Universidade do Minho
Escola de Engenharia

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Cognitive Assistance in Intelligent Environments

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Cognitive Assistance in Intelligent Environments

Tese de Doutoramento em Engenharia Biomédica

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É AUTORIZADA A REPRODUÇÃO INTEGRAL DESTA TESE APENAS PARA EFEITOS DE INVESTIGAÇÃO, MEDIANTE DECLARAÇÃO ESCRITA DO INTERESSADO, QUE A TAL SE COMPROMETE;

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Assinatura: _____

Abstract

Currently society responds badly to some social issues. One of the problems lies on the society concept itself. The common pyramid describing the social strata does not reflect the new social reality, given that the elderly strata largely exceed the teenage strata. This fact also implies a change in terms of social and medical needs. Thus, a great number of medical services should be adapted to respond to the needs of the elderly people. In fact, any common family cannot take care of an elderly person and, in many cases they cannot also afford the required medical care. Having less time, and often, less money, a family cannot have their older relatives in their homes. In addition, the necessary support required to overcome the elderly limitations, makes it even more difficult. One solution could be that elderly people go to nursing homes or care centers. However, due to the overgrowth of the elderly community, geriatric units are not enough to take care of all those people. As a solution, technology can provide wellbeing and assistance in the elderly everyday life through personalized services at low cost.

This thesis presents a cognitive assistant platform, named iGenda. A cognitive assistant provides numerous user oriented services, and it ubiquitously and transparently interacts directly with the user. Therefore, this research work has as motto: impacting the user's life without causing an impact. It means that the platform aim is to influence the user's life, by providing a greater quality of life, without being too complex to use.

The answers to our society's social and technological challenges are provided by the development of a platform that is intuitive to the user, cheap and able to be integrated in an Ambient Assisted Living ecosystem. Thus, this thesis presents a multi-agent, platform-independent architecture capable of intelligent scheduling. Being the cognitive assistant implemented in four case studies, namely: a sensor platform, a digital clinical guideline system, an orientation system based on augmented reality, and a fall detection application. These case studies validate the social and technological challenges, therefore the iGenda too. This is due to the complete integration with other systems, without major changes of the architecture and archetype.

Resumo

Atualmente, a sociedade debate-se com um problema para o qual não há uma solução simples. O problema reside na própria sociedade, mais especificamente no seu conceito. A pirâmide populacional clássica não retrata a sociedade como é atualmente, sendo que o número de idosos ultrapassa o número de jovens. Ora, este facto acarreta uma mudança nas necessidades sociais e cuidados médicos. Deste modo, um grande número de serviços médicos têm que ser reajustados para as necessidades das pessoas mais idosas. Com menos tempo e frequentemente sem dinheiro, a família não é capaz de ter um idoso na sua casa. Tendo em conta as limitações das pessoas idosas em termos de saúde, a incapacidade de assistir uma pessoa idosa é ainda maior. Uma possível solução é colocar os idosos em casas de repouso ou centros geriátricos. Contudo, devido ao crescimento da comunidade idosa, não existem unidades geriátricas suficientes para todas as pessoas. A tecnologia pode providenciar assistência e bem-estar na vida cotidiana de uma pessoa idosa, através de serviços personalizados de baixo custo, servindo como uma possível resposta aos problemas apresentados.

Nesta tese apresenta-se o iGenda, como uma plataforma de desenvolvimento de assistentes cognitivos. Um assistente cognitivo que assegura vários serviços orientados ao utilizador, interagindo com o utilizador de forma ubíqua e transparente. Este trabalho de investigação tem como lema: mudar a vida do utilizador sem o mudar. Isto significa que a plataforma tem como objetivo mudar a vida do utilizador, ao proporcionar uma maior qualidade de vida, sem que o utilizador tenha dificuldade a adaptar-se ou a utilizar a plataforma.

As respostas para os desafios sociais e tecnológicos apresentados pela nossa sociedade são fornecidas pelo desenvolvimento de uma plataforma intuitiva, barata e capaz de ser integrada num ecossistema de *Ambient Assisted Living*. Deste modo, o processo de agendamento inteligente é assegurado por uma arquitetura multiagente e independente de plataformas, apresentada nesta tese. Sendo que o assistente cognitivo é implementado em quatro casos de estudo: uma plataforma de sensores, um sistema digital de guias clínicos, um sistema de orientação baseado em realidade aumentada e um sistema de deteção de quedas. Estes casos de estudo validam os desafios sociais e tecnológicos, portanto validando também o iGenda. Isto verifica-se com a integração completa com outros sistemas, sem muitas alterações à arquitetura ou ao arquétipo.

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"Love does not consist in gazing at each other, but in looking outward together in the same direction"
Antoine de Saint-Exupéry

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1 Introduction

"Perfection is achieved, not when there is nothing more to add, but when there is nothing left to cut away."

