage improvements in the safety and health of workers at work;
- Council Directive 89/654/EEC: minimum safety and health requirements for the workplace;
- Council Directive 89/655/EEC: minimum safety and health requirements for the use of work equipment by workers at work;
- Council Directive 89/656/EEC: minimum health and safety requirements for the use by workers of personal protective equipment in the workplace;
- Council Directive 90/269/EEC: minimum health and safety requirements for the manual handling of loads where there is a risk particularly of back injury to workers;
- Council Directive 90/270/EEC: minimum safety and health requirements for work with display screen equipment;
- Guidance on Work-Related Stress;
- Council Directive 92/85/EEC: guidelines on the assessment of the chemical, physical and biological agents and industrial processes considered hazardous for the safety or health of pregnant workers and workers who have recently given birth or are breastfeeding;
- Council Directive 1999/92/EC: minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres.

The European Commission undertakes to verify the practical implementation of the Council Directives for the health and safety at work by member states of the EU and the definition of others directives relative to the individual states (see COM/2004/0062 final).

Even if significant work in this area has been already carried out, the EU and Member States should continue to work hard in order to:

1) update European and national directives and laws according to actual economical contexts and to the conditions and needs of workers;
2) study prevention plans for workers, based on actual scientific and technological resources;
3) carry out controls and verifications of the applications of directives on the health and safety of workers and of precautionary and safety measure in public and private work environments.

6.7.2 In the world

In order to have an idea of the health and safety conditions of workers worldwide and of the regulations related to this subject that have been adopted in countries in other continents, it is possible to refer to the International Labour Organization (ILO) (The International Labour Organization 2008).

The ILO is the tripartite United Nations agency, founded in 1919, that brings together governments, employers and workers of its member states in common action to promote decent work throughout the world. The ILO is devoted to advancing opportunities for women and men to obtain decent and productive work in conditions of freedom, equity, security and human dignity. Its main aims are to promote rights at work, encourage decent employment opportunities, enhance social protection and strengthen dialogue in handling work-related issues.

Since 1919, the ILO has produced different papers related to occupational health and safety. One of them, related to health and safety of the employees, was drawn up in 1981 (Occupational Safety and Health Convention) (The ILO Convention No. 155. 1981). This document proves the interest and necessity of the international community to define rules and to adopt strategies to guarantee and support workers' welfare and safety. Besides defining strategies and indications for the welfare and safety at work, the ILO is responsible for verifying and supervising the application of the conventions and recommendations in all the world.

7 Enabling technologies and functions

In this chapter the following enabling technologies are presented in detail: sensing, reasoning, acting, interacting (interfaces) and communicating.

7.1 Sensing

One universally accepted definition of "sensor" does not exist in the literature, although several attempts have been made to come to such a definition.

The terms "sensor" and "transducer" have often been used as synonyms. The American National Standards Institute (ANSI) standard MC6.1 defines a transducer as "a device which provides a usable output in response to a specific measurand" (Instrument Society of America, 1975). An output is defined as an "electrical quantity", and a measurand is ''a physical quantity, property, or condition which is measured". In 1975, the ANSI standard stated that "transducer" was preferred to "sensor", However, scientific literature has not generally adopted the ANSI definitions, and thus currently "sensor" is the most commonly used term (NRC,1995). Source: NRC, 1995

The following definitions seem to be generally accepted in technical and scientific literature.

Sensor element:

The fundamental transduction mechanism (e.g. a material) that converts one form of energy into another. Some sensors may incorporate more than one sensor element (e.g. a compound sensor).

Sensor:

A sensor element including its physical packaging, conditioning electronics and external connections (e.g. electrical or optical).

"Smart" sensor:

A sensor and its assorted signal processing hardware (analog or digital) with the processing either in or on the same package or discrete from the sensor itself.

Roadmaps on AAL mainly relate to the device/system/service level, having lower levels of technology (including sensors) as "enabling technologies". In this document, we will therefore not (or only very rarely) discuss "sensors", but we will more often refer to "smart sensors" or "sensing nodes" as significant elements of AAL systems and applications.

We will also refer in some cases to the evolution trends of new "sensor elements" (often also called "transducers", but we will avoid this, not to produce conflict with the ANSI definition mentioned above.)

In AAL applications, sensing is expected to take place in anything and anywhere: in- or on-body, in- or on-appliances or in the environment (home, outdoors, in vehicles, public spaces, etc.)

A survey conducted in the framework of the iNEMI Roadmaps (International Electronics Manufacturing Initiative) forecasts sensor technology issues and trends up to 2015. The report was based on responses to a survey by 174 international experts from academia, research institutes and industry. Their results included a ranking of present and future market importance of the principal sensor types and technologies. One of the most noteworthy trends is the importance of micro-electromechanical systems (MEMS) technologies for both present and future markets. The survey also indicates that biological/biochemical sensors and optical sensors will attain greater prominence in the marketplace over the coming ten years. Respondents to the survey ranked the potential global market volume on a list of topics presented as statements describing specific attributes of various sensor technologies. The top ten topics from this ranking were as follows:

1) MEMS-based miniaturized and low-cost sensor and actuator systems.
2) DNA-sensors for measuring genetic diseases and/or genetically modified food.
3) Sensor communication systems based on advanced mobile communication protocols.
4) Low-cost (less than 5 euros/unit) silicon MEMS sensors for food and health care applications.
5) Miniaturized energy supplies for integration in self-contained sensors.
6) Lab-on-a-chip sensing in food safety and medical diagnostics (e.g. capillary separation and optical detection).
7) Motion-control and collision-avoidance systems employing high frequency (>50 GHz) microwave sensors.
8) Ultra-small biosensors and actuators with wireless communication for use with implanted components in medical or other applications.
9) Biosensors for various applications.
10) MEMS devices based on polymer materials.

The Danish study also drew some conclusions regarding the perceived future market volume in relation to the perceived technological feasibility. Some of the key points include:

- the market volume for ultra-small biosensors and self-contained sensors integrating advanced polymer and miniaturized energy technologies is much larger than the technological feasibility;
- some sensor technologies are perceived as having limited future market potential despite having a high level of technological know-how. These include fibre-optic sensors, radio-frequency sensing, eddy current and ultrasound for use in manufacturing systems and nuclear based sensors;
- biosensors occupy a somewhat ambiguous position, having an overall high perceived market potential hindered in some cases by a low level of technological know-how. Specifically highlighted in this context were implantable biosensors, those which substitute for human sensing functions and those employing living organisms.

7.1.1 Sensors for environment, safety and security

Gas sensors

In the scenario of advanced sensors for environment, security and safety, gas sensors probably represent the most relevant class. In general, gas sensors allow:

- monitoring and reducing pollutants in the environment;
- providing early detection and forensic analysis for security;
- reducing pollution by improving efficiency in transport.

Further, gas sensors play an important role for AAL in healthcare applications, providing early diagnostics in healthcare and in workplaces, especially for monitoring complex processes that ensure a sustainable economy.

The principal markets for gas sensors are:

- fire and domestic gas detection: a mature market, with growth in domestic CO;
- automotive (ignoring lambda): rapid growth in cabin air quality monitoring, with large potential growth in emissions control;
- industrial safety: a mature market with rapid expansion in developing economies;
- process control and emissions monitoring: legislation- and efficiency-driven growth;
- breath and drugs: large potential growth in medical diagnostics, but research is needed;
- environmental monitoring: large potential growth, but technically challenging and legislation is not yet in place;
- security and military with event-driven growth.

The "grand research challenges" identified by the MNT Gas Sensors Forum relate to:

- VOC (Volatile Organic Compounds) characterization against complex backgrounds (e.g. BTEX, landfill, indoor and cabin air quality);
- improved selectivity and stability for semiconductor and nanomaterial gas sensors;
- combinatorial methodology for optimizing sensing materials;
- integrated MEMS using combinatorial sensing arrays with widespread applicability;
- room temperature mid-IR and far-UV low-cost, tunable light sources.

The graphical roadmaps in the following pages are taken from the MNT Gas Sensors Roadmap (by courtesy of the MNT Gas Sensors Forum).

The MNT Gas Sensors Roadmap can be downloaded from the MNT web site (Jane, H. 2009).