- Antoine de Saint-Exupéry in Wind, Sand and Stars

Currently population grows quickly, being sometimes unexpected. Looking back, several population changes can be observed all throughout history. For instance, think in the "baby boom" case. It happened after the II World War, when the population increased in 70% in just 10 years (United Nations, 2009). An analysis has revealed that those population fluctuations are influenced by external factors such as economy, quality of life, stabilizing population, and/or wars, among others.

Another example is the Generation Z (MacKay, 1997), socially known as the technological age. Currently, it is considered the most important change suffered by the human population. This advent of modern technology opens the access to more information and progressively improves people's lifestyle. Thus, taking advantage of technology is possible whenever people are the center and technology is surrounding them. However, this also brought its consequences. Among them, it is very expensive and high time-consuming. Comparing the current and past population trends (United Nations, 2009; United Nations, 2002), it can be concluded that the Generation Z has fewer children per family and people live longer, that is, aging more. From that, a new question arises: how will be the future?

1.1 Elderly Population

The developments in the paradigm of birth and the growth of elderly population have revealed that: a higher quality of medical services available to population, especially typical elderly health problems and treatments, a higher quality of housing and nutrition (United Nations, 2009). Another situation dramatically altering population statistics, is the decline of births. This fact usually results of significant advances in the education of women and their massive integration on labor markets (Ramachandran, 2009; Moehling, 2002).
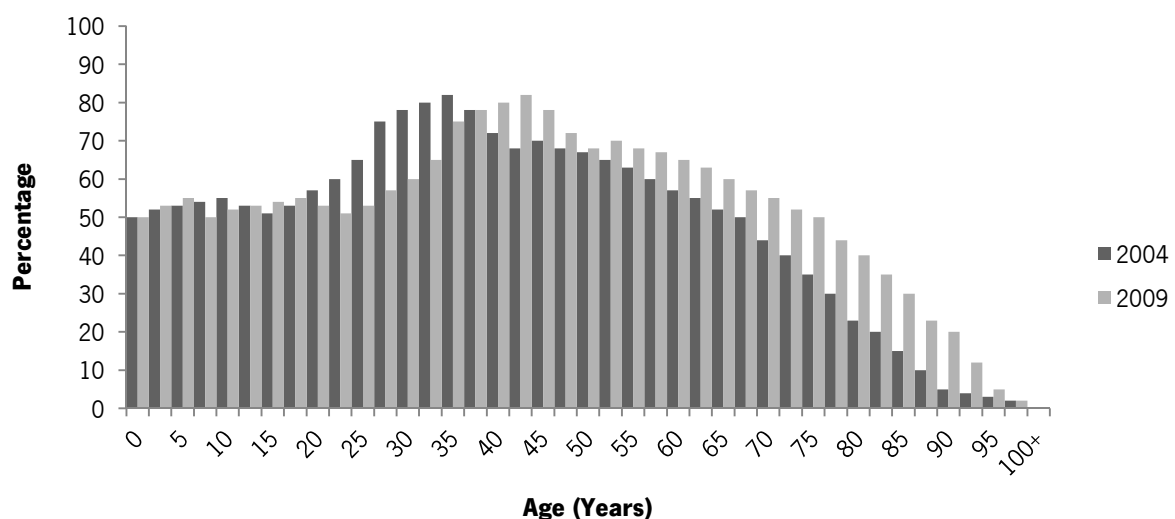
Figure 1: Age distribution graph in 2004 and 2009 in Portugal (United Nations, 2009).

As it can be seen in Figure 1 (Instituto Nacional de Estatística, 2012b) the growth of the elderly population has increased unprecedented, pushing the peak of the pyramid to older ages. In Portugal, a drastic reduction of large families (8 or more children) took place in the 50's, leading to future generations of 3 children per family in average (Instituto Nacional de Estatística, 2012b). This drastic reduction in the birth rate lied in suffering a considerable socioeconomic progress in a short period of time. This change meant an evolution from children leaving school at an early age to economically help their family, to children with extensive studies and university degrees (Instituto Nacional de Estatística, 2012a). This new context results in more family investment in children education, and, as a consequence, it makes more difficult to form a large family.
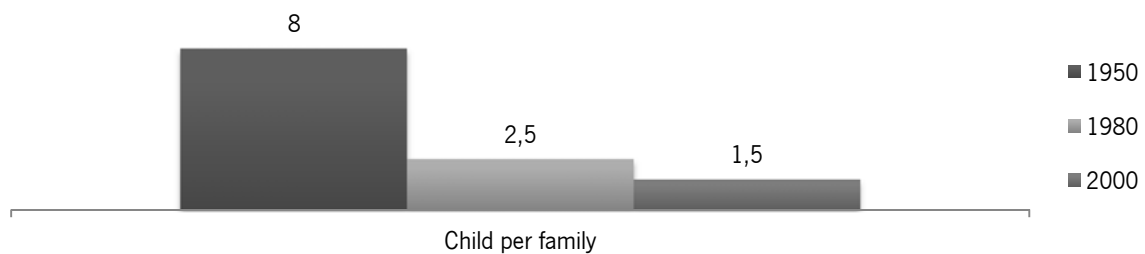
Figure 2: Children per family evolution
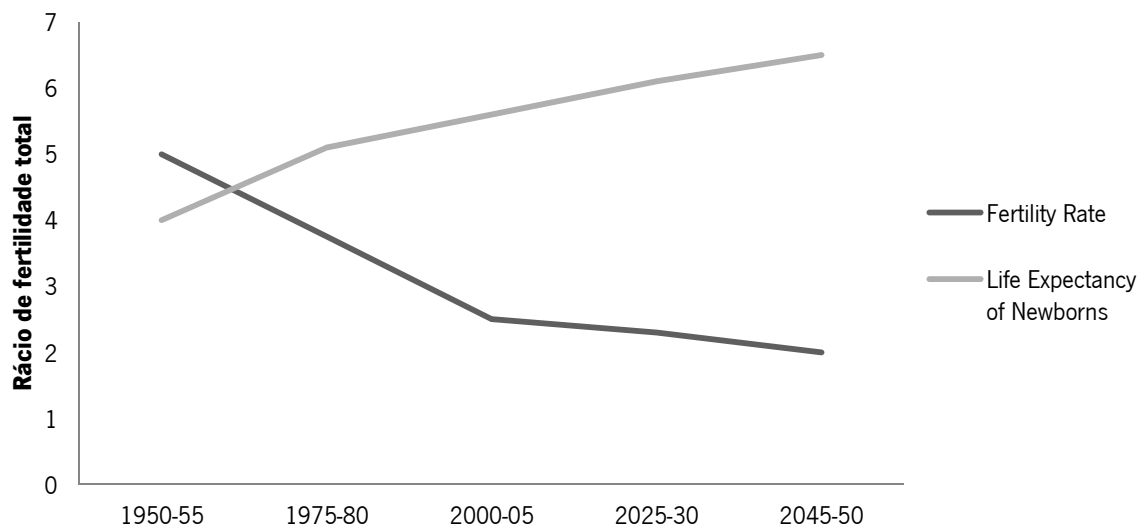
Figure 3: Fertility and life expectancy

By 2050 the elderly people community will greatly surpass the children and teenagers numbers combined (Figure 3 and Figure 4). This rapid growth of the elderly population and their dependency, coupled with the decrease in the active population may lead to the impossibility of supporting the population dependent on others (World Population Ageing, 2002; United Nations, 2002).
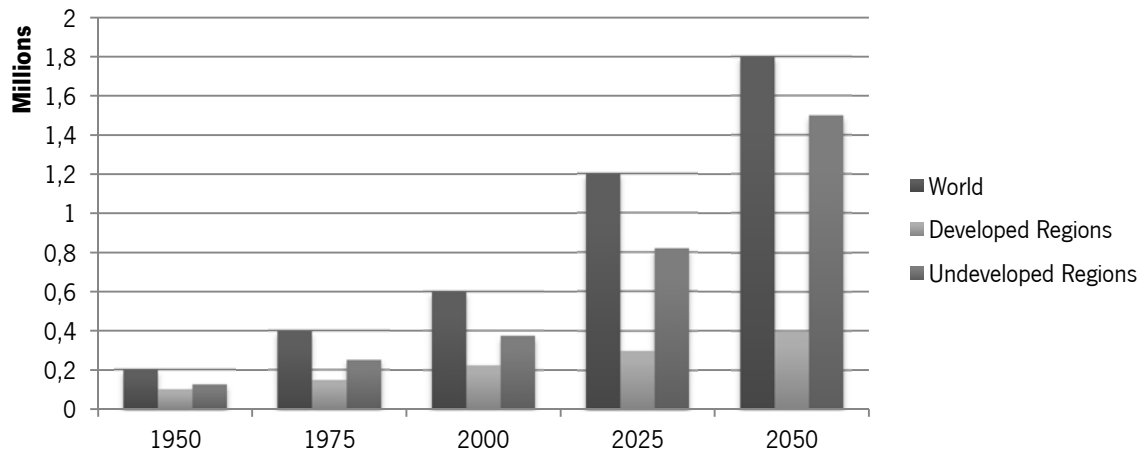
Figure 4: Population with 60 years or more.

This population scenario results in an increasing number of elderly people and, therefore, the subsequent health and socioeconomic problems that aging entails (Turner et al., 1998).

1.2 Aging Effects

Disabled people often need human assistance, particularly in the form of continuous care. Family or home care assistants can help them in common tasks, although this can be time consuming or expensive.

As a consequence, two situations can happen: the elderly person is left alone on his/her home, or, on the contrary, he/she is moved to a retirement home or another similar institution. The first situation is totally undesirable since the person may be exposed to several risks. On the other hand, although the second situation seems to be the best choice, it is expensive and not everyone can bear its cost. Moreover, this situation is aggravated from an emotional point of view because the person is leaving everything known and loved as their home, being usually reluctant to accept this fact.