Figure 5: MNT Gas Sensors Roadmaps – **FIRE DETECTION**

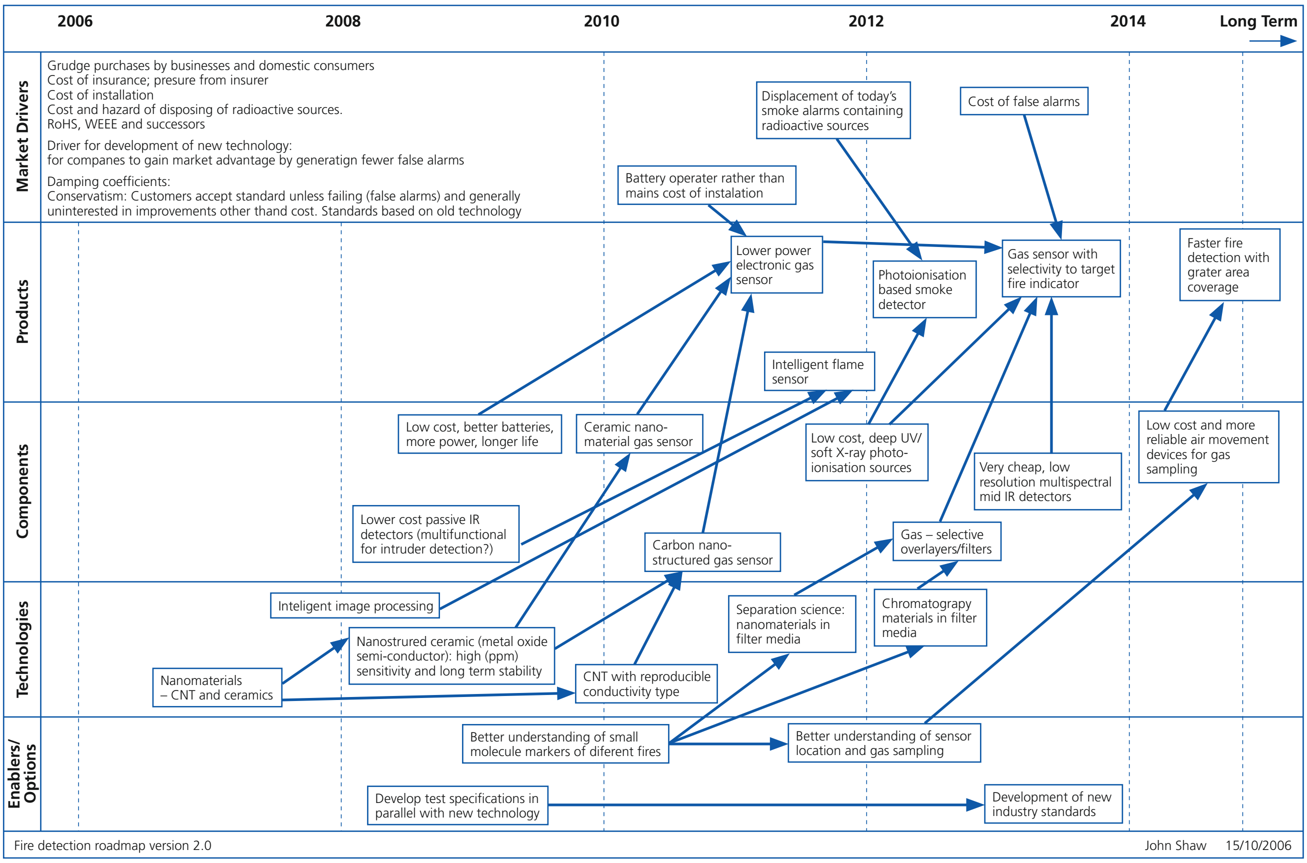


Figure 6: MNT Gas Sensors Roadmaps – **FLAMMABLE LEAK DETECTION**

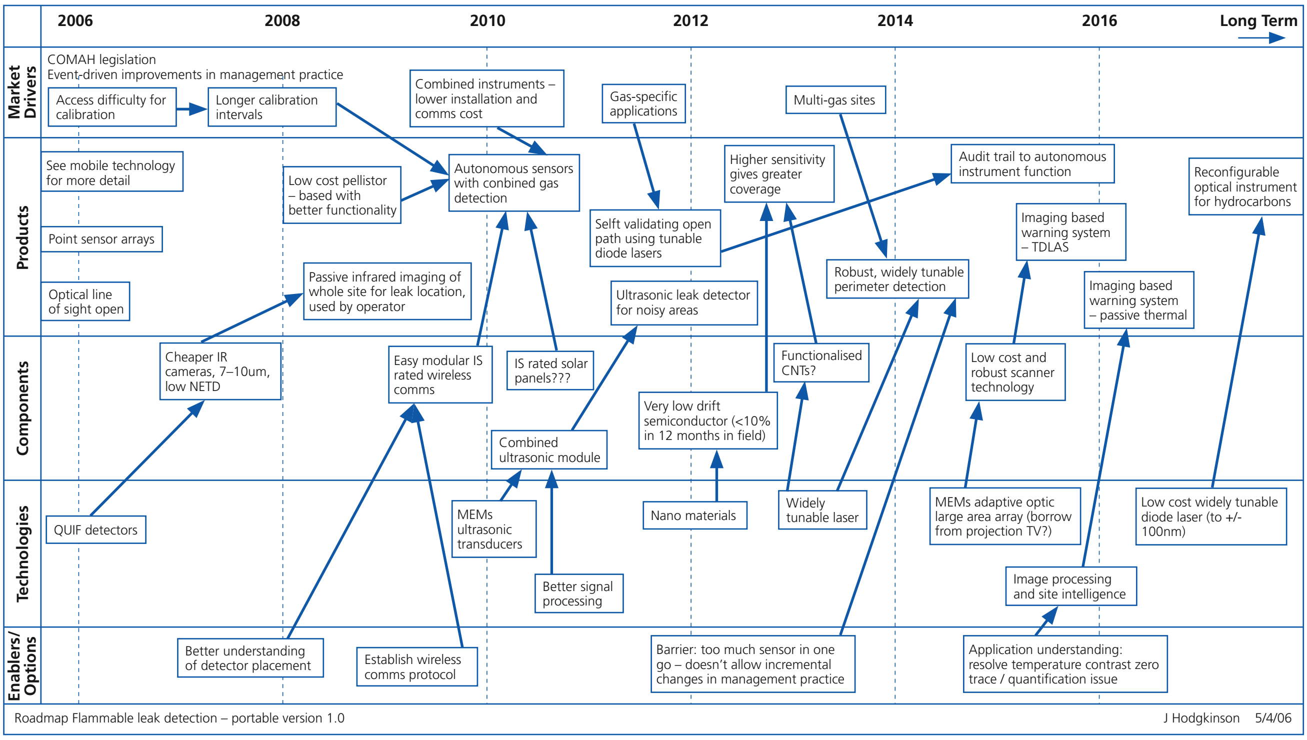


Figure 7: MNT Gas Sensors Roadmaps – **TOXIC LEAK DETECTION**

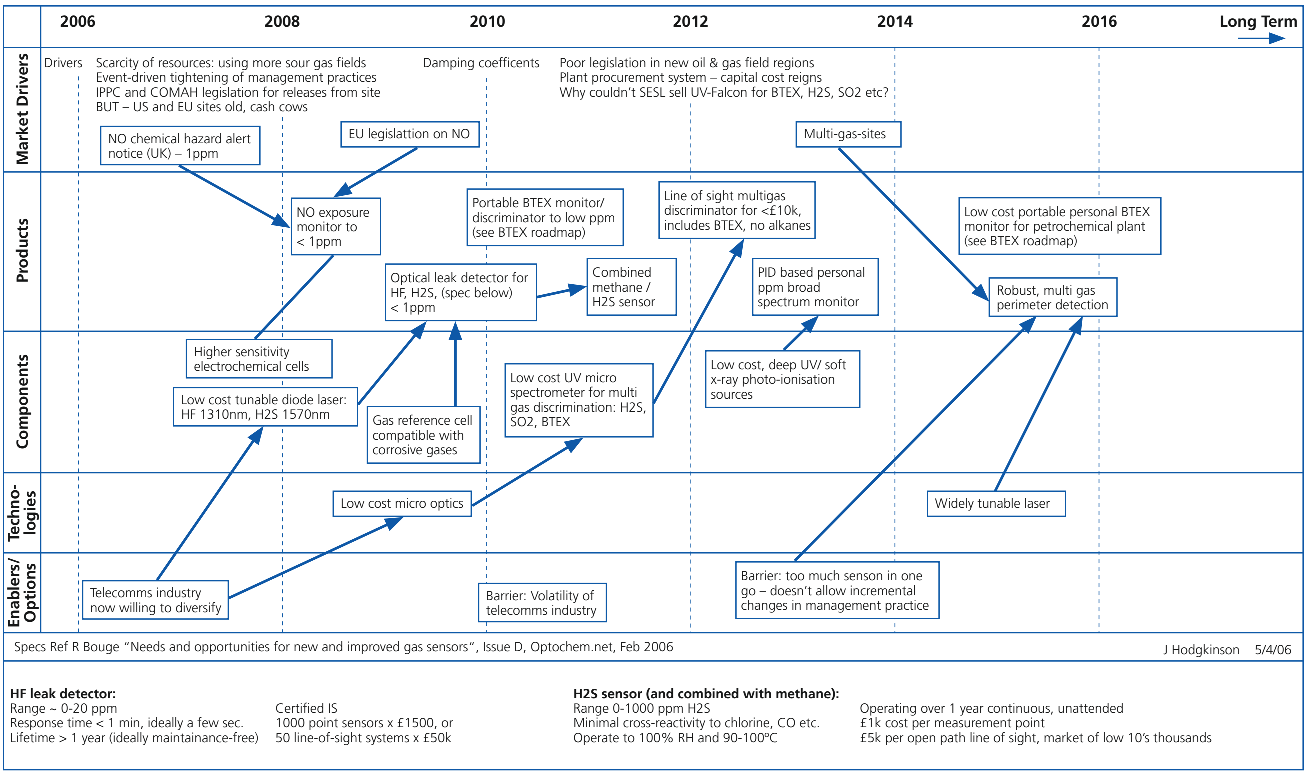


Figure 8: MNT Gas Sensors Roadmaps – **FOOD QUALITY**

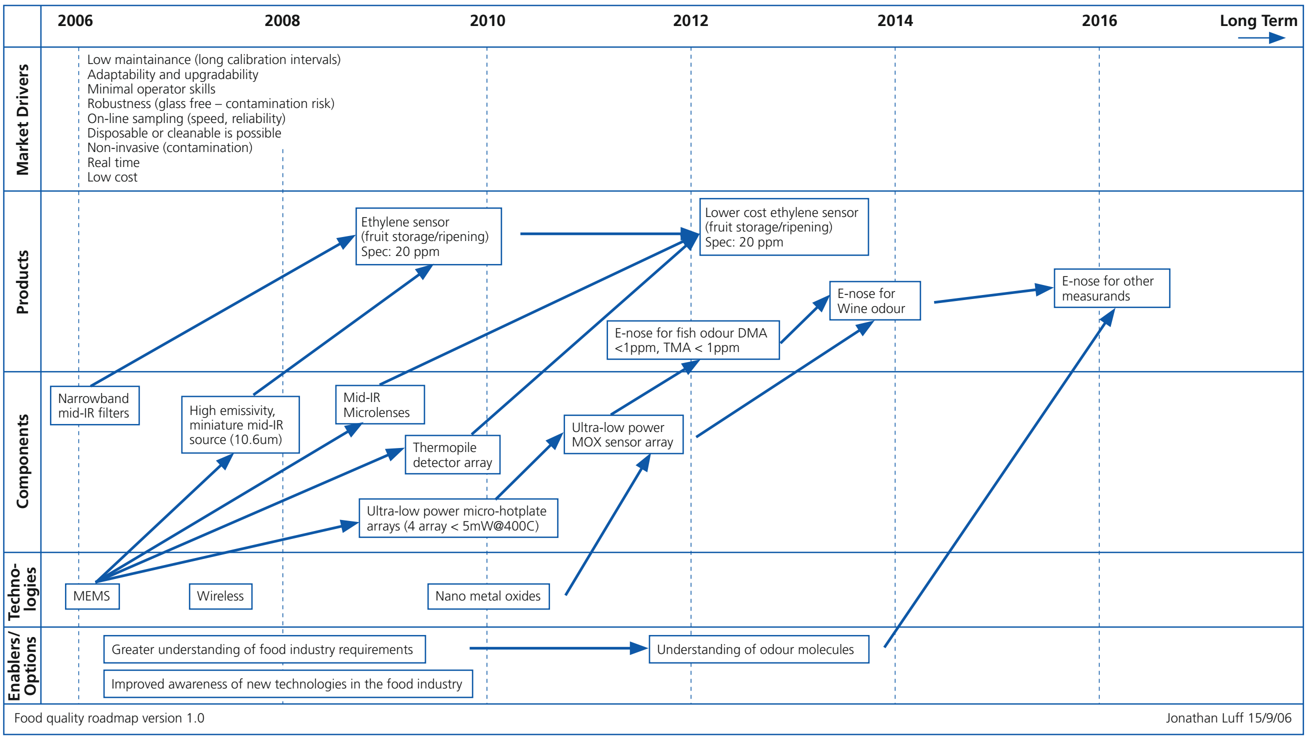
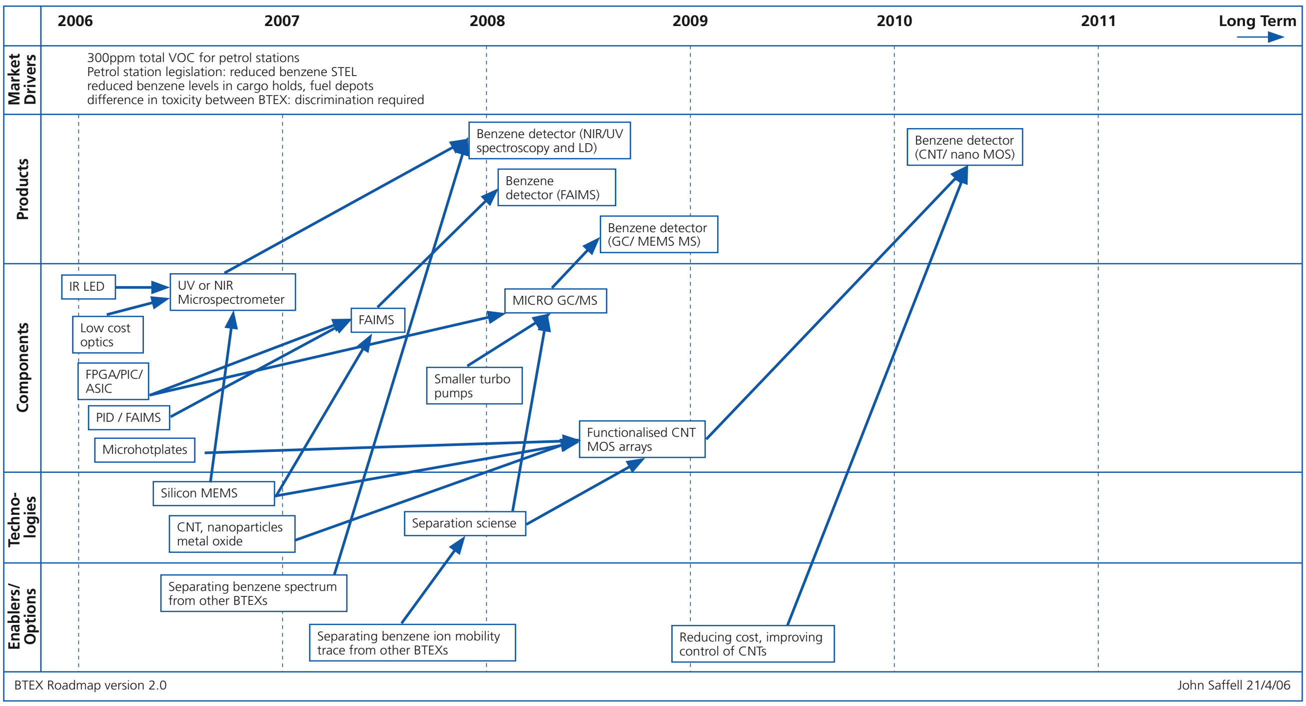
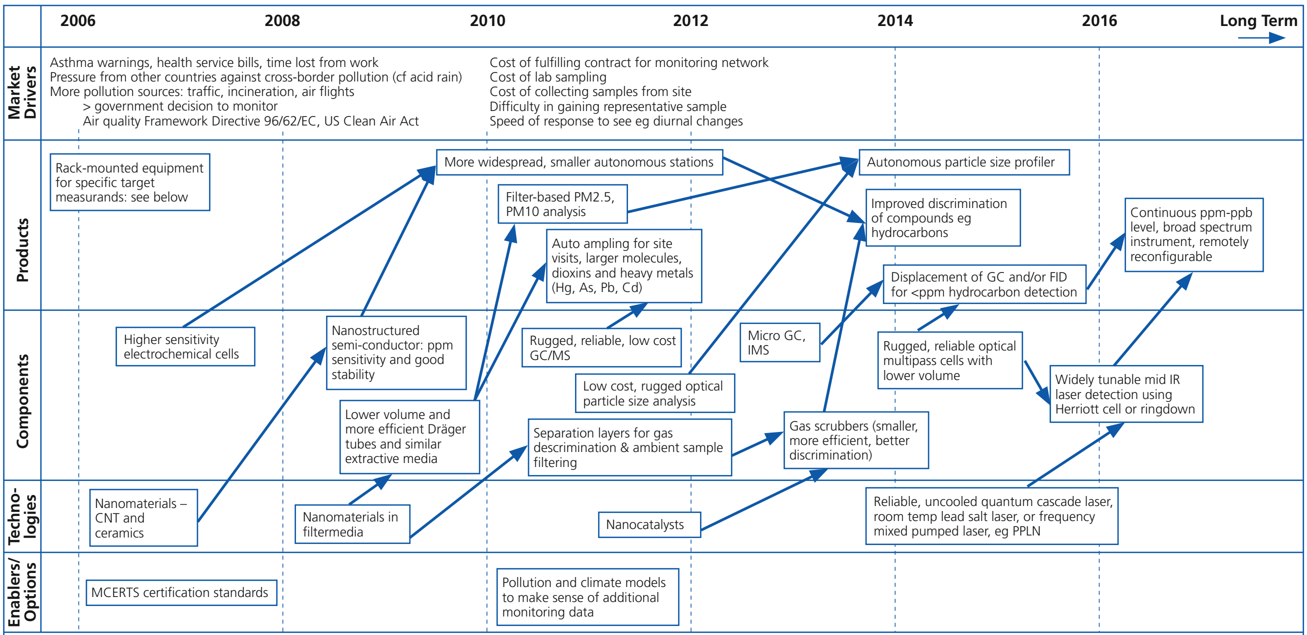


Figure 9: MNT Gas Sensors Roadmaps – **BTEX DETECTION**[2]



[2] BTEX is an acronym that stands for benzene, toluene, ethylbenzene, and xylenes. These compounds are some of the volatile organic compounds (VOCs) found in petroleum derivatives such as petrol (gasoline). Toluene, ethylbenzene, and xylenes have harmful effects on the central nervous system.

Figure 10: MNT Gas Sensors Roadmaps – **ODOUR AIR QUALITY**

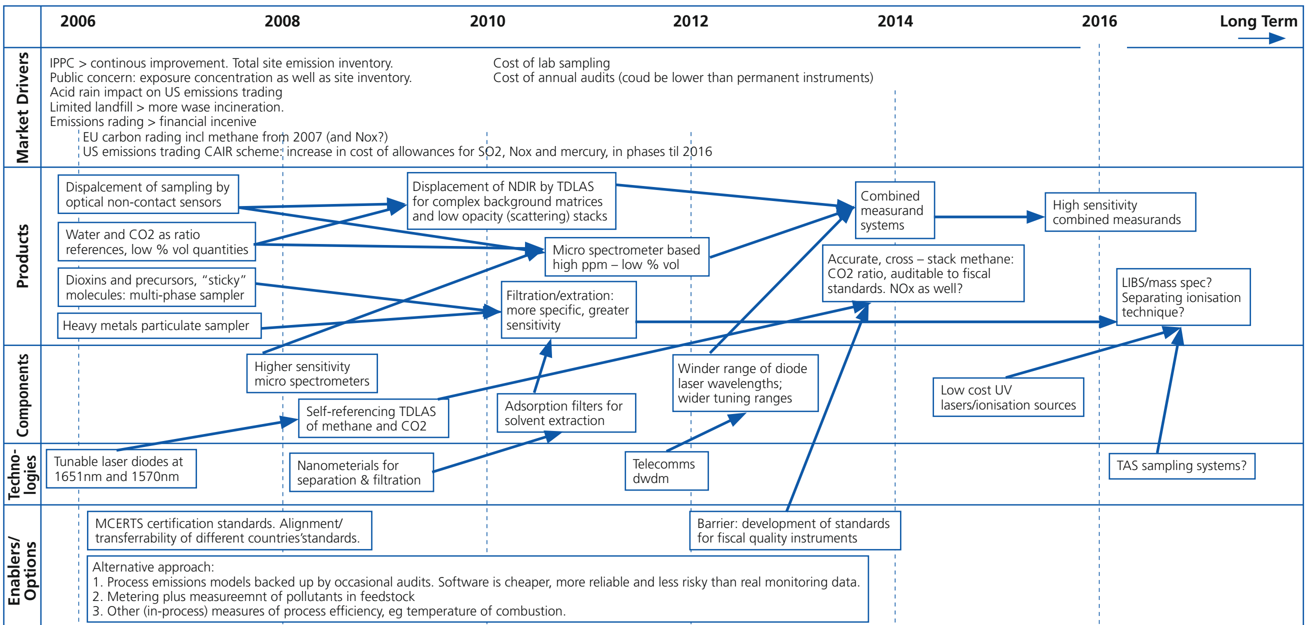


Outdoor air quality roadmap version 2.0 — Jane Hodgkinson 11/12/06

Limits of detection:

CO	0.1ppm	benzene	0.25ppb	Equipment cost approx £10k per measurand
NO2	2.5ppb	hydrocarbons	100ppb	Zero drift is an issue
O3	1ppb	SO2	2.5ppb	

Figure 11: MNT Gas Sensors Roadmaps – **STACK EMISSIONS**



Stack emissions monitoring roadma version 1.0 — Jane Hodgkinson 10/04/06

Accuracy can be important in this application, ratioed to eg CO2 emissions (absolute levels of which are determined by metering)

CO2 range 5% or more	SO2 range 20ppm	CL2 range 50ppm
H2O range 10%	NO2 range 20ppm	HCl range 50ppm
CO range 200ppm	NO2 range 20ppm	HF range 50ppm
	NH3 range 20ppm	H2S range 50ppm