In this respect, a recent concept is the Active Aging (AA) (Walker, 2002; Kalache & Gatti, 2002). This concept, according to the World Health Organization, aims to maximize health care, well-being and safety, which results in improving elderly people's life. However, the implementation process of AA is not straightforward since it requires major social and economic changes. So, it forces the government,

as a sovereign entity, to provide the necessary conditions and to fund these changes by means of more social contributions (Turner et al., 1998).

On the other hand, technological advances open a door to AA implementation. So, AA concept can be easily implemented by reducing the involved costs and allowing elderly people to remain at their home. Moreover, the recent development of mobile systems and miniaturization of medical devices allow remote monitoring. This remote monitoring can provide enough information to know people health status. In that way, these systems could be connected with hospitals, emergency services, and day centers, among others, to notify about the necessity of medical care at any time. That is, they enable the creation of a support circle directed to the elderly, forming a collaborative network and a network of virtual assistance (Novais et al., 2010b).

This new approach agrees with what is advocated by the Ambient Intelligence paradigm, specifically in the area of Ambient Assisted Living (WP7, 2005; Riva et al., 2010).

As age advances, the human being becomes more fragile and more prone to suffer diseases (Charness, 2008). In addition, old age usually leads to a typical set of conditions such as cognitive problems. These problems affect the part of the brain in charge of cognitive abilities. Therefore, they are insidious on the everyday living given that they limit person's actions and reactive capabilities (Seidler et al., 2004).

1.2.1 Cognitive Problems

Current studies show that from the age of fifty, people begin to lose their memorization ability in terms of both recognition and perception. This fact results in problems of reasoning (Barker et al., 1995). Studies have pointed out that the brain area to generate new ideas is seriously affected due to chronic memory loss. Furthermore, these studies determined that the *cause/effect* concept originates from the hippocampus (a brain region that is responsible for memory). Thus, new ideas result from the combination of previous knowledge and ideas association (Geda et al., 2008). With the aim of having a clearer idea, let's see an example. If a person likes bread and apples, the brain can associate these two elements and the fact that enjoys the flavor of these. On the contrary, if that person is provided with an apple flavored jam, their brain can form knowledge relating jam and apples and how they like both of them, associating jam and bread as a combination they may appreciate.

This type of associations is crucial on the day-to-day life of any person. Actually, these associations allows to determining what is known and how to learn that which is unknown. Thus, the association

action is responsible for providing the human identity, as researchers and psychologists have presented in their latest findings. Moreover, losing memory leads to a loss of identity, which can be perceived as amnesia in some cases, or has Alzheimer's, in the dementia stage (Kappeler & Epelbaum, 2005).

The progression of degenerative diseases should be considered due to greatly variations from person to person. To verify this condition, regular checks and tests must be performed, and, if possible, monitoring the performed actions to learn whether there is any significant change of normal behavior. The cognitive problems are easy to spot with a close observation because of the massive impact on human behavior like actions performed (Pinker, 1997).

The cognitive problems are divided into several subsets such as speech, writing or memory problems. One of the deficiencies manifested quite often is forgetfulness (Pinker, 1997; Mohs, 2007; McEntee & Crook, 1990).

Forgetfulness is something that occurs with some frequency, ranging from small things, like forgetting where are the keys, to serious situations, such as forgetting people names or how to open a door.
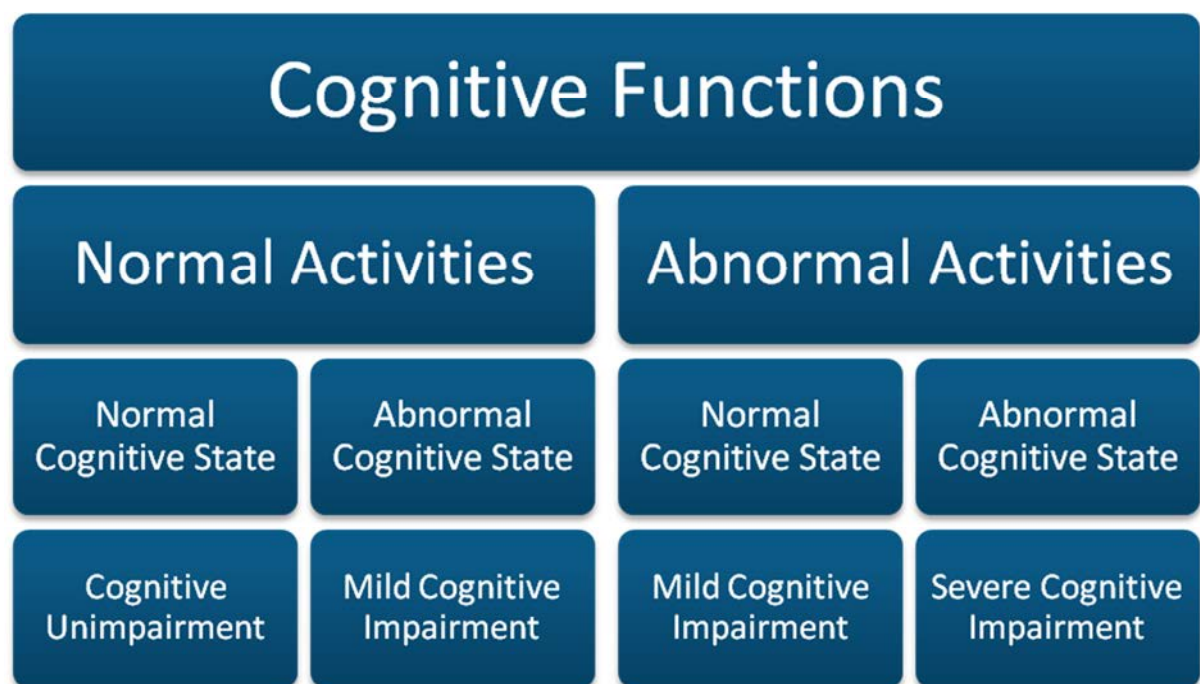
Figure 5: Cognitive impariment states

Studies conducted by McEntee and Crook, gathered in paradigm ''where are my keys'' that presents results in terms of progression and impact of loss of memory over time, as well as what level of addiction the person has (McEntee et al., 1990). From this research, the cognitive impairments level

classification, titled Memory and Cognitive Impairments and illustrated in Figure 5, was obtained (McEntee et al., 1990; Tucker, 1995; Geda et al., 2008).

The cognitive problems are detected by means of tests and observations of user everyday living. These tests show if a person is suffering from any cognitive problem and its severity. The early stages of memory loss (Cognitive Unimpaired and Mild Cognitive Impairment, as shown in Figure 5) have no major impact on people lives. On the contrary, people with severe impairment should be constantly monitored given their fragility and inability to perform more complex tasks (Severe Cognitive Impairment, shown in Figure 5).

1.2.2 Prevention of Cognitive Problems

While there are still no effective solutions to diseases like Alzheimer's, various researchers investigate to minimize their effects. However, the general developed projects focused on the prevention and containment of cognitive problems, are in progress. Exercises that promote the use of both short and long term memory by activating the brain self-stimulation process, help strengthen the connections between synapses, while prevent the weakening and loss of memory (Seron et al., 2008; Jorge, 2001; Sutton et al., 2010).

The complexity of exercises is not very high and they can be done at home. For example, a basic exercise would be remembering in detail what was done during the day. Unfortunately such exercises or games do not reverse the loss of memory, but being able only to prevent the advance of memory loss (Park et al., 2003).

Leisure Activities

Recreational activities are also a way to keep people active and concentrated, emerging them into something that makes sense and that is important to them. There is high commitment to this type of activities because people are motivated to practice them when they no longer have any kind of occupation. Even thinking about an activity compels a person to be active, focusing on, planning and implementing actions that require brain activity (Seron et al., 2008). Furthermore, these types of activities are enabling the engagement in an activity of several people, forming a strong helping community.

A good example of this idea is the Time Bank project (see Figure 6) (Castolo et al., 2004), which materializes mutual aid from several people in the way of specialized task exchange between them. The operation procedure can be described as follows: as a future user enters the project, he/she describes his/her specialty and how much time to be spent on it. The system crosschecks the availability with the needs for a specific task. The user, who receives the service, is indebted to the bank with time and the user, who did the service, will be credited with the spent time. This process is recursive allowing each user to provide or receive services according to their credit in the bank.

Figure 6: Portuguese logotype for the Time Bank project

This project presents some interesting aspects in terms of form and function: providing help to solve a problem, establishing connections between people and enabling the free time occupation. This combination of features requires that people are involved in something that motivates them, that is, something people feel that they belong to. Thus, this combination can generate a sense of responsibility that makes them think about their projects.

Another interesting concept that has emerged relatively recently, is the Senior University. This concept aims at providing its users, senior people, with challenges involving new knowledge learning. The participation of senior people in the learning process, possibly in a dual role of teacher/student, proves to be a connection maker between people, enabling mutual assistance in terms of information sharing and work execution.

Last but not least, there are simple activities in the sense that they can be performed by anyone due to the low level of complexity. These activities are aimed to join people, allowing a group of people to work for the same goal. These activities range from physical activity to those that require skill and logic, such as board games. All of them need a strong element of teamwork, requiring communication and socialization among peers. Consequently, they ease social integration and bond creation, what, otherwise, would be difficult to do.

Empowering the people with choice is also a priority. People have their own hobbies, and nurturing such activities is recommended. Therefore, user preferences should be taken into account, given that what matters ultimately is the wellbeing of the person, and this requires feeling comfortable and integrated into their environment.

1.3 Cognitive Assistants

The Ambient Assisted Living concept can be described as a technological area that is user-centered. It uses physical devices and applications to perceive an environment and act upon it, according to the user preferences. Thus, providing an improved quality of life and protecting the user. This concept is more explained in section 2.5 Ambient Assisted Living. From the Ambient Assisted Living concept emerged the Cognitive Assistants concept.

Cognitive Assistants are usually defined as technological products that attempt to provide a response to people cognitive problems. Cognitive Assistants can be described as complex, user-oriented systems that provide one or more services that help people on their daily tasks. Only providing automated systems would not be beneficial to the user because he/she may not be able to perceive what is being done or could not remember how to operate the system.