Figure 12: MNT Gas Sensors Roadmaps – **INDOOR AIR QUALITY**

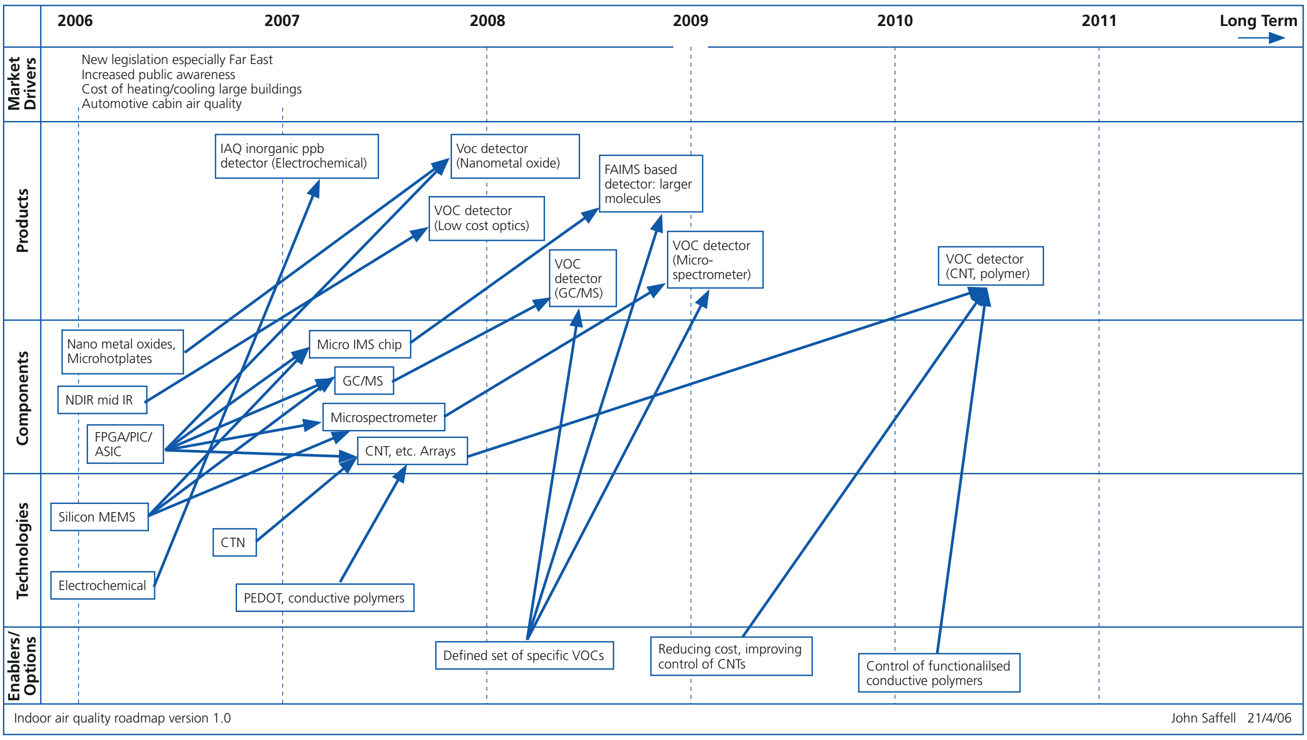


Figure 13: MNT Gas Sensors Roadmaps – **ODOUR MONITORING**

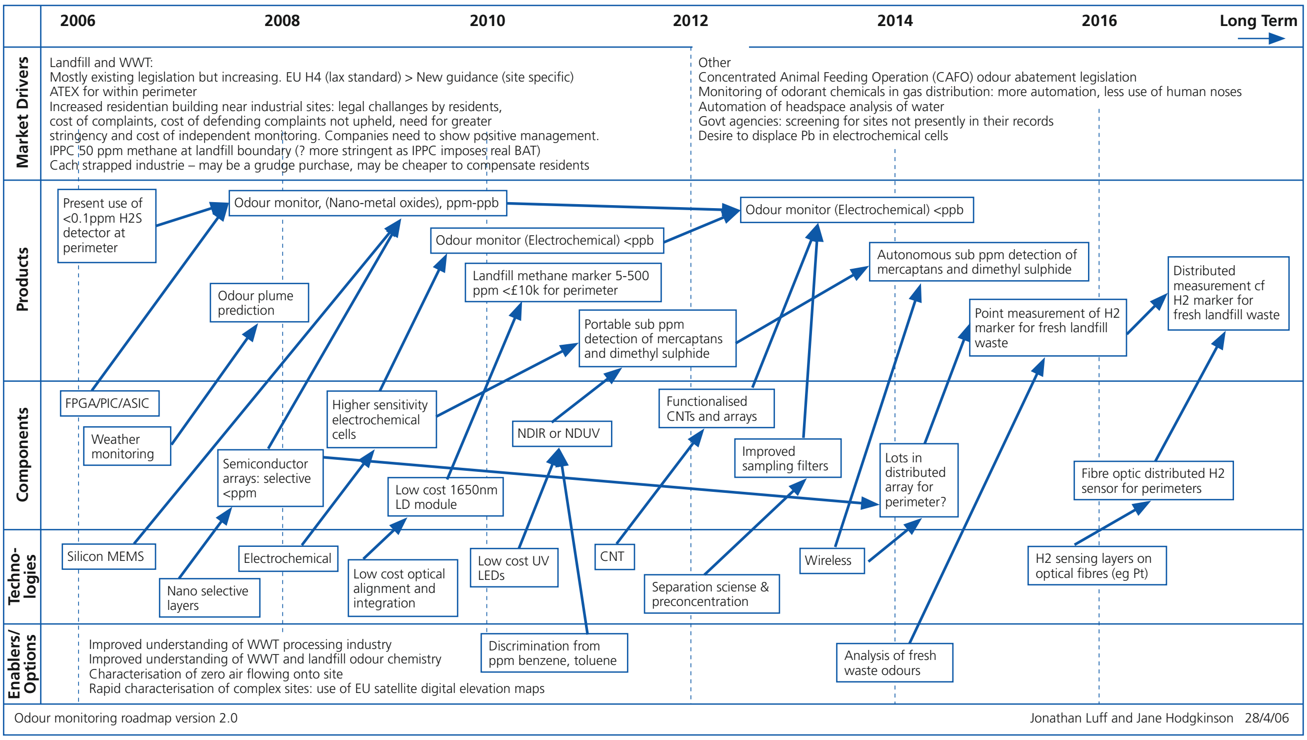
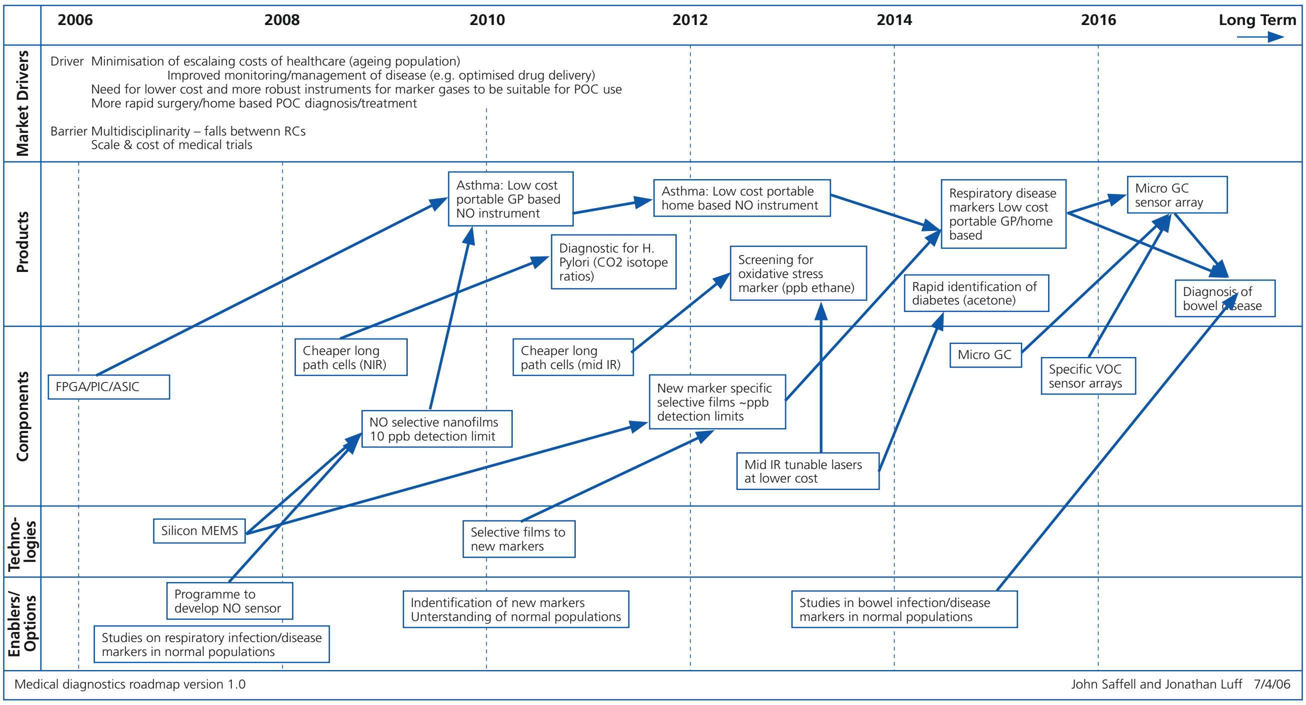


Figure 14: MNT Gas Sensors Roadmaps – **MEDICAL DIAGNOSTICS**



7.1.2 Vital sign data and activity sensors

Human-activity recognition is a broad field of research. We can distinguish systems that use wearable sensors and systems with sensors mounted in the environment, like cameras or infrared motion sensors.

Accelerometers or multi-sensor platforms worn on different parts of the body have been presented for recognition of such activities as walking, running and climbing up stairs. Two types of sensor are frequently used to measure physical activity: pedometers, which measure walking relatively well, and accelerometers.

Other typical (non-vision-based) ambient sensors for activity detection are simple infrared motion detectors, reed switches on doors and cupboards, and RFID tags on objects. A comparison of different types of non-intrusive sensing modalities for activity recognition was recently presented by Logan B., Healey J., Philipose M., Tapia E., Intille S (Logan 2007).

R&D trends in this important class of enabling technologies include the development of new families of wearable and contactless sensors.

3D CMOS image sensor (Suntharalingam 2009)

CMOS image sensors are able to extract visual information from the geometry of visible surfaces, interpret the 3D coordinate data, and capture both color and depth images simultaneously. Applications include surveillance and reconnaissance.

Image sensor is based on 0.35-micron technology. The 3-D imager is a 1-Mpixel (1,024- x 1,024-pixel) device fabricated with 8-mm pitch, per-pixel through-silicon vias (TSVs), and MIT can be ,'tiled together to realize very large arrays''. The imager has two basic tiers, which consists of seven layers. The first two tiers are the 3-D imager. ,'Tier 1 consists of 100 percent fill factor, deep-depletion photodiodes, thinned to 50-mm,'' according to the paper. ,'Tier 2 consists of SOI-CMOS pixel readout and selection circuitry that is 3-D connected to Tier 1 photodiodes.'' The remaining five layers have a multi-chip silicon stack, which includes two silicon chips with 64 12b pipelined analog-to-digital converters, a timing sequencer, tile address encoder, bias generators, I2C serial interface, and two 12b wide LVDS outputs running at 512-Mb/s. The imager is connected to the stack via a gold stud bump array at a 500-mm pitch.

7.1.3 Sensor networks

Communication is established from sensors and actuators with e. g. reasoning services and from reasoning services with other reasoning services to allow aggregation of data.

Several approaches might be used to implement part or whole of the solution:

- A single sensor connected to a reasoning service which might be connected to other reasoning services for aggregation. Those reasoning service will pass on the results to other interaction services and devices.
- Appliances, consisting of a sensor, reasoning and actuator for feedback implemented in a single device; such an appliance might pass on results to other reasoning and feedback services for aggregation.

The sensors, actuators, reasoning, aggregation and feedback services might be distributed on one or more of the following networks: body network, in-room or in-car network, home or building network, or outdoor network over a wide area.

In a recent roadmap document on Sensors Networks (Hirvonen 2007) VTT describes a number of future visions for the period 2010–2015, in the field of consumer applications:

Wireless body sensor network consisting of wearable BAN sensors and a mobile device

It is expected that wireless sensors will be in widespread use in consumer applications by 2015. People will have many personal devices (e. g. laptops, mobile phones, PDAs, mp3 players, tablet PCs and wrist computers) that will communicate seamlessly with each other. Increasing memory densities will enable ever-increasing storage of multimedia content in consumer devices.

Wireless body-area networks are coming into use in some niche areas in the form of wearable sensors, e. g. foot and arm sensors, wrist computers and smart clothing. Several sensors can be integrated into mobile devices for controlling the smart environment. Collaborative user interfaces are easily distributed. New applications based on RFID sensors will appear. The significance of position and location information will increase. Independent living applications for the elderly have emerged. The health status of the user can be analysed with sensors in mobile devices. Computer games are both mentally and physically interactive.

Typical future visions describe a world full of sensor nodes that are self-configurable. However, in consumer applications, only a few external sensors are needed and the user terminal may have internal sensors.

Short-term steps to the vision:

In the short term, the first devices to utilize sensors will be mobile phones and game pads. Internal sensors that measure environmental conditions. e. g. air pressure, temperature and humidity, have already been integrated into mobile phones

Long-term steps to the vision:

In the long term, there will be many WBAN solutions that will utilize on-body sensors to monitor health and physical condition status. The highest market increase is likely to occur in health and fitness applications.

Steps to vision:

- *Research on deployment of sensor network*
- *Implementation of real-time mobile applications that analyse and utilize sensor data.*

Technical solutions for long-term health and health monitoring

Viable methods for long-term monitoring of health and wellbeing in real-life settings are being developed. This includes easy wearability and management of personal wireless sensor networks, mobile phone-centred data collection, signal processing, wellbeing history presentation for self-care, and integration of wellness data with patient information databases. Easy WSN management includes maintenance-free units requiring energy scavenging and low-power wireless sensors and sensor platforms. The focus is on stress and weight management, and monitoring of wellbeing of the elderly. Development of low-power wireless (RFID) sensors with memory capacity capable of storing several measurements.

Medium-term steps to vision:

Mobile-phone-centred field trials with embedded or external sensors. Construction of a gateway to integrate sensor network protocols with mobile phone.

Long-term steps to vision:

Health and wellbeing monitoring will be carried out by a wearable system that includes an easily portable UI unit/gateway device (wrist unit, pendant), which may communicate with a mobile device online and process and store data. Sensor tags capable of storing a series of measurements will be developed. Physical selection should be included as a means of managing the configuration and measurements of peripheral devices.

Context sensing using wearable sensors and data fusion

Sensors are embedded in everyday gadgets like mobile phones and their accessories, and sports computers. The key challenge is to transform the increasing amount of raw sensor information into knowledge that is either usable for computer applications or directly human interpretable.

The context information (i. e. any information describing the situation) can be used in different ways by different applications. e. g. for automatically keeping a diary, for automatically adapting the user interface or user profile, and for automatically recommending a service or information for the user.

Weaknesses, limitations:

Lack of mobile user terminals and real-time analysis tools. The sensors should be small in size and waterproof, and they should tolerate movement. The location of the sensors should be optimized according to the application.

Medium-term steps to the vision:

Making use of data available from the user's own wearable sensors using a wireless sensor network. This involves real-time data preprocessing, analysis and classification in a portable device. The target is to turn the raw sensor data into higher-level knowledge.

Long-term steps to the vision:

Making use of all data available via wireless networks: data from the user, nearby users and objects, data available via servers and services, etc. The target is to combine data from many users and the environment into higher-level group or area contexts..

VTT's roadmaps also address future visions in the fields of **Industrial Applications** – especially for 1) active sound control, 2) vibration measurement and control and 3) human-centred automation) – and of **Infrastructure, Buildings and Environmental Applications** (sensor networks for built environments, for infrastructure management and for natural environments).

Finally, VTT presents its **Technology and Theory visions**, centred on the development of **open frameworks** for SN design, modelling, analysis and implementation of techniques and applications based on **multimodal interaction**, and of techniques for dealing with **spatial uncertainties**.

Roadmap 9: Sensing

	Short term (2013)	Mid term (2020)	Long term (2025)
Sensors	Heartbeat Detection – ultra-sensitive accelerometers Non-invasive peripheral neural interfaces Internet-connected sensors and actuators – SODA, Mulle3 etc Universal Positioning – Galileo/GPS/MPS/WLAN/UWB/signal space trilateration Location technologies for in-door navigation Sensors for indoor localization Adaptive sensors and actuators Item identification – RFID (standalone, bracelet-worn), NFC, BT, ShotCode Super low power sensors Sensors for human state detection	Invasive peripheral neural interfaces Non-invasive cortical interfaces Camera with object detection, classification and recognition End-to-end, close-loop systems from sensors, actuators and data analysis	Biologically human inspired sensors Biologically inspired sensor-actuator integration
Processing	Advanced signals and image processing for detection Algorithms for better signal filtering Advanced methods for position detection of persons; Video-motion analysis Video-motion prediction Context Acquisition and Use Valid and reliable techniques for the specific physiological signal;	Advanced pattern recognition Sensor data aggregation and fusion from different sensors Reliable classification of relevant situations from sensor signals and context information	
Power	Energy scavenging and management	Endless power to mobile sensors, actuators and processors (wireless/battery)	

7.2 Reasoning

Roadmap 10: Reasoning

	Short term		Mid term		Long term	
	2010	**2012–2013**	**2015**	**2017–2018**	**2022–2023**	**2025**
Reasoning	User model Context model System model	Domain model Ontologies, environment models Model mapping Context-exchange framework Environment aware platform	Ontological (semantic) everyday artificial intelligence Neural artificial intelligence Semantic context fusion Reasoning systems Automated activity-flow modelling	Model Evolution	Artificial nursing intelligence	Situation analysis engine Intelligent assistant system for analysis and reaction on individual and current needs Neuroscience-based models of limb motor control Awareness and intelligence in any home appliance

7.2.1 Reasoning for AAL

A core function of AAL systems is the conclusion of knowledge about the activities of the user and the current situation in this environment from low-level sensor data. Not only daily activities and situations have to be considered, but also emergency situations have to be detected which need an immediate reaction as well as analysing the user's mid-term and long-term behaviour to assess the development of the physical and psycho-social status. The characteristics needed for this task are to reliably and quickly detect situations based on input information provided by sensors which must be considered as inherently imprecise and unreliable. Multiple heterogeneous information streams must be fused. The reasoning system must be adaptable to varying environments and users. But most importantly, the reasoning in complex human activities or behaviour requires highly expressive models.

7.2.2 Models

The main requirement for valuable reasoning is that any information characterizing the situation of an entity can be used. A.K. Dey (Anind 2001, S. 4–7) uses the term "context" to define this information. An entity includes a person, a device, a location or a computing application. Entities are characterized by attributes, e.g. the location could be characterized not only by its topology, but also by its noise level, light intensity, temperature and humidity.

Recent approaches have described this information using models, because they improve the separation of concerns of application logic from structural characteristics. Constructing platform-independent models and using mapping and transformation techniques to transform and refine models improves interoperability, extensibility and reuse in software applications. Issues of model evolution and complexity have still to be resolved. To refine reasoning, the models used will be extended and additional background knowledge will be included. Background knowledge, e.g. medical, reaches a high degree of complexity that has not yet been handled efficiently. Model evolution is a further challenge. Models are not fixed but change over time. They could perhaps be reorganized because of recent research findings or extended to reflect new knowledge. In any case, it should be ensured that a dynamic adaptation of the models does not have a negative influence on services that use the model.

7.2.3 Situations and behaviour

In recognizing situations and behaviour, a differentiation is made between critical situations whose detection must be performed in an online analysis of the information streams provided by the sensor infrastructure, and mid- and long-term behaviour which is monitored and does not require online analysis. A common classification of situations and behavior for AAL is:

- **Emergency situations:**
  - helplessness/lying on the floor;
  - indicators of falls;
  - motionlessness;
  - critical values in vital parameters (i.e. pulse rate, respiration rate, blood pressure).

- **Activities of daily living:**
  - sleeping; a discrimination between real sleeping and simply lying in bed should be possible;
  - toilet usage; an analysis of the qualitative or quantitative properties of this activity;
  - personal hygiene, i.e. washing activities in shower, bath or washbasin, general hygiene activities including the use of such devices as electric toothbrushes or hair driers;
  - preparation of meals: cooking activities as well as the preparation of small snacks, taking of beverages, etc.

- **Psychosocial behaviour:**
  - going out;
  - meeting people, i.e. visitors coming to the user's apartment;
  - communication, i.e. usage of phones, email, etc.self-entertainment, i.e. usage of radio, TV, video-/DVD-players, PCs, etc.

- **Motion:**
  - occupancy of rooms, i.e. which rooms are occupied and for how long;
  - locomotion, i.e. walking, standing, sitting, lying, falling;
  - quality and quantity of motion, i.e. walking speed, walking distance, duration of physical activity, motion patterns.

- **Vital parameters:**
  - pulse rate;
  - respiration rate;
  - blood pressure;
  - body weight.

7.2.4 Activity recognition

The reasoning tasks for the recognition of situation and behaviour can be differentiated in five different levels of semantic abstraction:

Basic physical activity: The basic physical activity of the user in terms of motion is detected. This includes basic motion information from location tracking, movement of the hand, body motion or general activity.

General activity: The characteristics of physical activity are evaluated for describing general activity towards the modes of locomotion (e.g. sitting, standing walking or lying), and the user's location within the environment, on room level, on the level of functional areas in the environment or in spatial relation to objects in the environment.

Specific actions: Specific actions performed by the user are inferred from punctual observations, describing interactions of the user with the environment (e.g. opening the front door and leaving the house) or specific events in motion (e.g. falling, stand-up-and-go).

Complex processes: Most activities of daily living follow a planned sequence of action steps, which are executed in order to fulfil a certain goal. To monitor these complex processes, multiple actions and events must be correlated in respect to their temporal ordering. Further information about these activities can be gathered by regarding their effects on the environment (e.g. when the user is showering, the humidity level in the bathroom will increase). The complexity for modelling and recognition of these processes increases as the fact that the same person often performs the same activity differently, and also different people perform the same activity differently has to be taken into account,.

Behaviour analysis: To detect relevant situations medically, changes in the user's behaviour and vital data must be inferred and evaluated to the extent that they are affected by changes in the physical health status of the user. From analysing trends in the user's activities and vital data, deteriorations in the physical health status can be derived. Another impact factor is the circadian rhythm in the performance of daily activities. Detected activities are evaluated against "normal" behaviour that a user shows during the day, in order to infer changes in the habitual schedule of the user.

The complexity of the reasoning task increases with each level of abstraction, on the one hand by the complexity for the modelling of activities and situations, and on the other hand by the amount of heterogeneous information that must be fused in a situational way. Challenges for activity recognition which must be met by the reasoning system are:

- **Variations in the execution of activities:** People tend to perform the same activity in different ways. For example, the preparation of meals can cover the preparation of a quick snack or extended cooking. These intrapersonal differences in carrying out activities affect the type and order in the steps that are performed, as well as the length of time in which the user spends on this activity. Besides this, the reasoning system must also be able to adapt to interpersonal differences in carrying out activities, as each person shows individual characteristics in their behaviour.
- **Simultaneous activities:** Activities performed by the user can be interwoven, as people tend to multitask when one activity does not fully engage their attention.
- **Incomplete execution of activities:** When the user changes his or her plans, an activity can remain incomplete.
- **Temporal ordering of the activity:** The sequence of steps which is executed for fulfilling an activity must be modelled. Furthermore, to recognize activities, the preceding activities can give a strong indicator of what might be done next by the user.

Currently, for "ambient" sensors mounted in the environment, the largest amount of activity recognition is carried out using cameras and computer vision techniques. For example, Thiago Teixera **(**Teixeira 2006) et al. describe a behavior interpretation framework that recognizes unsafe and out-of-the-ordinary human behaviour. It uses a camera network covering the apartment and two types of patterns are observed. The first are well- defined activities and rules that raise exceptions. The second type is based on longer term statistical properties of behaviour. These are meant to recognize shifts in behavior patterns over a period of time. The network recognizes a set of behavior patterns and rules by reasoning using areas and locations.

7.2.5 Reasoning approaches

For reasoning systems and choosing appropriate algorithms for activity recognition and situation detection, the following requirements must be considered:

Handling imperfect information:
Information in the real world is subject to various causes of imperfection like missing data, credibility of information sources and error in measurement. Any system designed for reliable diagnosis and recognition in such an environment has to take these aspects into account when combining information.