Given this problem, the cognitive assistant concept was developed. However, more features than merely support the user in specific tasks, but assist him/her in all his/her tasks were considered, such as reminding the user of crucial events in life. There are already some developments in this area, like memory assistants. Nevertheless, they are very limited since they are not providing functionalities to the extent of the services initially provided.

Figure 7 illustrates the different areas that may be present in a cognitive assistant. The development phase must take into account the people inherent problems, which the solution is aimed to. As an example, an aging population requires a system that helps them to remember objects and events, or a system that monitors their actions and provides them suggestions about what is taking place. Therefore, a cognitive assistant should address all the issues stated above, and relate to all the issues resulting from cognitive problems.

The cognitive assistants can differ considerably among themselves, assuming different formats. They can be classified as mobile, centralized or hybrids.
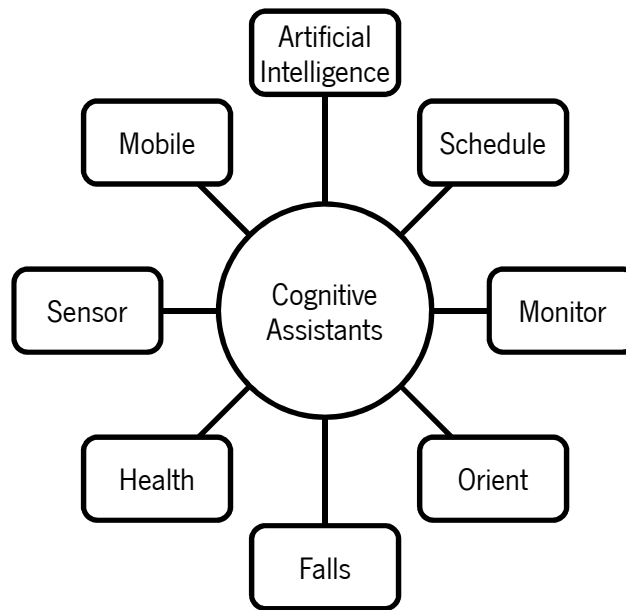
Figure 7: Strands of cognitive assistants

The mobile systems focus the whole system on a mobile device, which can severely limit the number of features and responsiveness. The centralized systems consist of a servers and client network. Thus, communication between them must be constant. In case of communication failure, all platform crashes. Hybrid systems are a mixture of mobile and centralized systems, taking advantage of their best features. This means that the mobile systems can serve as user interfaces by performing simple processing of information, and centralized systems can be used for archiving information and complex processing.

The development of such projects requires sound archetype and architecture, resulting from a thorough investigation that distinguishes the social and technological challenges.

1.3.1 Social Challenge

It was demonstrated several problems that are needed solvency, taking into account the social delimiters (i.e. the costs involved, public acceptance and functionality).

The social challenge is aimed to support older people in their everyday living by using technological solutions that are ubiquitous and transparent. So, they must interact with people, as an assistant or a

cognitive memory exerciser, serving as a helper of the healthcare provider and the user. Moreover, the functionality/cost of this technology solution is very attractive because it addresses these issues using the least possible resources, bridging the user to other helper services.

Acceptance by users is also very important resulting in developing a solution that takes into account user limitations what can completely change the system architecture. Consequently, development must be carefully structured, anticipating all possible issues and investigating the real user needs, following the user profile.

The social challenge obligates to consider the community when the solution is designed. This can open the path to a social network where users can share tasks and events, and enable the system to manage the different user necessities, like home assistance. Furthermore, the use of these platforms by the medical community and other services enables interactive help, where assistance can be performed remotely. For example, we can have the following scenario: with the aggregation of multiple services and users, a physician can remotely adjust the schedule of the users according to their health state, skipping bureaucracy and its delays. Moreover, the user can select in advance a taxi service to take him/her on time to an appointment.

These are the social challenges that must be overcome, providing answers to the arisen questions such as: what technology will be presented to the user and how it can be used?

1.3.2 Technological Challenge

We are living in an era of advanced technological development, the era of the portable, that is introducing new ways of computing and providing the user with a more dynamic and personal interaction.

Portability is a key feature, allowing a real implementation of ubiquitous computing. Now mobile devices like smartphones have more computing capacity than desktops made 5 years ago. The services and features available have to be performed as quickly as possible, being optimized to use fewer resources. In these devices, the interfaces were designed to take advantage of the system space and responsiveness, besides being attractive. Over the years, interfaces were refined creating what is called a usage guide. This is something that developers must follow to design a product with harmonious and intuitive forms, minimizing the user's learning curve.

On the healthcare area, the sensors have received the most attention and, therefore, they have the most evolved. As computer systems, the sensors are being improved in terms of reliability and size reduction. For instance, electrocardiograms can be obtained very accurately by using only discrete and portable sensors. These should be only glued to the body, being hygienic and disposable.

The user enjoys a greater freedom due to being freed of stationary devices. To the user, portability is a crucial feature since this is the way he/she can perform their tasks while are being continuously monitored. Easy use is important, given that the goal is to instill the patients in the responsibility of caring for themselves, i.e., if they can successfully operate sensors, then they liberate medical personnel for other tasks.

There are already autonomous systems that control the hardware effective and efficiently. Furthermore, the concept of agents in terms of architecture is a response to complex and inflexible systems. They divide the systems into subsystems and modules resulting in separate features that work to achieve goals through strong collaboration and data transfer. The separation of roles and workload is beneficial for both simple and complex operations. The reason lies on the fact that it enables the editing of small data blocks targeted to specific services along with the addition of new agents and greater security in terms of error and fault tolerance.

1.4 Research Hypothesis

Taking into account all the challenges, both social and technological, a solution should be available. Minding all the features and limitations, in this project our aim is to build an archetype and subsequent architecture of a cognitive assistant. This cognitive assistant may be used to develop useful solutions to different scenarios, which will be object of study on this thesis; indeed this project relies on a multitude of different user-oriented services.

The social challenges are the starting point as they sustain the aim and the reason of why this project is worthy. The presented population statistics are alarming due to two situations: the fast advance of a non-planned event, and the population that will suffer by it and its consequences. Furthermore, it is not just fixing an evolving problem, but preventing it. By changing the perception and using the technology

so far available, the tools and services here developed aimed at a community of people in need, and, in the future, it may be used by anyone.

What the social problem requires is, in this case, advanced technological solutions. It does not mean that the project will be costly to the user, but otherwise. By presenting a low-cost solution, this project will benefit more people and, therefore, it may reach more users. Also, it aims at intelligent solutions to keep the cost of devices and services at a minimum. This means that one is speaking of an agent-based architecture, such that the hardware is kept to a minimum of complexity. In this way, it is expected that the system will come out with its full potential.

Adding into account the people's profile and the current technological trends, we look at mobile computing as one possible, if not the best solution. Ubiquitous solutions better fit the user's needs, without the usual limitations that technology imposes. Moreover, due to the features provided by the mobile devices, and the tendency for an "always available" communication, it is normal that such devices should be used in anyway.

The multitude of services requires an architecture that relies on a multi-agent methodology for problem solving. Due to the different services available, it is clear that they should be module-based, such they may be configured according to the user needs.

To conclude, in this thesis hypothesis one *intend to prove that the presented Cognitive Assistants architecture and archetype is the appropriate model for the design and development of Cognitive Assistants platforms,* i.e., the aim of this work is a user-centered system providing a solution to potential problems in the user's daily lives and offering them a better quality of life.

1.5 Work Aim

In terms of goals, it is necessary to define, in a general sense, what must be addressed in this work, which may be summarized as follows: defining and implementing a platform to deal with events and the management of the user's daily activities. That is, the system may be able to intelligently resolve conflicts between events, and to provide a solution inserted in a social environment. Also, it is built possessing several modules which provide complementary services related to the health and safety of the user.

To achieve these goals, the following steps must be implemented:

- Study designs, products and components of Ambient Assisted Living environments;
- Study computer systems that support the agent platform development and allow the addition of new modules;
- Development of a multi-agent architecture;
- Development of communication ontologies that support current and future standards;
- Drawing an archetype of a platform;
- Development of the iGenda platform, in terms of agents leading to ubiquitous design;
- Drawing the modules structure of complementary services;
- Development of the services complementary structures; and
- Testing of the developed archetype and platform in different scenarios.

1.6 Research Methodology

The work resultant from this PhD follows the Action-Research methodology. This methodology favors the continuous development of a solid research. Its structure relies on a hypothesis defined through research. To develop this hypothesis, a state of the art research is done by involving both project literature and technology. This step allows an analysis of all information to produce a report of available resources and the possible failures. Therefore, a design proposal that describes the possibilities to solve the problem is done. Finally, the conclusions are presented, referring the results and the possible impact of these in the destination community. This research model follows six established steps, which must be strictly followed:

1. Define the problem and gather its issues: this step states the problem and investigates what originates it, gathering all its features and formulating a hypothesis. Next a plan to solve the problem in question is submitted.
2. Constant update of the state of the art: the state of the art features all the projects related to the current research. This can generate a theoretical stage that enriches the available knowledge of known problems.

3. Design and construction of a model: the information gathered in the previous steps enables the designing process, consequently allowing to building a model along the available information. In that way, the hypothesis is confirmed and an innovative way that complies with the desired aims is presented.

4. Implementation and experimentation through prototypes: formalization of a prototype that contains all the features, components and behaviors. Hence, the implementation along specific settings allows the matching to the objectives of the proposal. Therefore, checking the experiments results as knowledge to be evaluated against the proposed settlement.

5. Analysis, result validation and conclusion formulation: the analysis results and validation serve to verify that the proposed implementation achieves the expected goals, and allows to using this knowledge to develop conclusions.