Handling temporal information:
Behaviour (both human and regarding technical systems) is characterized by changes of (system) states over time. Formalisms for modelling behaviour – as a first step towards recognizing it – therefore have to be capable of expressing these temporal aspects.

Expressiveness of models:
The reasoning algorithm must work on underlying models which are adequately expressive to describe complex situations and complex interrelations between parameters in the description of human capabilities.

Scalability of models:
The reasoning algorithms must work in a scalable way in respect of the model complexity and the number of significant parameters in the model.

Online performance:
The reasoning algorithms for activity recognition and situation detection must be able to perform online analysis. This means that a trade-off must be made between the model complexity and the computational complexity of the algorithm.

Modelling of a-priori knowledge vs. learning:
The layout and equipment of environments in which the system will be deployed can vary largely, as can the user's performance of activities. This makes it impracticable for the reasoning to rely solely on models of a-priori knowledge. Using supervised learning, the reasoning models can be adapted to the characteristics of the specific environment and the specific user during an explicit training phase.

On the other hand, it is necessary to provide a-priori knowledge to the reasoning system, e.g. the medical knowledge modelled by domain experts. The reasoning system should be able to handle this trade-off between user adaptability by learning and explicit modelling of a-priori expert knowledge.

Reasoning approaches can be distinguished according to two major aspects, namely the underlying knowledge representation formalism and the type of semantics used. The underlying formalism largely influences the expressive power: approaches based on first-order logic are much more powerful than propositional formalisms, whereas extensions of description logics or relational schemes lie between these extremes. On the other hand, semantics determines how information (i.e. valid sentences in a knowledge representation language) is interpreted. Whereas there are countless syntactic variations in knowledge representation systems, most existing formalisms can be seen to follow either a proof-based or a model-based semantics. In the following, the different approaches are described briefly.

Rule-based reasoning gives no inherent support for reasoning of incomplete data or the handling of uncertain information (probabilistic information). While extensions towards these features can be made, this leads to an increase in the overall model complexity and/or computational complexity. Temporal orders in input information are not supported for reasoning by the approach itself. However, temporal concepts can be explicitly introduced to the system's rule base, which will increase the overall complexity of the rule base.

The complexity of the model affects the computational complexity for reasoning only to a small extent, but as rule bases cannot be checked for consistency in an automated way, the definition and extension of complex models is difficult and error-prone.

Furthermore, rule-based reasoning is well suited to online analysis and is also scalable to handle large amounts of data.

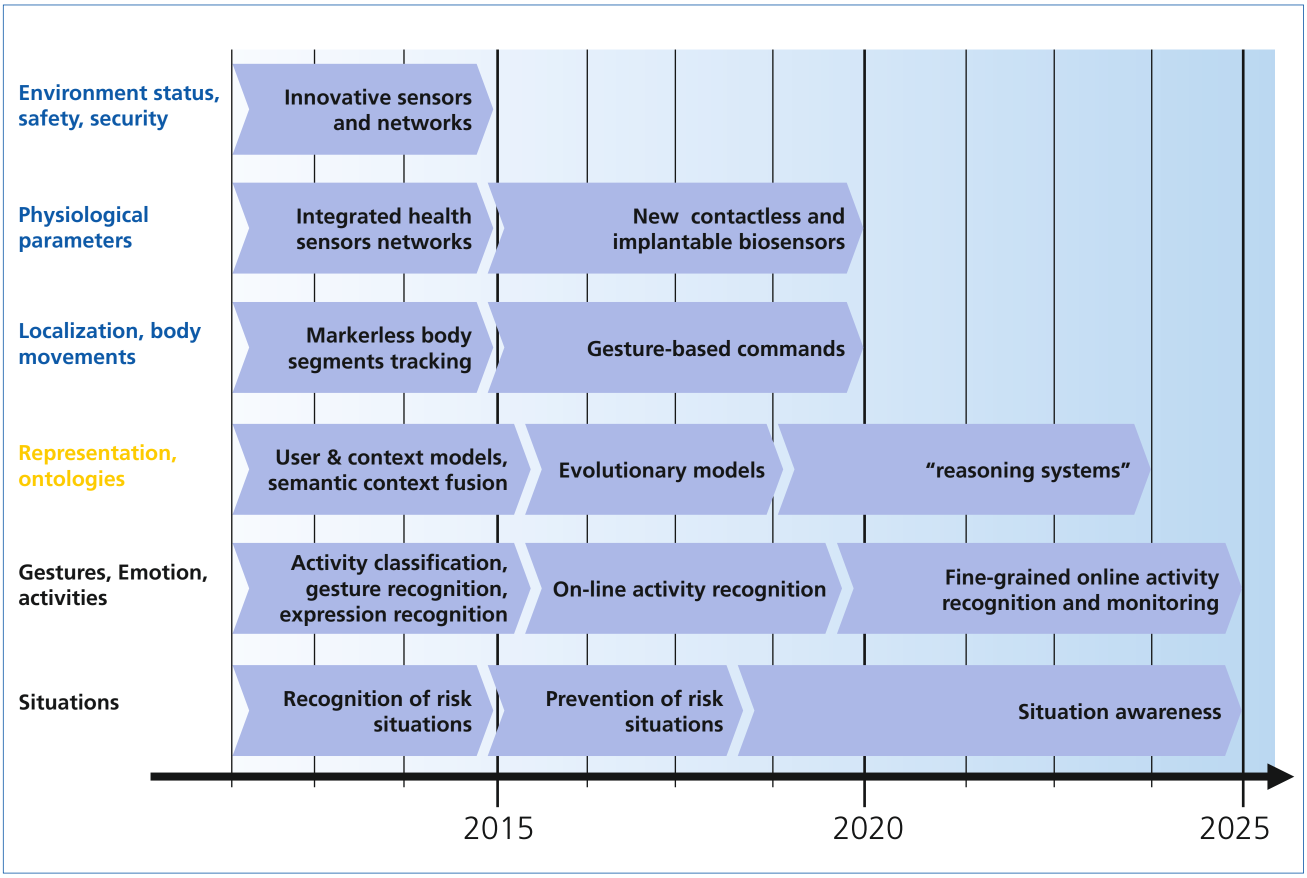
Case-based reasoning is able to handle incomplete data as well as uncertain data as input for classification. Temporal ordering of input information cannot be considered in the reasoning. The scalability of the model towards handling its complexity and the computational effort for reasoning is neutral, as complex situation models will increase the computational effort for matching and classifying the current case, but efficient algorithms already exist for this task.

The expressiveness of models is high, as no generalization in the description of the classified cases is made and each new case is evaluated in respect to previously acquired cases.

In general, case-based reasoning is suitable for carrying out online analysis, as efficient algorithms are already available for this task.

Description-logic(DL)-based reasoning is suitable for reasoning of incomplete information and also extension towards reasoning with uncertainties and temporal reasoning exits. The expressiveness of the DL-based models is very high. Moreover, the consistency of the models can be checked automatically, which supports the definition of very complex models. As complex models seriously affect the computational effort for classification, a trade-off between the model expressiveness and the computational complexity of the reasoning on these models must be made. DL-reasoning is suboptimal for real-time analysis when handling large amounts of data.

Roadmap 11: Sensing & Reasoning



The probabilistic reasoning approach of Bayesian Networks (BN) offers a mathematically founded treatment of uncertain information and can also handle incomplete information. In the classical approach, no explicit support for temporal reasoning is given, while there are existing extensions to this. In comparison to other approaches, Bayesian Networks scale quite well as an inference in a BN is "only" NP-complete. The expressiveness of Bayesian Networks is probably unsuitable for representing complex situations or even human behaviour. For online analysis, efficient reasoning algorithms already exist.

Markov Models allow – like Bayesian Networks – support reasoning of uncertain and incomplete information. Besides that, temporal reasoning is supported inherently by this approach. As Markov Models are even more restricted in their expressiveness than Bayesian Networks, they will not be suitable for recognizing complex scenarios. For online analysis, this approach is suitable, as very efficient and easy-to-implement algorithms already exist.

Time maps are inherently suitable for reasoning temporal orders of information, but they neither support the handling of uncertain nor incomplete information. The expressiveness of time maps and their scalability is limited, and so they are most suitable for the detection of well-describable and simple situations or activities that follow a defined schedule. The computational complexity increases non-linearly with the amount of input information, but online analysis with time maps is possible.

Answer Set Programming (ASP) is based on the stable model semantics for Logic Programs. Because of its declarative nature, expressiveness and efficient implementations, ASP plays a relevant role in decision-problem solving, planning, diagnosis, and more generally, knowledge representation and reasoning. The computational complexity is higher than for propositionally based approaches.

Ongoing developments show that no single approach exhibits all the properties required for reasoning in AAL applications. The approach could be to realize a modular reasoning layer enabling the combination of different reasoning approaches.

7.3 Acting

7.3.1 Human musculoskeletal system-based actuators

The increasing need of robots closely interacting with humans shows some limitations for current mechatronic technologies in AAL. While electronics, mechanics, sensors and control units do not appear as a limitation, a great obstacle seems to be represented by actuation. Any time the human-robot interaction is considered – and this is crucial in AAL mechatronic technologies (e.g. prostheses, operative robot and/or wearable robots for rehabilitation and assistive purposes) – the attention is focused on the following issues: safety, compliance, adaptability and dependability. The robotic system, interacting with humans, should be intrinsically stable and easy to control, compliant and safe with respect to unpredicted/unpredictable events, and capable of storing energy passively in order to improve its efficiency.

Most of the research concerned with these issues has been focused on the development of robots powered by muscle-skeletal based actuators, commonly called *artificial muscles*. In many cases they are inspired by the mechanical characteristics of human muscles, with special attention given to the intrinsic muscle compliance and their variable dynamic behaviour.

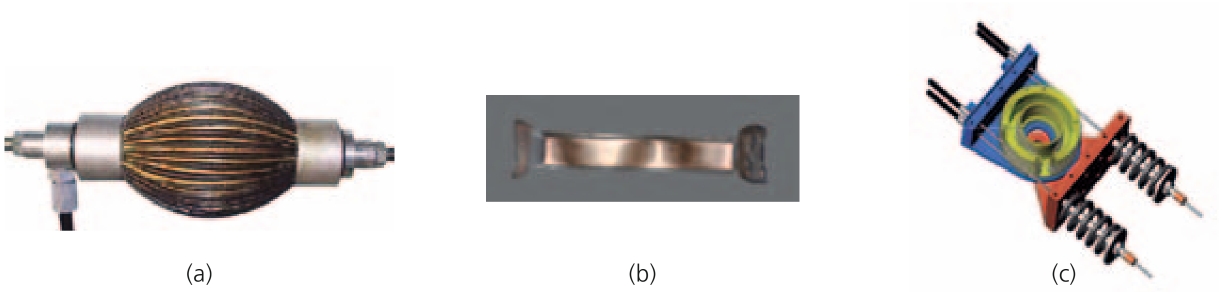
Looking at the current state of the art of muscle-like actuators, it emerges that many solutions have been investigated, such as pneumatic artificial muscles, electro-active polymers, series elastic actuators, or mechatronic joints, having one or more electromagnetic motors properly controlled to mimic human muscle mechanical features (i.e. stiffness, viscosity).

So far, **artificial muscles** can match only certain temporal, spatial or force regimes typical of biological muscle, but they cannot fully replicate all these capabilities together. In particular, they cannot obtain at same time the same high-density energy source and the adjustable mechanical impedance properties.

The emerging roadmap, establishing the main priorities in the short, middle and long terms, is:

- **short term:** strengthening of the current technologies and development of stable and reliable

Figure 15: Overview of the main technologies used in the current state of the art to implement a human muscle-skeletal based actuator



a) McKibben artificial muscle, b) electroactive polymer and c) series-elastic actuator (Venemam, 2005) mechatronic systems for AAL-based artificial actuators; definition of a new design paradigm leading to emerging technologies for new bio-artificial muscles;

- **middle term*:*** implementation and strengthening of new bio-artificial muscles (by 2020);
- **long term:** development of stable mechatronic systems for AAL, based on new bio-artificial muscles.

7.3.2 Safe and highly back-drivable/ under-actuated mechanisms

In advanced research for robotic hands, two main fields can be identified: manipulation and grasping. Efforts have been made to design grasping hands that have mechanical and control architectures which are simple enough to be made available widely on a commercial basis, as for example prostheses for amputees or industrial grippers for pick-and-place operations. Many researchers have therefore used under-actuation as a strategy to reduce the number of actuators while preserving the capability of the hand to adapt its shape to the grasped object. Surprisingly, very few under-actuated hands have been successful as industrial grippers, probably because they can lead to somewhat non-intuitive behaviour and produce non-stable grasps. Good examples of such an approach are those of Barrett Hand, RTR II Hand, SARAH and MARS Hands.

On the form-closure capability and on the grasp stability (according to Lyapunov) of robotic under-actuated hands, innovative models will be available. Under-actuated robotic hands have been effective as industrial grippers because of simple control architectures. Thanks to new implantable interfaces, robotic under-actuated hands have been commercially successful as prostheses for amputees.

7.3.3 Neuroscience-based models of limb motor control

Human motion control strategies

A thorough knowledge of the human motion control strategies is a crucial aspect in the development of high-performance robotic systems for AAL. Ideally, the implementation of motion-control strategies based on neuroscience models will enable robotic systems to behave like humans. If we think of an active orthosis for limb motion support, we can imagine that it is unnecessary for its control system to be as accurate and precise as an industrial robot. Instead, it is desirable that active orthosis could be flexible and versatile, capable of supporting a wide range of motion tasks.

Many aspects of human motion-control strategies are still being considered: neuroscience investigations are still ongoing and are being conducted by various means in human and animal subjects. Many "standard" methods are based on data recording from human and animal subjects, such as:

- the application of mechanical disturbances (impulses, vibrations, etc.) to the limb during natural movements, and the contemporary observation of the limb disturbance rejection;
- central nervous system activity recording, through the fMRI, during natural and prototypical motion tasks;
- peripheral and central nervous system monitoring through temporally implanted electrodes.

However, there is an increasing need to test neuroscientific hypotheses on human motion-control theories by implementing them on a model system that is under the full control of the experimenter. In this way, the results obtained by means of the "standard" neuroscience methods can be compared with those obtained from the model system. While this can be achieved to some extent through numerical simulation, these results are only as good as the accuracy of the numerical model as conceived by investigators. As a supporting tool to these mathematical analyses, the implementation of a certain hypothesis on a real mechanical system can reveal the effects of unmodelled dynamics and provide critical insight into how the human system functions in a real environment. For this reason, the importance and the employment of robotic tools for neuroscience investigations is developing as a separate study, leading to what is called *neurorobotics* (i.e. the fusion of neuroscience and robotics).

The emerging roadmap, involving actions with increasing level of complexity, establishing the main priorities in the short, middle and long term, is:

- **short term:** strengthening the "neurorobotics paradigm" and the development of robotic tools, focusing on the specific feature of human limbs, such as functionally inspired robots mimicking specific human features (i. e. dynamic properties, impedance, antagonistic actuation scheme, kinematic and dynamic redundancy) (2015);
- **middle term:** developing high-complexity and fully bio-inspired robotic limbs (2020);
- **long term:** developing high-complexity humanoids for the investigation of whole body human motion control theories (2025).

Neural-machine interface

There are several ways of tapping into neural information, ranging in hierarchical location (cortex, spinal cord, peripheral nerves, and nerve ending at muscles) and invasiveness (direct electrodes [needles, cuffs in tissue]) or surface electrodes (EMG or electroencephalography [EEG]). The most advanced technology in clinical practice for controlling prosthetic hands is based on myoelectric control (Zecca 2002) and interesting results have been achieved by several groups extracting motor information. More recently a new neural machine interfacing technology called targeted muscle reinnervation (TMR) has been developed that improves control of multifunctional myoelectric upper-limb prostheses. Recently, several strategies to use invasive and non-invasive interfaces with the peripheral nervous system (PNS) have been implemented: PNS invasive interfaces can be used to discriminate different neural signals (Navarro 2005; Dhillon 2004; Citi 2008). The possibility of extracting "global" information related to grasping tasks seems more likely than information related to the detailed kinematics and dynamics of the task. In particular, the combination of multisite intraneural peripheral interfaces and advanced processing techniques seems to be able to increase the amount of information that can be extracted.

Regarding upper-limb control, new models will be available thanks to extensive clinical experimentation with primates. Motor-control information will be extracted centrally (brain) and peripherally using different levels of invasiveness interfaces. These include invasive implantable electrodes in the brain and in the peripheral nerves (bidirectional neuro-prostheses), and superficial electrodes picking up EEG and EMG signals. Research on algorithms, as well as on innovative interfaces with better signal-to- noise ratio, will provide more accurate signals for modelling.

Innovative implantable interfaces that are able to intimately collect the neural signal process it and wirelessly transmit it to external recording systems will help the understanding of the neuroscientific models of motor control. Biocompatibility and implants that are implanted once and will last almost for the whole of life will be assured by using materials delivering drugs to the tissue, thus avoiding rejection of the external device.

Global information and precise fine manipulation upper limb motions will be well modelled; implantable chronicle interfaces will be available, as well as highly dexterous artificial arms, hands and legs. This will result in the market exploitation of cybernetic functional substitutes of lost or damaged limbs.

Robotic neuro-rehabilitation

As regards upper limbs, studies have used a robotic manipulandum to create velocity-dependent forces analogous to inertial Coriolis forces in order to investigate upper limb motor control (Shadmehr et al., *J Neurosci*, 1994). Unifying principles of movement have emerged from computational studies of motor control: specific models emerging from a computational approach provide a theoretical framework for movement neuroscience. (Wolpert et al., *Nat Neurosci*, 2000). Humans are learning to stabilize unstable dynamics using the skilful and energy-efficient strategy of selective control of impedance geometry (Burdet et al., *Nature*, 2001). Successful manipulation requires the ability both to predict the motor commands required to grasp, lift, and move objects and also to predict the sensory events that arise as a consequence of these commands (Flanagan et al., *Curr Opin Neurobiol*, 2006). As regards lower limbs, evidence for spinal pattern generators in cats and primates, including humans and interaction with sensory signals from limbs was found in different studies. For all species, the sensory feedback from the moving limb is very important to achieve effective locomotor behaviour by adapting to the environment and compensating for unexpected postural disturbances

(Hultborn et al., *Acta Physiol*, 2007). These works have been crucially important for the development of new rehabilitation paradigms following spinal cord injury. Future trends are:

- development of a comprehensive biological theory of motor control in humans;
- integration of contributions from experimental trials using traditional and ubiquitous robotic systems for validating neuroscience-based models and models of limb motor control;
- integration of different technologies (including robotics, mechatronics, wireless technologies) in shared standardized networks for validation in different environments (e.g. home, clinical, workplace);
- development of comprehensive computational neuroscience-based models to be integrated into shared standardized networks (motor, sensory and cognitive prediction in healthy and disabled subjects);
- development of individualized self-adaptive neuroscience-based models for monitoring, predicting and supporting motor, sensory and cognitive behaviours in healthy and disabled subjects;
- validation of self-adaptive neuroscience-based models in healthy and disabled subjects (different classes of disability – motor, sensory and cognitive- and severity);
- integration of individualized self-adaptive models for monitoring, predicting and supporting motor, sensory and cognitive behaviours in healthy and disabled subjects into pervasive networks;
- development of specific pervasive networks for different environments (e.g. home, clinics, workplace) and different needs (healthy young, healthy elderly, disabled subjects);
- validation of individualized self-adaptive specific pervasive networks.

7.3.4 Integration of sensors and actuators in intelligent devices

Sensory fusion strategy

Looking at the current state of the art, intelligent devices for AAL are mainly traditional mechatronic systems capable of reacting to predefined and well-known stimuli with a stereotyped action. The current intelligent devices are not capable of cognitive skills, so they cannot fully adapt to both unstructured environments and user needs.

One of the key features needed to enable cognitive skills is the possibility of implementing a sensory fusion strategy. In many cases, current mechatronic devices, although equipped with several kinds of sensors, lack a real sensory fusion strategy. The sensory-fusion strategy is not a simple integration of data recorded from multiple-sensor system, but a strategy leading to new variables summarizing information coming from both the external unstructured environment and the user. What is expected for intelligent mechatronic devices is a sensory fusion process that starts from all afferent inputs, and by means of a three-step process (i.e. data-dimensionality reduction, features extraction and classification) permits an holistic impression of the external environment. This would be the starting point for intelligent devices to *perceive* the external world instead of simply *sensing* it.

Another important aspect that emerges from the current analysis regards so-called embodiment. This is the idea that biological systems contain something that is called structural intelligence or morphological computation. In other words, the morphology of biological systems is naturally oriented towards performing specific tasks. In this way, biological systems can reduce the effort needed to control their motion. Among others, a critical example is the muscle skeletal apparatus of humans. In fact, the antagonistic muscles powering a joint, because of their intrinsic non-linear elastic properties, make the articulation intrinsically stable and easily controlled.

The combination of sensory fusion and a morphology with computational skill would increase the intelligence level of the device. The idea of defining the roadmap priorities in the short, middle and long term is to gradually decrease the computational effort dedicated to motion control (i.e. the system will have a morphological computation capability) while increasing the efficiency and the effectiveness of the sensory fusion techniques (i.e. the system will be able to perceive the external world holistically):

short term: investigation and development of reliable and efficient sensory fusion strategies; strengthening of morphological computation design paradigm (2015);

middle term: development of platforms integrating both advanced sensory fusion strategies and having morphological computation skills (2020);

long-term: investigation and development of complex high-level strategies using the sensory fusion strategy to promote adaptive perception-action mechanisms (2025).

Mechatronic robotic devices (robotic hand)
An interesting field where the concept of sensor and actuator integration has been exploited is that of robot hands for prosthetics. In fact, in such a field the need for low power, low weight while still retaining "dexterous and sensorized" fingers is of paramount importance. Several examples of intrinsic prosthetic hands in research may be listed: the Southampton-REMEDI hand, the RTR II hand, the MANUS hand and the Karlsruhe hand. The SmartHand prosthesis (Controzzi 2008), developed by SSSA within the PRIN2006 program is an innovative transradial hand because of its tight design that includes actuators, a control system and an extensive sensory system with 40 sensors. Many other examples may be listed: the TBM hand (Dechev 2001), the RTR II hand (Massa 2002), the Soft hand (Carrozza 2005), the KNU hand (Chu 2008). Other significant research related to extrinsic hands used as bionic prostheses platforms include the Cyberhand (Carrozza 2006, Cipriani 2008b), the Yokoi hand (Ishikawa 2000), and the Vanderbilt University prototypes (Fite 2008).

Exploiting RFID technology, sensors will include transceiver units for wireless communication with the host controller. The reduction of wired buses will drastically increase the robustness of devices. Innovative low-power consumption buses for such communication systems will then be available. The development of smaller actuators with high efficiency will allow engineers to fit high numbers of sensors and actuators inside intelligent devices.

Sensor technology will be strongly dependent on silicon development. In 2020 sensors will include programmable digital-signal processing algorithms and filters for the autonomous extraction of its features. Signal processing together with wireless transmission will reduce the burden of the host controller dealing with such sensors. In other words, the actual concept of smart sensor will be carried through to the silicon chip.

Posture and movement support
One of the main topics in which sensors and actuators have been integrated to help elderly people during their daily activities is the reduction in the risk of falls. From the literature it is possible to distinguish: 1) small and powerful sensors/algorithms aimed at gathering information from the state of the subjects (e. g. movement, temperature, heart rate) during daily activities (e. g. walking and sleeping); 2) actuators aimed at supplying energy while subjects, especially seniors, carry out motor tasks.

The main limit of these systems is the low level of integrability. In particular, although there several examples of sensor network worn by subjects that are useful in detecting their state in real time, these are not integrated with devices that are able to help people when they need to recover their balance control. On the other hand, several devices, exoskeleton-like, have been developed to provide power supply when a lack of balance occurs, but these devices usually work in structured and small environments – sometimes they are only integrated in a treadmill-based platform – such that they cannot be adopted during daily activities.

In the next few years, the integration of both sensors and actuators should be made into wearable devices that are able to gather information from the subjects, analyse their balance control and in cases of lack of balance control, supply energy to restore the balance. At this time these devices could still work in structured environments.

Currently, solutions should be found to make these devices work in unstructured environments. Then, reduction of the energy required by the mechatronic components and the development of wearable and rechargeable power suppliers could represent the main roadmap for research.

7.3.5 Internet-connected sensors and actuators

Relatively recent advances in micro-electro mechanical systems (MEMS), in wireless communication and in digital electronics have allowed the development of low-power and low-cost sensors to communicate wirelessly within a limited range. The integration of a large number of these kinds of sensor has led to the idea of developing large wireless sensor networks (WSN) able to monitor different parameters (including positions, temperature and humidity. These pervasive networks are able not only to sense important parameters of the environment but also to provide some actuators that can act based on the sensed data. The use of the Internet to supervise these networks, to gather data and to command some actuators inside the networks, greatly increases the impact and the utility that WSN can have in different applications, such as environmental monitoring, healthcare, home automation and commercial applications. Different research projects are intended to demonstrate and investigate the potential of WSN: in the GoodFood project, for example, a WSN was implemented in a vineyard, to monitor in real time physical and chemical environmental parameters.

However, the integration of sensors and the Internet presents some issues that have to be resolved in the near future to fully exploit the capabilities of WSNs. The first problem is that of addressing over the Internet – the available number of addresses is low with respect to the huge number of sensors that we would like to control individually. The second issue is the standardization of “smart sensors”. Much research has been undertaken on these smart sensors providing plug-and-play features, but a true standardization is needed to exploit the ease of integration of different kinds of smart sensor into increasingly complex WSNs.

The IPv6 standard will allow a large number of available addresses for the sensors of the WSNs and standardization for the smart sensors will probably be present; in fact, the IEEE1451 standard family is already moving in this direction. These two factors will allow WSNs with a large number of sensors to be easily controllable by the Internet. Furthermore, the sensors will be easily integrated into the networks. WSNs will become a very reliable and mature technology, popular and in widespread use in many everyday applications. For example, they will be widely used in the medical field to provide an interface for patients affected by some forms of handicap; they will be used to monitor physiological parameters. In the home-automation field, sensors will be deployed in different domestic devices such as refrigerators and central-heating system, so as to provide interconnected services to the user which can interact with different devices from any location by means of the Internet. They will also be in widespread use in farming, enhancing the quality/quantity of produced food.

The idea of inserting actuators in networks will be investigated further, considering as actuators robots that can move in the environment.

Currently, robotics will probably be so mature as to be enabled to move in unstructured/partially structured environments integrated in a WSN. The challenges that have to be faced are mainly issues involving the localization and navigation of the robots in an autonomous/semi-autonomous way. The robots will greatly enhance the effectiveness of WSNs because they will provide a double benefit to the networks: they will be movable sensors, enabling the network to investigate locations where no sensors are present and they will also act as movable actuators, being able to intervene in every location of the workspace. For example, robots could move to help people whenever WSN realizes they need it.

In parallel to the use of moving actuators, the sensors will provide enhanced self-configuration capabilities, will present reduced dimensions/weight and will have an extremely low power consumption. These features will enable wider integration in everyday life applications and in diverse field applications.

WSNs will be in widespread use in the environment in which we live, enhancing the quality of our lives. The reduced dimensions of the sensors, the ease of their integration in the WSN and with the Internet will bring technology in every area of everyday life. WSNs will allow recognition of the user while he or she moves along roads, providing personalized services. Furthermore, sensors embedded in people’s clothes will monitor the health of the user, sending requests to an ambulance to collect the patient when some parameters vary from standard values.

The large numbers of sensors immersed in the environment will provide real-time information on dangerous situations: the fast response that a human or robot could give based on this information would be essential in preventing disasters. For example, a fast intervention when a fire starts would solve the problem before it becomes out of control.

Robots will be commonly present in roads and they will move around autonomously: a WSN will decide when and where the robots have to move to in order to provide their services, considering both environmental parameters and information coming from people.

In addition, people will have own personal robots, which will provide some help in everyday life.

However, this immersion of human users into wireless networks will raise issues in terms of security and privacy. These issues have yet to be tackled and solved.

7.3.6 Domotics and "smart home" appliances and objects

Researchers at the House_n research group at the MIT Department of Architecture are investigating how the home and its related technologies, products and services should develop to better meet the opportunities and challenges of the future. Using a strongly interdisciplinary perspective that integrates backgrounds of computer science, user- interface design and usability, architecture, mechanical engineering, psychology and materials science, the House_n research team is aiming at creating design strategies for more flexible environments that better meet occupants' physical and cognitive needs by: 1) demonstrating a new type of building methodology that makes it possible to embed technology within the infrastructure of environments and then easily change and upgrade it; 2) providing an environment in which to study home life scientifically, particularly the relationships between space and information; and 3) providing a means for evaluating whether new types of pervasive computing interventions have a long-term and meaningful impact on behaviour in the home (Intille 2002, S. 76–82) (Intille 2005, S. 79–88).

The Gator Tech Smart House (Helal 2005) was defined as a programmable pervasive space, specifically designed for disabled and older users, and as "an assistive environment that can sense itself and its residents and enact mappings between the physical world and remote monitoring and intervention services". The concept of the GatorTech Smart House is comprehensive, and it describes a pervasive distribution of intelligence and sensing throughout the home environment. In order to allow such a deployment of technology-based services, the GatorTech research group at the University of Florida developed a generic reference middleware architecture, applicable to pervasive computing spaces in general, and composed of separate physical sensor platforms, service, knowledge, context management, and application layers, built around the Open Services Gateway Alliance (OSGi) (OSGi Alliance 2008) framework.

The Aware Home Research Initiative started in 1999 at the Georgia Institute of Technology, with the construction of a house composed of a couple of identical flats, and the definition of two research agendas: a technology-centred one focused on context awareness and ubiquitous sensing, on person-environment interaction and on specific solutions like a "smart floor", or a "Frequently Lost Objects finder"; and a human-centred one, addressing as specific applications those providing support to older people ageing in that place, for example at home (Kidd 1999, S. 191–98). Some examples of the applications developed in the framework of the Aware Home Research Initiatives are: the Gesture Pendant, a wireless device to be worn around the neck, with an embedded camera and motion sensors, that can monitor user- activity levels and accept commands in the form of hand gestures; the Cook's Collage, a prototype system providing surrogate memory support for general cooking tasks, by emphasizing the temporal order of cooking events and arranging visual snapshots as a series of panels, similar to a comic strip, on a flat-panel display mounted on a kitchen cabinet; the Digital Family Portrait, an in-home monitoring system that informs family members about an older relative's daily activities, health status and potential problems, by creating a visualization of the older person's day at home from available sensor information and displaying the information to a family member in a different location by means of iconic representations of information (Mynatt 2004, S. 36–41).

Household robotic appliances

Personal robots are being investigated also as robotic appliances. An example (Yoshimi 2004) deals with the need for simplifying the use of home-network systems, whose usability, in particular by older users, is often quite low. In this framework, a Robotic Information Home Appliance is conceived as an advanced human interface aimed at connecting advanced home appliances or information equipment and their users, and making control of such apparatus easier.

The most successful robotic appliance is the iRobot Roomba, a consumer floor-cleaning robot based on an idea developed as a prototype in 1989 for a students' competition at the Mobile Robotic Group at the MIT Artificial Intelligence Laboratory. The development of the commercial version of the robot – as reported by the author – was led by five principles: application is primary, cost matters, only real-world testing can reveal a robot's flaws, "usually" is unreliable and complexity kills (Yoshimi 2004).

Floor cleaning has been until today by far the most successful application for household robots; besides the iRobot Roomba described above, a number of other products have reached the consumer market during the last five years, especially in Korea, where service robots with floor-cleaning functionalities have been developed among others by Hanool Robotics and by Samsung Electronics.

Most products constructed so far have not been able to successfully move from the status of prototype to commercial product for a number of reasons, including cost, design and acceptability issues, insufficient focus on application and the fact of often being designed to satisfy the "special needs" of a specific user group.

Besides this, consumer robotics – and in general, all technologies for AAL – suffer from an important lack of universally accepted standards to support multi-part development of interoperating devices and systems.

Several attempts have been made during recent years aimed at developing a common software control architecture that can operate a large class of robots for a large number of applications: this has been identified as one ultimate goal for robotics. Such an architecture needs to be defined as independent of the specifics of robot hardware, its sensors and actuators, its geometry, its mechanics, its dynamics, the target application and the environment. Suggestions for universal standards include the OPEN-R framework developed by Sony for the AIBO entertainment robot (Ken'Ichi 2004), the Evolution Robotics Software Platform and Architecture (Pirjanian 2005), and the URBI framework (Baillie 2005).

7.3.7 "Artificial beings" (service and companion robots)

Service robot development is defined by the EURON Consortium as the art of integrating technologies and embedding systems into existing environments. As pointed out in the case studies described in the 2004 EURON Research Roadmap (EURON 2004), the way towards a competitive and marketable system depends on the following factors:

- Rigorous systems approach. Given overall requirements in terms of cost effectiveness and quality of task-execution, a design is valued by:
  - its integration into existing environments;
  - user acceptance regarding physical appearance and usefulness;
  - compatibility to user's investment and service policies;
  - the qualification requirements of its users;
  - clear interfaces to its embedding environment and the user.

- Development and system costs. In contrast to industrial robots, service robots are designed for specific tasks generally taking place in an unstructured environment with the possibility of direct human-machine interaction. Cost advantages can be achieved by using application-independent components or subsystems with key functionality. In this context the components are both hardware and software.

- Technical requirements. Numerous components of service robots can be adopted from industrial-robot technology. However, the need for significant extensions in functionality and increased performance of components or subsystems is obvious for many applications:
  - environmental perception and modelling;
  - navigation (in dynamic environments);
  - task planning;
  - interaction and communication with human and the environment.

- Safety. In many cases, task execution by service robots takes place in public areas and therefore requires well-defined human-machine interaction. Existing safety regulations are often difficult to apply and may also limit the available workspace considerably.

Only a few industrial robot manufacturers have entered service-robot development and manufacturing. Most companies offering service-robot solutions have either built up their own advanced robot technology or accessed it through partnerships.

A large variety of service-robot applications with significant installation numbers seems now to be within reach. To address these applications, a coordinated and integrated approach to research and development within a network of service-robot users, research organizations, and component- and system manufacturers is needed.

In a later version of the Roadmap, the EURON Network focused more specifically on the application area “Adaptive Robotic Servant in Intelligent Homes”, which shows significant overlapping with AAL.

Objectives in this application area are identified as:

- time saving in daily repetitive work;
- having a companion and a servant/assistant;
- personal robots adaptation to individual needs;
- exercising robots;
- medical support;
- reaching high acceptance by inexperienced users;:
- 24-hour service in household environments;
- robots in environments dangerous to humans;
- mobility;
- incremental development of robots.

The EURON Network identifies the following scientific challenges:

- Architecture and components:
  - plug-and-play systems;
  - comparability.

- End-effectors (hands):
  - two-handed manipulation;
  - zero-inertia manipulation;
  - control of mechanically flexible systems.

- Head:
  - coordinated eyes and ears;
  - focus of attention and visual serving.

- Affective interfaces:
  - haptics for interaction as well as for grasping.

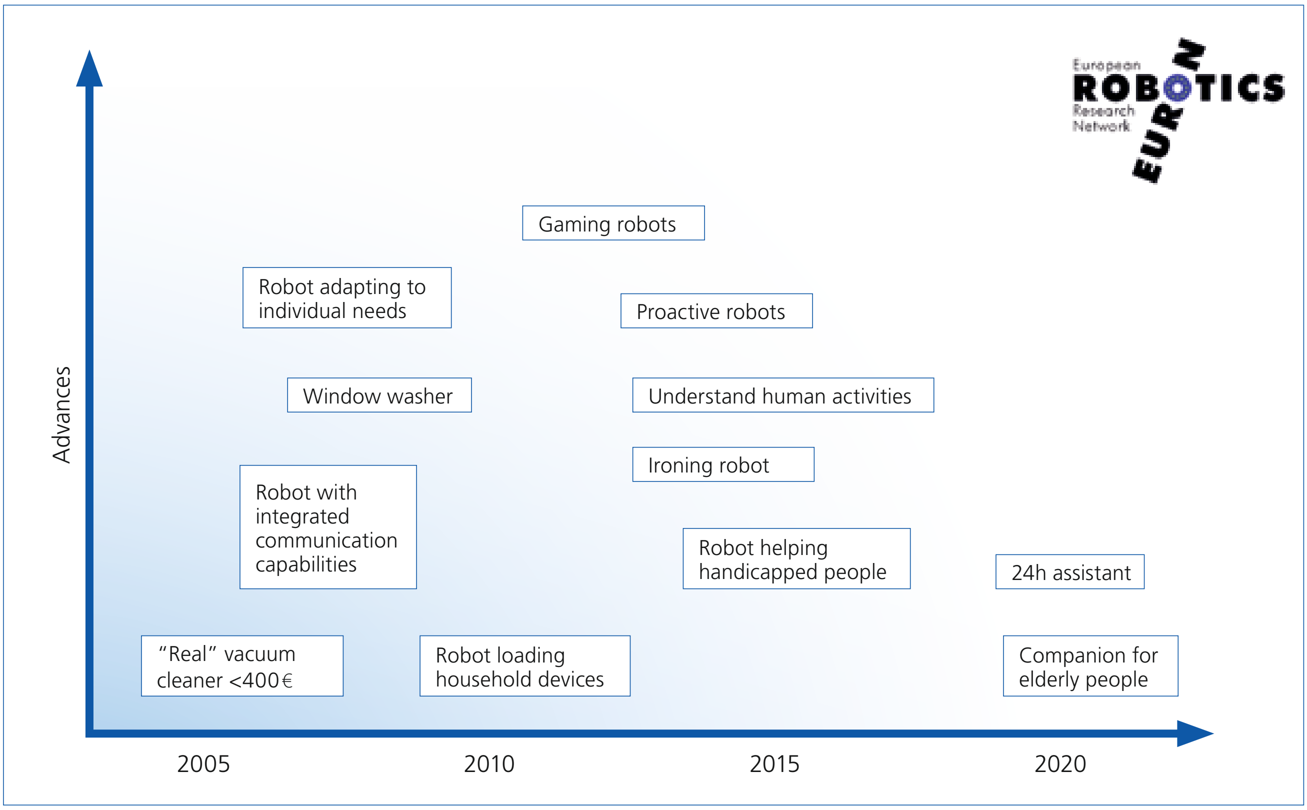
- Interface for teaching and advice;
- Cognitive systems;
- Representations:
  - semantics + language.

- Learning, generalization and action generation:
  - actions, skills and tasks;
  - situation assessment;
  - decision making;
  - planning;
  - new object manipulation and grasping.

- Autonomy:
  - zero-maintenance robots;
  - self-evaluation, failure analysis, self-optimization, self-calibration.

- Multi (and rough) terrain mobility;
- Reliability;
- Real-time control;
- Design methodologies:
  - build systems that can be verified.

Roadmap 12: Adaptive Robot Servants & Intelligent Homes (EURON 2004)



- Dynamic environments, open-endedness, scalability;
- Perception:
  - object categorization + recognition;
  - real-time constraints.

- Human-Robot, Robot-Robot and Robot-environment cooperation;
- Navigation in cluttered dynamic environments.

Based on the objectives and challenges listed above, and on Technological Drivers, research priorities are identified by EURON as follows:

- Human robot interaction;
- Long-term autonomy in general environments:
  - mobility;
  - 12 months without reboot;
  - adaptation.
- Cognition:
  - representations;
  - learning, reasoning and planning;
  - symbol grounding.

- Complex manipulation:
  - flexible manipulation (flexible materials and manipulators);
  - multi end-effector manipulation.

- Architectures and control:
  - software engineering.

- "Active" perception;
- Hardware development.

A complex technology roadmap on robotics is included in the Technology Roadmap for Japan, edited by NEDO (New Energy and Industrial Technology Development Organization), Japan's largest public R&D management organization for promoting the development of advanced industrial, environmental, new energy and energy conservation technologies.

Figures 16 and 17 provide a snapshot on Japan's vision on robotics and service robotics evolution in the next 15–20 years.

Ubiquitous Robotics/Network Robots paradigm
Ubiquitous Robotics is a new, emerging paradigm that is related to the fields of Ambient Intelligence and Ubiquitous/Pervasive Computing. Ubiquitous Robotics arises from a shift of focus, from information to matter and physicalness: networked, ubiquitous robotic system will therefore convey data and physical actions, like motion and forces, in intelligent environments, leading to a profound and pervasive impact on virtually all new products and at different levels: global, local, "personal", external and internal, macro and micro/nano, etc.

By going beyond robotics and mechatronics, and even beyond "traditional" ICT, the new envisaged scenario will provide far wider application to individual users and to communities in a broad sense.

An overview of current research in the field of Ubiquitous and Network Robots is provided in a white paper produced by the EURON Special Interest Group on Good Experimental Methodology: (Two "Hot Issues" in Cooperative Robotics: Network Robot Systems, and Formal Models and Methods for Cooperation) (Bonsignorio 2008).

Figure 16: Japan's general roadmap on robotics (2006)

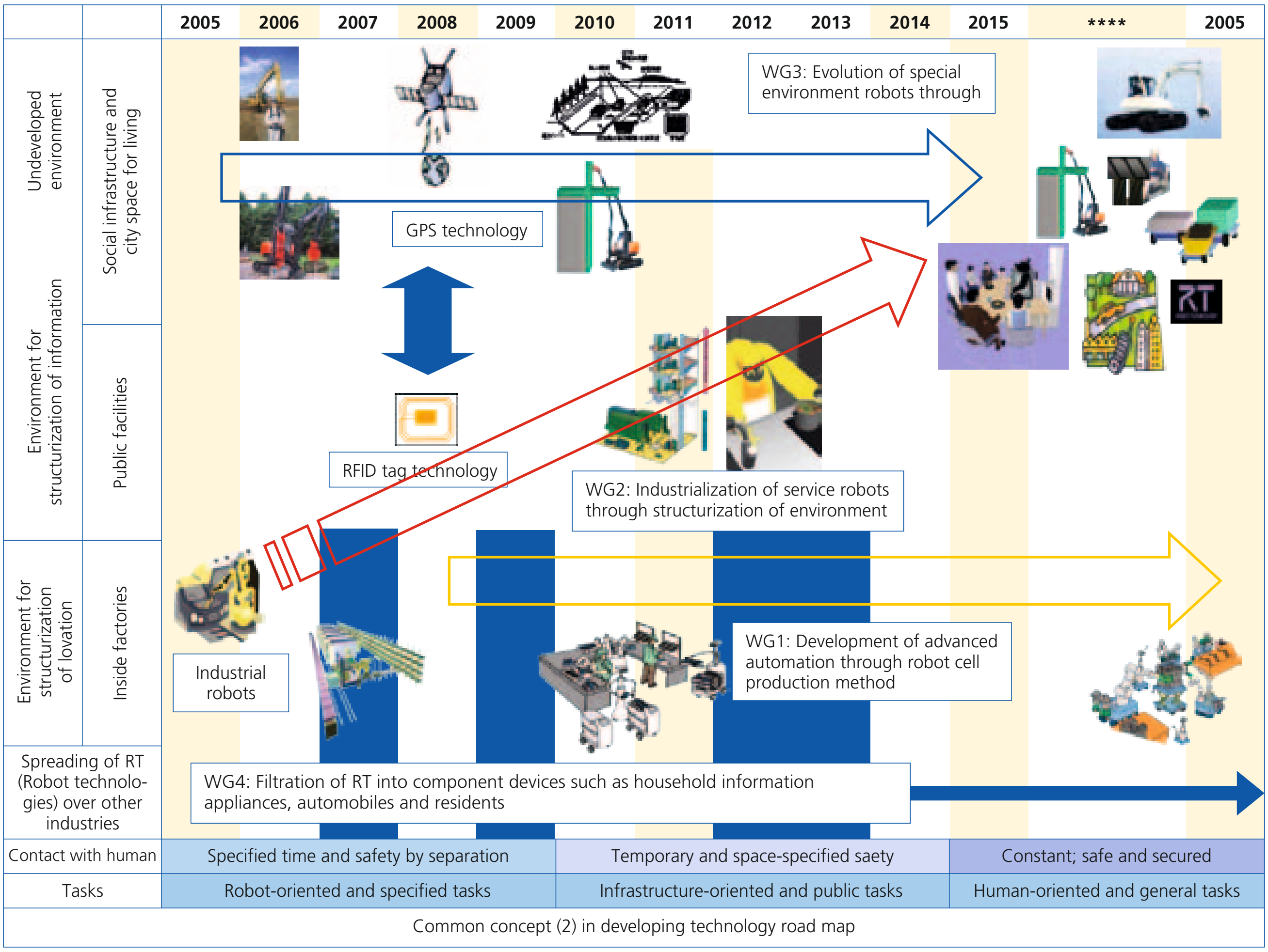
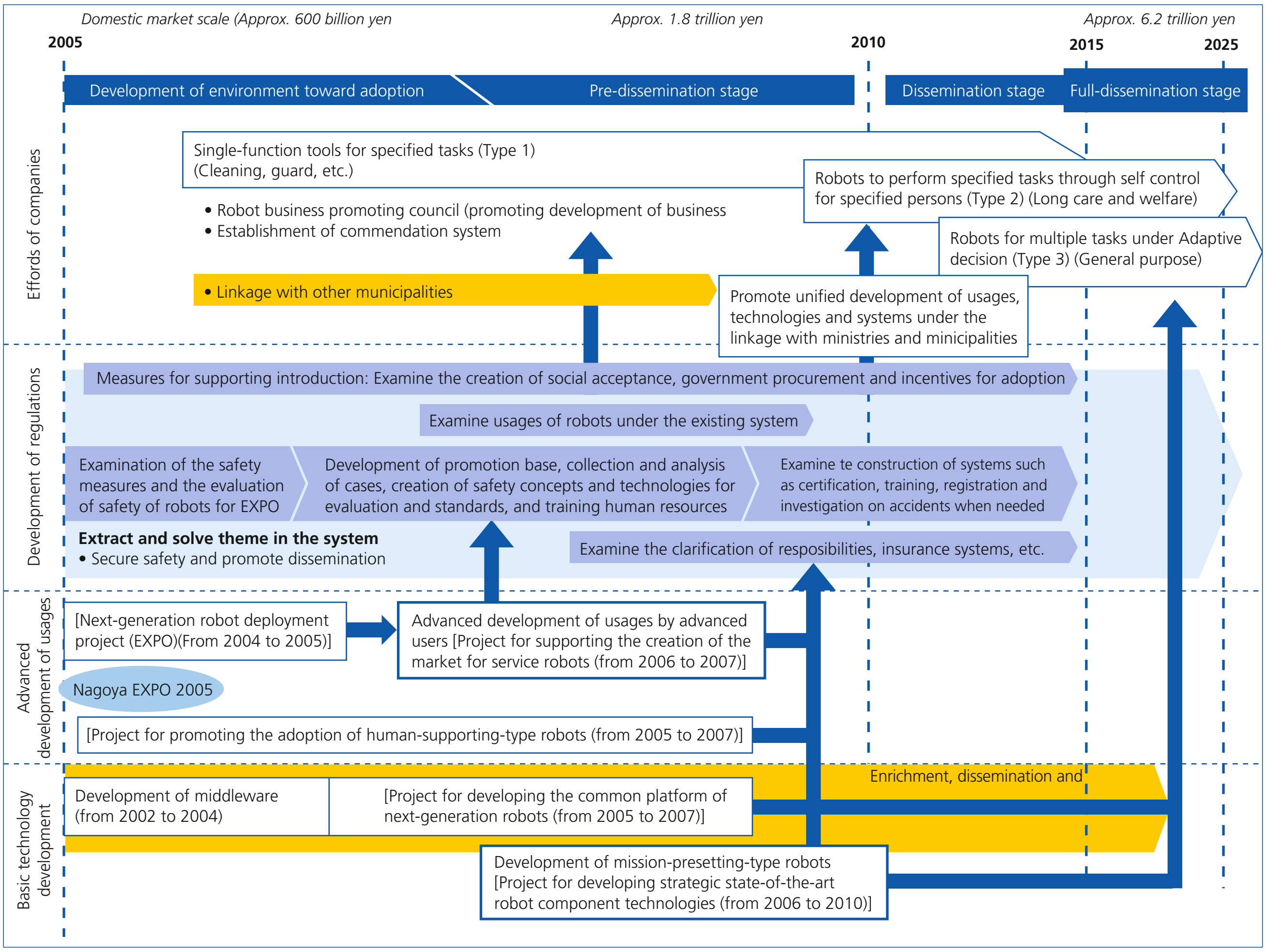


Figure 17: Japan's general roadmap on service and personal robots (2006)



Ubiquitous Robotics in Japan and Korea

The concept of Ubiquitous Robotics first appeared in East Asia, almost simultaneously in Korea and in Japan; its better name is Network Robots.

The Korean concept of Ubiquitous robot (Ubibot) was introduced in 2004 as the third generation of robotics. The Ubibot paradigm incorporates three forms of robot: software robot (Sobot), embedded robot (Embot) and mobile robot (Mobot), which can provide users with various services by any device through any network, at any place anytime in a ubiquitous space.

Sobots are virtual robots, which are able to move to any place through a network; Embots are embedded within the environment or in a Mobot; Mobots provide integrated mobile services, which are seamless and context-aware.

Research on Network Robots in Japan is mainly led by the National Institute of Advanced Industrial Science and Technology (AIST), which has developed a system prototype in 2006, resulting from the combination of robotic techniques with IC tags, a face authentication system and a network node using a middleware technique (RT middleware), in a human living environment.

A European approach to Ubiquitous Robotics: PEIS

The fusion of robotics and ambient intelligence is being explored from different perspectives also in Europe. One example of a European approach to this process is the concept of an Ecology of networked Physically Embedded Intelligent Systems, or PEIS (Saffiotti 2005). The PEIS Ecology is aimed at providing cognitive and physical assistance to the citizens of the future, and help them to live a better, safer and more independent life.

The concept of PEIS Ecology draws together insights from the fields of ambient intelligence and autonomous robotics to generate a radically new approach to building assistive, personal and service robots. Most current approaches to building a "robot companion" aim at building one isolated robotic device (often human-like) empowered with extraordinary abilities for perception, action and cognition. By contrast, the PEIS-Ecology approach redefines the notion of a robot to encompass the entire environment. Perception and manipulation of objects are therefore replaced by direct communication between subsystems in the environment. In the PEIS-Ecology vision, the robot would disappear in the environment in the same way as computers should disappear according to the well-known vision of ubiquitous computing.

Standardization issues

Standardization in the field of Ubiquitous/Network Robots is an important issue and a critical technological challenge. Many initiatives and pilots are being developed in the world in this domain, but in most cases they are carried on without coordination.

This often leads each research group to independently develop different instances of the same components – especially software components, and especially middleware layers.

An attempt to develop a standard in this field is being pursued by the Robotics Domain Task Force of the OMG (Object Management Group), the most important standardization organism in the field of modelling (UML – Unified Modeling Language – and MDA – Model-Driven Architecture) and middleware (based on CORBA).

The purpose of the Robotics Domain Task Force is to foster the integration of robotics systems from modular components through the adoption of OMG standards. To realize this purpose, the DTF:

- Recommends adoption and extension of OMG technologies that apply to the specific domain of robotics systems where no current baseline specifications exist, such as MDA for Robotics. The object technology is not solely limited to software but is also extended to real objects. This effort promotes the use of OMG technologies in various markets.
- Promotes mutual understanding between the robotics community and the OMG community.
- Endeavours to collaborate with other organizations for standardization, such as the one for home information appliances, making an open effort to increase interoperability in robotics.
- Coordinates with the appropriate OMG subgroups and the Architecture Board in technological areas that overlap with other OMG Task Forces to determine where the work will be accomplished.

7.4 Interacting (interfaces)

The convergence of pervasive computing, ambient networks and intelligent-user interfaces has enabled the development of ambient intelligence and associated services. Human beings and machines will be surrounded by intelligent interfaces supported by computing and networking technology in everyday objects. This will lead to situations in which the environment is "aware" of a human or agent presence, and in which the agents and devices are aware of their environment and of their location. Taking into account the individuality and current activities of the person present and the behaviour of machines, services will be capable of tracking users and of responding intelligently to all kinds of interaction technologies.

The intelligent interaction for people with systems and services is an important aspect for applications and will have specific requirements to cope with people's abilities.

This vision of AAL is firmly based on technological developments. Technological advances enable the design of new functions and features. These new functions and features could well support people who need help, e.g. by assisting people in their daily activities, by creating social networks or by stimulating healthy behavior. Ideally, AAL products and services

Roadmap 13: Interacting

Cathegory	2010–2015	2015–2020	2020–2025
Design Process	Common generic interface standards Toolkits Living Labs		
Initiative	User initiative, adaptable interfaces	Mixed initiative, self-adaptive interfaces	Avatar robots, brain-computer interfaces Social + emotional awareness
Modalities	Local (touch) screen-based	Rich interaction through distributed objects	Avatar robots, brain-computer interfaces
Awareness	Context-awareness of predefined factors	Learning	Social + emotional awareness
Connectivity	Standalone products (including mobiel phones)	Products networked inside home	

support people in dealing with real-world problems, are intuitive to use and automatically adapt to user needs and context of use.

The present focus on technology-related issues might result in products and applications that do not relate to problems in the field. Furthermore, the ever-increasing system complexity might affect usability and product adoption. Whereas traditional desktop solutions are linked to a single user and single location, AAL products and services tend to be distributed across a wide area, resulting in a dynamic context of use. The use of context-aware technology enables dynamic system behaviour in order to manage these changing contexts. The increase in system adaptation might however lead to usability problems, and consequently to problems related to product adoption (Jameson 2003, S. 305–330). In terms of creating adoptable assisted living solutions, the delicate balance between user-perceived benefit and user-perceived complexity (Vastenburg 2008) should be constantly kept in mind; end users tend to be hesitant towards adopting new technology.

Context-aware systems are still relatively new, and the design process towards creating adoptable solutions is still under development. The current trend towards setting up living laboratories in which product concepts can be easily tested in the field supports designers by providing user feedback on design concepts. Concepts can be improved in fast iterations based on this realistic feedback.

Design process

The interaction-design process, which results in user interfaces for the AAL applications, is a structured process. End users are generally involved throughout the design and development process. Whereas the early stages of the design process tend to be paper based (using for example paper mock-ups), the later stages tend to be based on working prototypes. The development of prototypes and stable systems can be facilitated by providing common interface standards, design guidelines and toolkits. Furthermore, the user-testing phase can be supported by providing living labs, which enable designers to make fast design iterations based on user feedback in a realistic setting.

Connectivity

Nowadays, most products in the home are standalone. Each product has its own unique user interface, and end users need to learn how to use each new product. Product connectivity is increasing due to the rise of home networks including WiFi and Bluetooth. It is expected that products will be increasingly linked together in such a way that users can choose the appropriate user interface based on the context of use and can control all functions available in the home. For example, a user might use the mobile phone for dietary advice, or use the television screen to order groceries. Eventually, virtual avatars or avatar robots could serve as a common interaction device for accessing functions in the home.

Awareness
A central theme in AAL is context awareness. Systems will be aware of the context of use, including living patterns and user preferences. These patterns are different for each user, for each location and in time. Context awareness enables personalization and adaptation of user-system interaction, for example by providing medical information that is relevant to the actual stage of a disease of an individual. Whereas a system would ideally automatically infer the exact state of the context, it is expected that user input will be needed to interpret the sensor data. To create trusted products, we should therefore make sure that users can inspect and update system information at an appropriate level.

7.5 Communicating

Because AAL is based on ideas from ambient intelligence, it means that infrastructures are becoming pervasive, with an increasing number of distributed devices that can communicate between themselves as well as with centralized services. Moreover, in the context of mobility, temporary co-location of such devices can be exploited to build networks dynamically without a pre-existing infrastructure, or to complement existing infrastructure by an ad-hoc one. Important issues in this context are the discovery of devices by others, and processes for devices to join a network, e. g. pairing.

Sensors and actuators are connected to one or more aggregating or reasoning systems which in turn might be connected (including dynamically, e. g. a person moving from home to vehicle to some public space) to other systems with optional additional actuators connected to them. Next, there is communication between people in the context of certain tasks or activities and the communication of people with local and remote systems or services. Communication is more than just connectivity: it also involves the exchange of information and the ability to understand the information leading to the following list of issues.

Connectivity and protocols

- For personal area networks, local area networks and wide area networks multiple alternatives exist. For an approach where multiple products, application and services have to collaborate, choices have to be made.
- Products in the personal-area network or local-area network might still have an alternative or even proprietary technology as a kind of peripheral interface to sensors as long as a control unit supports the connection to the PAN or LAN network. A home-control unit can, for instance, have X10 interfaces to sensors or switches and a WiFi interface to other devices.
- For the wide-area connectivity, we have to rely on technology which is available from telecom or cable domain. The choice might be different for each region, according to the offers by telecom companies, but it is certainly based on Internet protocols; however we should remember that a transition from IPv4 to IPv6 is coming.

Data exchange

- The exchange of data is important when systems and services have to collaborate. To enable usable data exchange, agreements on messaging formats and data models within the message are important. In the healthcare domain, also for tele-monitoring, standards are available. In practices, interoperability and integration of systems of tele-monitoring devices in a home environment remains an issue (in January 2009 the first CONTINUA compliant monitoring device came onto the market). In other domains, like home control, safety and alarm systems this kind of standard is lacking.

Understanding data

- The understanding of other authority’s data is important when systems and services have to collaborate and reasoning needs to take place on the aggregated information. To understand data, vocabularies, unit codes and ontologies have to be defined. For the healthcare domain, such standards are already available, although they are not in use everywhere, and especially in trans-mural settings, interoperability and integration of systems still remains a significant issue. In other areas, such as home control, safety, and alarm systems this kind of standard are still lacking.

Dynamic composition of systems and services
Ultimately, each object can be abstracted as a service provider that can be compounded with others. In this context, service-oriented architecture technologies enabling standardized ways of modelling, discovering and negotiating – for example the exchange formats, reserving and composing services – are essential. They need to involve appropriate levels of semantics to enable automated service composition; there is for example the objective of semantic-web technologies for networked services.

- In the area of PAN and LAN networks, the dynamic configuration of systems is important because people are moving through a home or even outdoors, so not all systems might be within reach all the time. This requires facilities for auto-configuration, registration and discovery. Multiple alternatives are available so choices have to be made here with respect to which technologies to use.
- In the area of Web-based services many standards exist and choices have to be made:
  - basic web services technologies and standards: SOAP, REST, UDDI, Web Services Description Language (WSDL), Web Service Modeling Language (WSML);
  - collaborating web services: WSFL, ebXML, BPEL4WS, BPML/WSCI, XLANG;
  - semantic web services: RDF, OWL, OWL-S, Web Services Modeling Ontology (WSMO), Semantic Web Services Framework (SWSF), Semantic Web Services Language (SWSL), Semantic Web Services Ontology (SWSO);
  - ontologies, vocabularies and coding systems: from the healthcare sub-domain: SNOMED, ICD and LOINC, and also: Standard Ontology for Ubiquitous and Pervasive Applications (SOUPA), Context Ontology (CONON), The Unified Code for Units of Measure.

Security
- Security, confidentiality and privacy are issues which should lead to dependable and trusted solutions. Challenges in this area are:
- protection of unauthorized access, requiring identification and authorization not only for people but also for devices and services;
- certificate handling for devices to ensure the identity, and the related quality aspects, of a device to other devices and services;
- protection of privacy: anonymity, pseudonymity, unobservability and unlinkability – technologies such as cryptography and steganography, for example trusted third-party services;
- safe buying and selling on the Internet – technologies such as electronic identification for applications such as electronic trading;
- creating easy, reliable and secure personal identification – technologies such as electronic signatures;
- keeping track of electronic transactions – technologies such as services for trusted data management: a networked environment where the security, confidentiality and privacy of data can be trusted, for applications such as an electronic notary;
- to achieve trustworthy and dependable distributed systems solutions in the area of autonomous computing are needed;
- single sign-on for ease of use.

Network properties
- Speed might be a selection criterion, especially when high-volume streaming data or real-time data is involved. Within the current technology offers, high- bandwidth solutions are available: wireless in personal area networks 100 Mbps, wireless local area or home networks more than 100 Mbps networks, wired-home networks 200 Mbps for HomePlug, 10–100 Gbps for Ethernet. For wide-area networks, the offerings vary from provider or subscription, from 1 Mbps to more than 100 Mbps.
- Ease of installation is an important issue, especially for existing houses. The ideal is to use no new wires, which means in practice using wireless technology (WiFi) or recently using powerline (Homeplug). This might be a solution with respect to hardware but software configuration problem, configuring firewalls, network address translators etc. still remain. Solutions from the area of dynamic composition could help here and with a transition towards IPv6 auto configuration could mean progress.

7.5.1 Personal or body network context

In this context, the connectivity, communication and data exchange from PAN devices between each other and with one or more devices in the LAN network is realized. This means that besides basic connectivity and communication protocols message formats are also important. Potential technologies are:

- basic connectivity and communication: IEEE 802.15 (1.3a.4.6), Bluetooth, Zigbee, Z-wave, USB, UWB, RFID and NFC.

The network should be able to handle dynamic configurations, so that registration and discovery or pairing protocols are needed. Potential technologies are:

- Bluetooth, Zigbee, Z-wave;
- UPnP;
- device profile for web services.

Security is a topic when it relates to safety (prohibiting unauthorized access to certain devices and especially to the application-hosting device) and transfer of sensitive data (e.g. healthcare data). Important issues here are: pairing procedures, bi-directional authentication, certificate handling and encryption.

In this area, the need for electronic readable or accessible product information for e.g. medications and food also needs to be mentioned. The Electronic Product Code (EPC) defines a message format.

7.5.2 Local or home network context

In this context, the connectivity, communication and data exchange between devices in a local area network is considered and basic connectivity and communication protocols and standardization of messages is important. Potential technologies are:

Basic connectivity and communication

- IEEE 802.15 (1.3a.4.6), Bluetooth, Zigbee, Z-wave, UWB, Homeplug (using in-home power-line);
- Internet protocols and web based protocols (http, https);
- specific networks, some usable on several physical layers, in local setting might be used e.g. in the home control area: X10, or more recent alternatives LonWorks, and INSTEON. KNX, the successor to three previous standards: the European Home Systems Protocol (EHS), BatiBUS, and the European Installation Bus (EIB) is a widely accepted (CENELEC, ISO, ANSI) protocol for home control and is able to run across several physical layers.

Data exchange

- in the healthcare sub-domain a number of standards for data exchange exist like ISO/IEEE P11073-10404, USB device class for personal healthcare devices, Bluetooth health device profile.
- in the home control and security sub-domains broad accepted technologies are lacking.

The network should be able to manage devices and applications and to handle dynamic configurations. Potential technologies (some of them shared with the personal area networks) are:

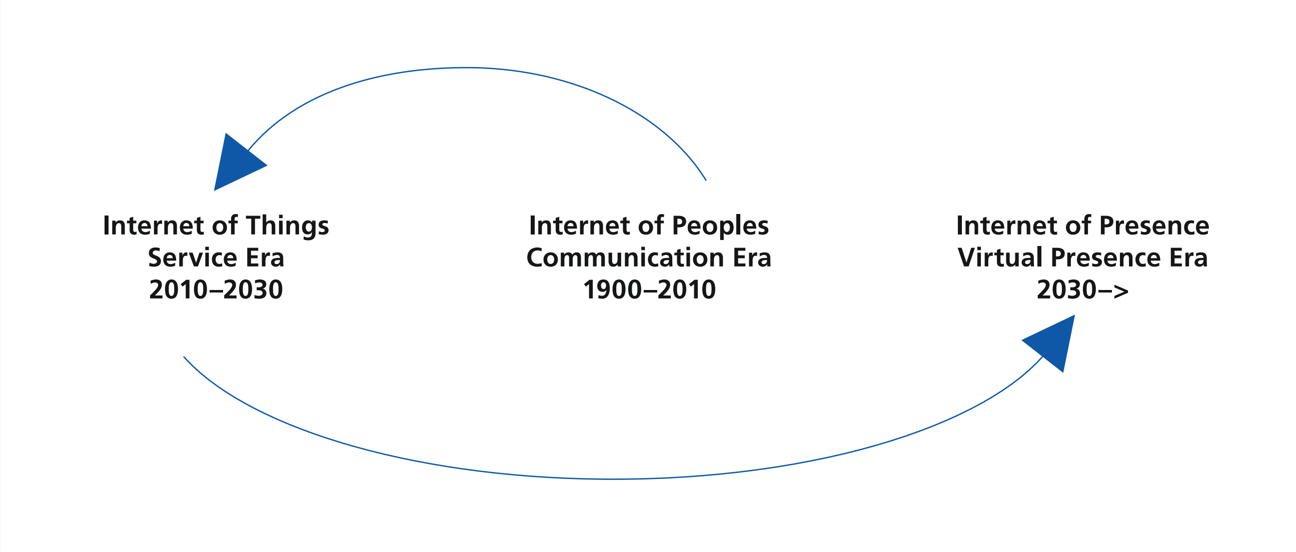
- Bluetooth, Zigbee, Z-wave;
- universal plug and play;
- device profiles for web services;
- open service gateway initiative.

Security is a topic when it relates to safety (the prohibition of unauthorized access to certain devices and especially to the application-hosting device) and transfer of sensitive data (e.g. healthcare data).

7.5.3 Public area context

A personal device to a system communication in a public area connects the home or mobile devices with services somewhere on the Internet and also to services on the Internet with each other. In-home devices might use the in-home LAN interface to connect to these external networks.

Figure 18: The future of communication



Connectivity in the wide-area network domain is mostly based on using the Internet, hosted accessibly through different access networks:

- landline based: ADSL, CATV cable, and fibre-optic to home;
- wireless/mobile (GSM/GPRS, EDGE and UMTS and future technologies as developed e.g. by 3GPP), wide-area wireless broadband networks like WiMAX.

Data-exchange facilities beyond the common Internet data-exchange facilities are available through telecom services like SMS and IMS, which might be relevant in mobile setting and as reminder service.

Besides the data exchanges between devices and services, remote control and access through mobile devices like mobile phones is important, which further emphasizes the need for security solutions.

7.5.4 Evolution of communication capabilities

The following diagram, proposed by Nokia, predicts the way communication capabilities are used over twenty years:

1) The current **Internet of Peoples,** i.e. Communication era connects people via recognized artefacts.
2) The future **Internet of Things,** i.e. Service era connects artefacts to serve people. Transmission capacity limits solutions. An awareness of home scenario suits this era. AALIANCE is for this era.
3) The distant future **Internet of Presence,** i.e. virtual presence era connects people again so that the artefacts are transparent. Transmission capacity does not set limits.

The vision of the "**Internet of Things**" (Internet of Things in 2020 (2008)) era can be described as "Interconnected objects having an active role in Internet networks". It is foreseeable that any object will have a unique way of identification in the coming future, creating an addressable continuum of computers, sensors, actuators, mobile phones; i.e. any thing or object around us. Having the capacity of addressing each other and verifying their identities, all these objects will be able to exchange information and, if necessary, actively process information according to predefined schemes, which may or may not be deterministic.

With respect to AAL, the integration of communication capabilities between objects with RFID tags, sensors and actuators into hybrid wireless sensor networks is of utmost importance and these networks are characterized by modularity, reliability, flexibility, robustness and scalability. It is to be expected that the Internet of Things will exhibit a high level of heterogeneity, as totally different objects in terms of functionality, technology and application fields will belong to the same communication environment. Real-time communications will be possible not only by humans but also by things at anytime and from anywhere. The advent of the Internet of Things will create a plethora of innovative applications and services, which will enhance quality of life.

The big vision for the "**virtual presence era**" can be described as a geographically distributed home. A geographically distributed family (including, e.g. grandmother) is joined by communications that are transparently together with an impression of presence (tele-presence).

- The home of this big family is geographically in several places (father's location, mother's location, adult children's location, grandmother's location or even certain working locations. The members of the family feel that they are somehow in a common space.
- In proper virtual tele-presence, e.g. older people have a familiar gestalt that is present transparently and remotely in every life.
- Virtual presence can be implemented, e.g. a wall as a window to other parts of the home. A wall acts as a big screen so that those inside the home feel as if there were only a big glass between them and other locations.
- Virtual presence can be implemented, e.g. using some kind of human-like robots.
- Virtual presence requires either huge transmission capacity or advanced human like robotic development.

8 AAL systems composition

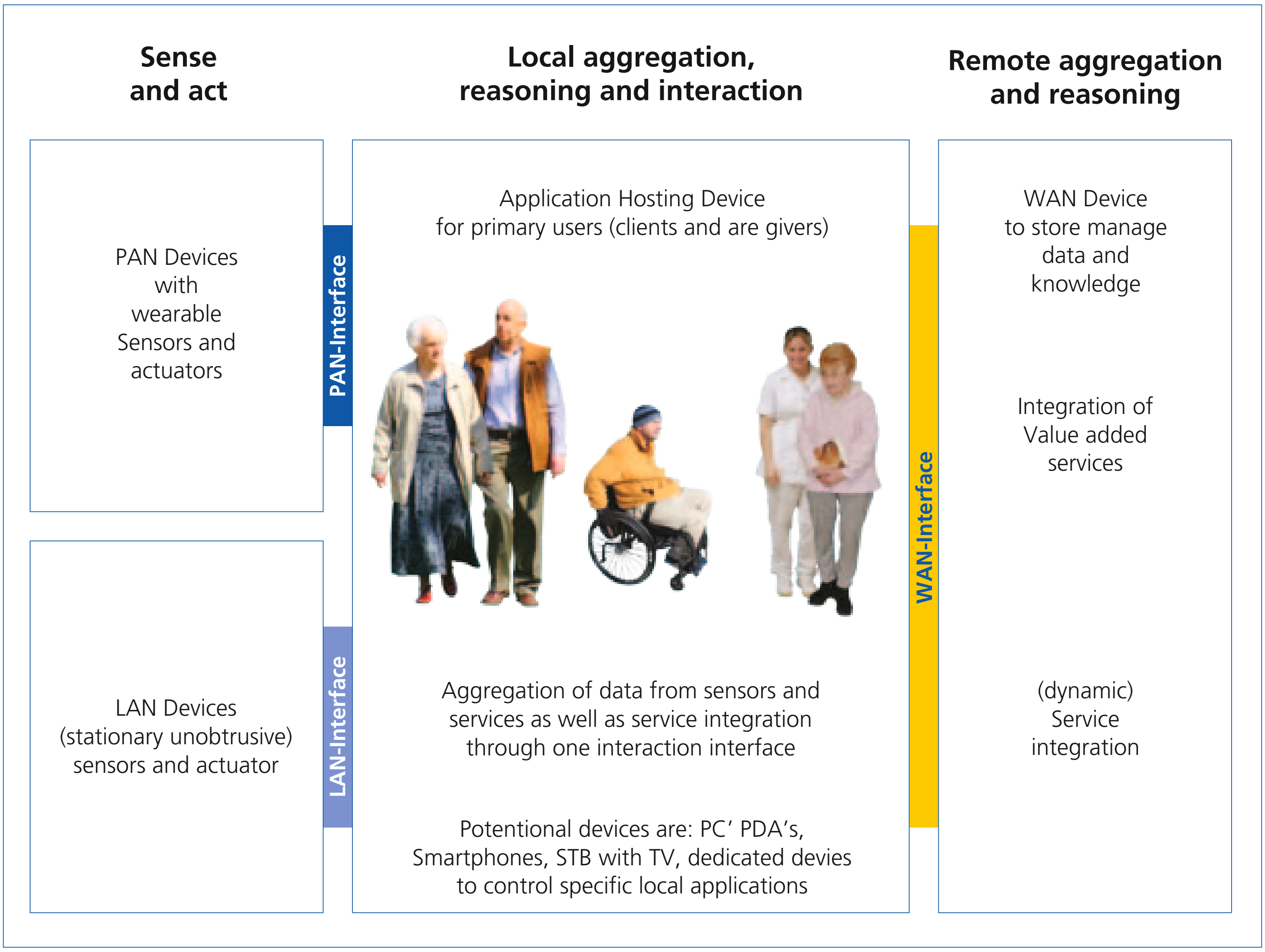
8.1 Reference architecture

The chart below depicts a three-layer networking approach to enable communication and connectivity between devices and services in the area of AAL. This model has been presented in the European project MyHeart for tele-monitoring and remote patient monitoring and has been adopted and translated into a more abstract form by the Continua architecture team. This version is slightly adapted to reflect the two main categories of users.

This top-level view of AAL systems consists of seven classes of components:

- **PAN devices:** this class of consists of sensors and actuator devices which are in-body, on-body or wearable near-body devices. They will collect raw data from one or more sensors or control one or more actuators. They can have local processing from raw data and aggregate data from multiple sensors. They can also give some basic emergency feedback, e.g. using lights and/or sound, when relevant or as a fallback, e.g. when communication to an application-hosting device is not possible for some reason.
- **PAN interface:** this class is intended to realize the connectivity, communication and data exchange from PAN devices with one or more application hosting devices. This means that besides basic con-

Figure 19: Communication and connectivity between devices and services in AAL domains

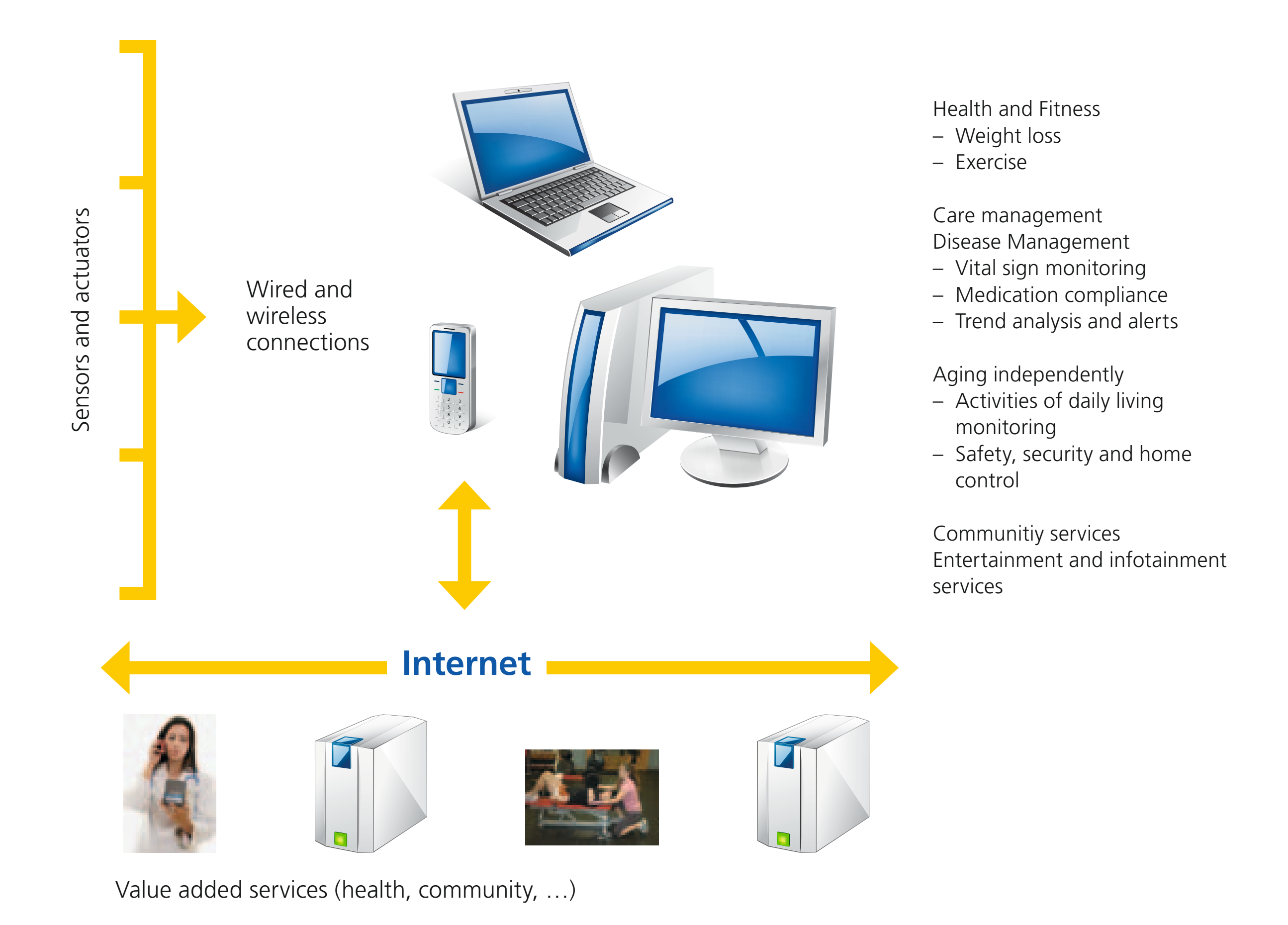


nectivity and communication protocols standardization of messages is also important. The network should be able to handle dynamic configurations so registration and discovery or pairing protocols are needed. Security is important when it relates to safety (the prohibition of unauthorized access to certain devices and especially to the application-hosting device) and transfer of sensitive data (e. g. healthcare data). Due to the characteristics of the PAN devices, low power is also an issue. It is important that a device does not simply drop dead when it is out of power but a timely warning is given for recharging or battery replacement.

- **LAN devices:** this class of consists of sensors and actuator devices which are stationary, may be movable in a room, house, car or public spaces. The devices will collect raw data from one or more sensors or control one or more actuators. They can have local processing from raw data and collect data from multiple sensors. They can also give some basic emergency feedback, e. g. using lights and/or sound, when relevant or as a fall back, e. g. when communication to an application-hosting device is not possible for some reason.
- **LAN interface:** this class is intended to realize the connectivity, communication and data exchange from LAN devices with one or more application-hosting devices. This means that besides basic connectivity and communication protocols standardization of messages is also important. The network should be able to handle dynamic configurations so registration and discovery or pairing protocols are needed. Security is a topic when it relates to safety (the prohibition of unauthorized access to certain devices and especially to the application-hosting device) and transfer of sensitive data (e. g. healthcare data). Power constraints might be less sensitive than for the PAN interface but for devices that are not connected to power outlet it is still an issue. It is important that a device does not simply drop dead when it is out of power but a timely warning is given for recharging or battery replacement.
- **Application hosting device:** this class of devices has four important functions. Firstly, to communicate with the PAN and LAN devices to collect sensor data and to send commands to the actuators. Secondly, to communicate with the WAN services to forward sensor data to the relevant back-end services and to process the response. Thirdly, the local storage of data, aggregation of data and reasoning about this data. Fourthly, to interact with the user to present information or support the user in his or her work.
- When processing data, reasoning is involved. This means that not only standardization of messages with respect to syntax (format and coding systems) is needed but also standardization of semantics (ontologies and vocabularies) is important.
- Some data might be made available through special networks, e. g. location data.
- For stationary application-hosting devices like a computer, STB or car system power constraints are not so relevant (except for environmental reasons) but for mobile devices like PDAs, smart phones or movable robots, power constraints are important and timely warnings for recharging are needed.
- Since these devices interact with people and have access to sensitive data or are able to control devices, security and privacy are important topics.
- **WAN interface:** this interface connects the application-hosting devices with services somewhere on the Internet. This includes wired or wireless access networks like ADSL, cable, mobile (GPRS, EDGE and UMTS) and public wireless networks. In-home device might use the in-home LAN interface to connect to these external networks.
- **WAN services:** these back-end services of the different systems store the collected information, forward relevant information to other services, analyse and reason about the data and raise triggers for clients and/or care givers and other services, and fulfil a reporting function. It is important that the dynamic configuration of a set of services matches the developing needs of clients as well as their care givers. Important issues for services are security with respect to access (preferably role- and task-based access control combined with a treatment or care relationship with the patient) and privacy of sensitive data.

It should be clear that AAL systems will vary in composition and not all functions or components will be present in every system, it depends e. g. on the level of support a person needs and often the system for a care giver does not have sensor or actuator functionality. There might also be appliances consisting of sensors, reasoning func-

Figure 20: Seamless interoperability beween sensors and actuators with application hosts for aggregation and reasoning



tions and actuators for feedback implemented in single device or a collection of devices using proprietary connections. Such appliances might pass on results to other reasoning and feedback services for aggregation using the PAN, LAN or even WAN interface.

An AAL solution that is intended to provide effective support to an older user and to his or her caregivers, and also to adapt itself to the changing needs of the user throughout his or her life, needs to be constructed as a modular and easily reconfigurable composition of multiple applications and services.

Integration of services and applications in a customized package for a specific user should in particular address the following dimensions:

- presentation integration of relevant information through a single interface;
- data integration allowing aggregation and understanding of data by relevant applications and services;
- process integration to support different sequences of tasks or steps that are relevant to the user as an individual, but also as a member of a team in a care plan.

There are also several possibilities for feedback loops which will also vary between instances of system. Some PAN or LAN devices might where relevant give immediate feedback, e. g. an alarm, to the user and also pass on the alarm to relevant services or care givers. Other systems will use the application-hosting device for immediate feedback or applications based on information sent by one of the services in the WAN.

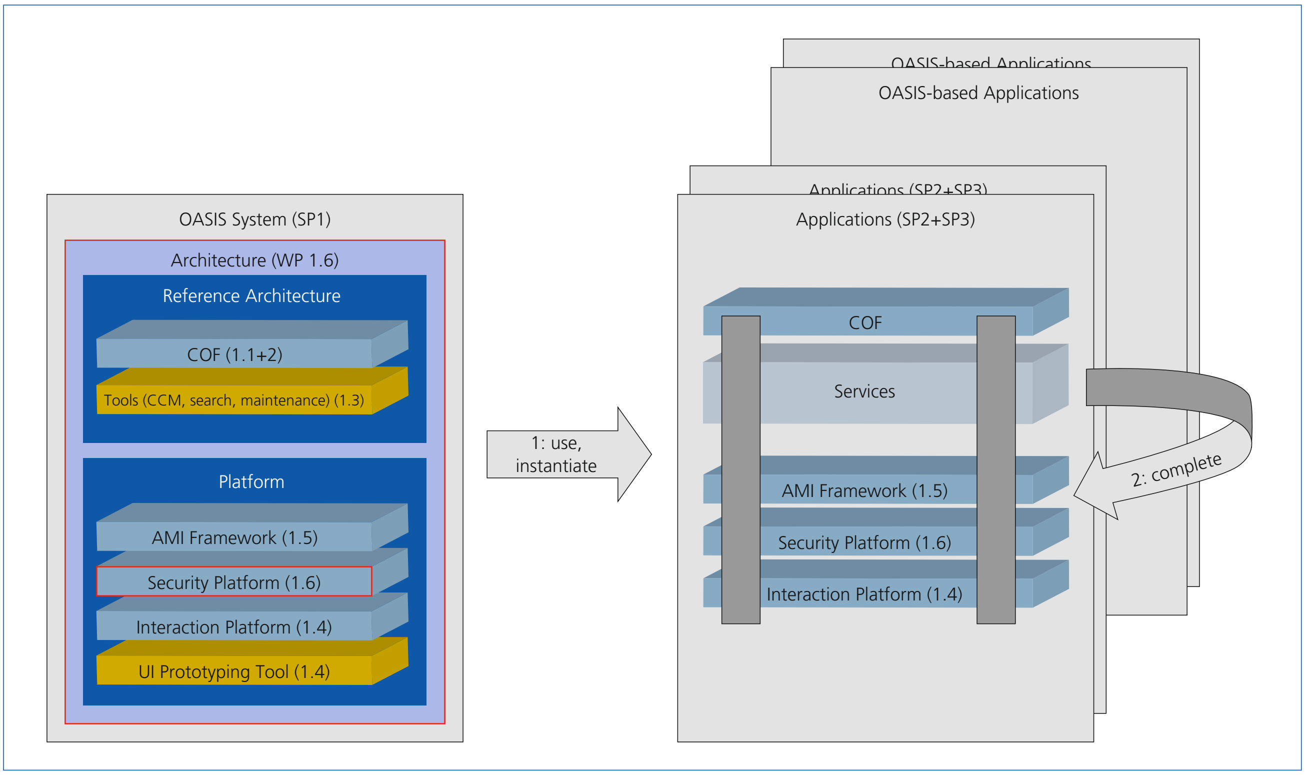
All this should lead to a seamless interoperable set of systems and services as shown in Figure 22.

An innovative approach is followed by the project OASIS (Open architecture for Accessible Services Integration and Standardization) funded by the EU in the 7th framework program. OASIS aims to introduce an innovative, Ontology-driven, Open Reference Architecture and System, which will enable and facilitate interoperability, seamless connectivity and the sharing of content between different services and ontologies in all application domains relevant to applications for the elderly and beyond. The OASIS System will be open, modular, holistic, easy to use and have constant standards. In order to achieve interoperability of services and sharing of contextual information between different services and objects, it is first necessary to model them, by extracting each service's individual structure up to its most basic level. In current approaches, this can lead to more or less ad-hoc solutions. The OASIS solution is to provide foundational ontology components, specifically tailored to the requirements of the applications to be covered and the services provided.

The core of the reference architecture is the Common Ontological Framework (COF), an open and extensible **hyper-ontology** containing two major resources:

- a library of component ontologies and ontological modules supporting inter-operability across the knowledge sources and services of the application scenarios, and
- a library of inter-ontology mappings maintained within a formalized, logically well-founded generic framework that supports the addition of new ontologies and the construction of complex services drawing seamlessly on diverse information sources.

Figure 23: OASIS system and its intended usage



- This hyper-ontological framework will be able to automatically, where possible, and semi-automatically where not:
- connect single services to ontologies in their area, by aligning them to a higher level model;
- interconnect heterogeneous ontologies that remain in the hyperontological framework in a common domain;
- interconnect ontologies of different domains that remain in the hyper-ontological framework;
- develop ontological frameworks that are compatible to this hyper-ontological framework in areas where these do not exist.

In order to link existing and newly developed ontologies to this new hyper-ontology, efficient tools will automate the process and support the service providers and developers in making their services OASIS-compliant.

8.2 Domain modelling

Because of the complexity and the high number of different scenarios in the context of AAL, the modelling of domains is an important procedure to develop sustainable, effective and affordable solutions for the social inclusion and independent living of elderly and people who are not self-sufficient and to validate and analyse the future impact of the application of AAL technologies in the same scenarios. Domain modelling development considers at least four standpoints: scientific, technical, psychological and economic/political. From the scientific point of view, the main topic is to find solutions and AAL services in order to support people for social inclusion, support in daily activities, early risk detection, personal protection from health and environmental risks and support in mobility and displacements within his or her neighborhood/town. The technical aspects focus on the development of an integrated technological platform that allows easy access to those services indicated above, and to empower citizens to adopt ambient intelligence as a natural environment in which to live. The psychological aspects are the development of pleasant and easy-to-use integrated solutions, in order to motivate elderly people to adapt their lifestyle and improve their quality of life and reduce dependency. From the economic/political point of view, the aim is to demonstrate that the solutions found are affordable for elderly citizens, the solutions are cost effective and produce tangible benefits for all (for welfare system stakeholders), and the AAL concept is practical and sustainable and represents an important segment of economical activity (for service providers).

8.3 Interoperability

Since an AAL solution consists of several quite often independently developed systems that come from multiple suppliers or providers, interoperability is an important issue and relies on the use of standards.

The goal of AAL however is to come to interoperable systems that can work together and from the view of the users presented as an integrated system that collects information from different subsystems and can even reason about it to give adequate responses to the user. To realize this, interoperability in the following areas are needed.

AAL is becoming increasingly dependent on electronic and communicating systems. Until the last twenty years, most electric and electronic systems were self contained and were not capable of easily communicating with one another; they did not need to. Convergence of communication, systems, networks and services has changed this. In most environments, multiple services and systems need to share resources and may need to “know” about other systems and services and what resources or information they can provide. Hence the importance of interoperability.

Interoperability is important in the digital home and increasingly also for mobile situations.
Within AAL we have already seen a number of dissimilar systems in the home (the entertainment system, the telecommunication system, tele-monitoring systems and often security systems and the PC Network). These operate independently of one another although they may use one another’s resources and already there is significant convergence between these systems.

Convergence is driving systems to work together in an interoperable manner. Almost all electrical devices use some form of electronic computation in their designs, and because this implies the use of microprocessors and in general microprocessors now have communication capabilities, this means that almost all electric devices in the home and workplace, i.e. most domestic and commercial appliances, have a communicating system as an integral part.

The physical area
This includes mechanical, electrical, frequency and magnetic aspects. At this level CENELEC plays an important role.

Connectivity and protocols
For personal-area networks, local-area networks and wide-area networks, multiple alternatives exist. For an approach where multiple products, application and services have to collaborate, choices have to be made. CONTINUA, for example, has made their version 1 specification the choice for Bluetooth, USB and WiFi.

Products in the personal-area network or local-area network might still have an alternative or even proprietary technology as a kind of peripheral interface to sensors as long a control unit supports the connection to the PAN or LAN network. A home-control unit can for instance have a X10 interfaces to sensors or switches and a WiFi interface to an application hosting device.

Data exchange
The exchange of data is very important when systems and services have to collaborate to enable workflow support between different tasks not only for the clients but especially for care givers in a trans-mural setting, e.g. in the context of managing patients with chronic diseases but also in proactively managing safety and assistive systems. To enable usable data exchange, agreements on messaging formats and data models within the message are important. In the healthcare domain, also for tele-monitoring, standards are available but they are not in use everywhere; interoperability and integration of systems of tele-monitoring devices in a home environment remains a significant issue (in January 2009 the first CONTINUA compliant monitoring device came on the market). In other domains, such as home control, safety, and alarm systems, this kind of standards is lacking.

Much work still needs to be undertaken in this area both in research as well as in increasing acceptance.

Understanding of data
The understanding of the data from the various systems and services is important when they have to collaborate to enable workflow support between different tasks, not only for the clients but especially for the care givers in a trans-mural setting, e.g. in the context of managing patients with chronic diseases. This is also important in the area of proactive safety and assistive systems to allow collaboration between these types of systems.

To understand data, vocabularies, unit codes, and ontologies have to be defined. For the healthcare domain such standards are available, but they are not in use everywhere. Especially in trans-mural settings, interoperability and integration of systems remains a significant issue. In other domains, such as home control, safety, and alarm systems. this kind of standards is still lacking.

Much work remains to be undertaken in this area both in research as well as in increasing acceptance.

Dynamic configuration of systems and services
In the area of PAN and LAN networks, the dynamic configuration of systems is important because people are moving through a home or even outdoors, so not all systems might be within reach all the time. This requires interoperable implementations for auto-configuration, registration and discovery. Choices have to be made here with respect to which technologies to use. Within CONTINUA version 1 specification, for example, the choice for UPnP has been made. In projects like PERSONA, other choices have demonstrated.

In the area of Web-based services a lot of interoperable solutions exist; however, choices have to be made.

Activities related to interoperability that play an important role are:

- CENELEC SmartHouse activities, the document "SMARTHOUSE PHASE 4 II DRAFT CODE OF PRACTICE" covers the following aspects:
  - the Service Provider aspect;
  - content, broadcasting (narrowcasting), DRM and security;
  - the Network Operators' aspect and Broadband delivery;
  - Network Termination and Residential Gateways;
  - customer premises equipment (any electronic appliance or equipment in the home);
  - home networks and in-home communication (and considerations for the building);
  - the User Interface, A/V equipment and displays;
  - the Consumer (Subscriber), interface and privacy;
  - architectures.

- Home TAHI Interoperability Framework Initiative that concentrates on interoperability to define a framework that will support the integration, delivery, use and payment for the applications and services provided;

- The architecture presented by the PERSONA project, which builds on results of four earlier EU projects. The architecture covers basic topics like bus systems for communications, service building blocks and ontologies;

- CONTINUA that concentrates on the interoperability of health and fitness devices and the communication with application hosting devices in home (later also mobile) and services on the Internet, using existing standards like IEEE 11073 and harmonized with NCCLS/CLSI, HL7, CEN, TC251, ISO TC215, and IHE.

To solve the issue of interoperability, it might be useful for there to be an organization that is responsible for Certification of AAL devices and services. Such a certificate would guarantee the interoperability of subsystems and to allow a plug-and-play installation.

ANNEX

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