6. Dissemination of results in the scientific community: this step serves to disseminate the results to journals, conferences, workshops, among others, acknowledging the advances and research results.

1.7 Document Structure

The thesis is divided into seven chapters and one appendix.

Chapter 1 (the current chapter) outlines the motivation, aging effects, social and technological challenges, hypothesis and aims of the research, as well as the methodology.

Chapter 2 analyses different aspects of ambient intelligence, such as technologies and concepts. Moreover, it is presented our approach to the ambient intelligence, remarking the strengths and weaknesses, as well of what is missing.

Chapter 3 presents the related work and projects in the ambient intelligence area. These projects are critically analyzed and compared, being described concerning the aspects in what they succeeded and in what they failed, therefore allowing the creation of a knowledge base of the correct and incorrect approaches.

Chapter 4 presents the technologies used to develop the iGenda cognitive assistant. It explains the options that were taken and the solutions that they provide, solving specific problems that were found.

Chapter 5 presents the architecture designed for the cognitive assistant as well its archetype and architecture. Moreover, it is described the most important modules, their features and the logic systems that supports them.

Chapter 6 provides a description of different case studies carried out to validate the system. The validation is performed using the different modules developed that integrate in each scenario.

Chapter 7 draws the conclusions of this research work. The hypothesis and goals are revisited, and the major contributions are outlined and several issues are discussed. Future avenues of research and challenges are also sketched, and the chapter ends with some final remarks.

The thesis also includes one appendix that provides more information about technical aspects of the work such as the type of data used by the system and the internal structure.

2 Ambient Intelligence

The Ambient Intelligence (AmI) concept is present since the year 2000 (Assisted Living Inovation Platform, 2009; Augusto, 2007; IST Advisory Group, 2001). According to Costa et al. (Costa et al., 2007), the definition of AmI spaces consists of environments equipped with sensors and actuators, that observe and change their features according to a set of predefined rules. Besides, the AmI is well accepted by the scientific and industrial community, so much that some devices we have at home already fit this concept. The aim of AmI is to facilitate our lives in daily tasks, increasing our quality of live through the use of common devices.

The product design must allow the building of devices to truly meet the population needs. This has great importance, promoting a more independent life and a full social integration. Moreover, it promotes the development of smart homes equipped with sensors and devices that capture the environment and

act according to a set of predefined rules (Afsarmanesh & Camarinha-Matos, 2009; Almeida & Marreiros, 2005; Camarinha-Matos et al., 2003; Markopoulos et al., 2004). In addition, they can control environmental features such as lights and conditioning air, refrigerators or televisions. The whole home automation help explore the communications between all devices, that is, between buttons and actuators (Bonino et al., 2009a; Bonino & Corno, 2009b; Pellegrino et al., 2006).

So, the introduction of the AmI concept is gradually changing the type of devices and services that are provided to the population. Investing in emerging systems results in higher levels of technological demand terms because of the continuous devices adoption by the population (De Paola et al., 2011; Acampora & Loia, 2009). Creating intuitive user interfaces helps the user guide himself since he can control complex devices with the least effort (Camarinha-Matos, 2002; Almeida & Marreiros, 2006; Marreiros et al., 2007). Inserting intelligent agents in these systems was auspicious since they provide features beyond just action-reaction. Unlike typical home automation systems, the data gathered from various sensors, the environment state and the user preferences are used to reason a solution to be delivered to the actuators (Soltysiak et al., 1998; Wooldridge, 1997; Steblovnik & Zazula, 2009). This concept leaded to the development of what is known as smart environments (Augusto, 2009).

The smart environments are composed of a compendium of concepts, which have emerged in the areas of home automation (e.g. ubiquitous computing and pervasive computing). This enabled the creation of a group of features and a universal communication standard between the various concepts. That is, its aim was to create communication protocols and interaction and integration procedures between the various devices (Foundation for Intelligent Physical Agents, 2002b; Foundation for Intelligent Physical Agents, 2002a; Crockford, 2006). Therefore, the smart environments can be prospected as intelligent homes, with automation and computer systems, whose con-joint provide more complex actions than those offered by simple domotic.

The AmI is understood as a conceptual technological environment involving the user, and providing means that facilitate the user's life, as seen in Figure 8. This can be achieved by using technological devices and services which communicate with each other, generating an aggregation of decisions and actions that must be performed. Keeping the cost/effectiveness of the environment means reusing the devices already present in the user home, refurbishing them with embed systems in order to communicate with the rest of the platform.
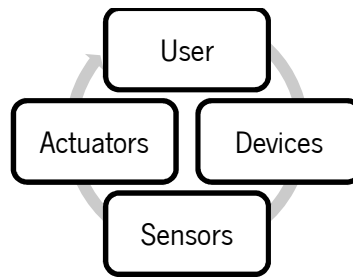
Figure 8: Concept layers of AmI

Thus, systems based on the concept of AmI must follow a set of primary features:

- The devices that will accommodate this type of concept should be very simple in terms of user interaction, presenting an easy workflow comprehension;
- The interactions between the person and the system should be natural and not intrusive;
- The devices must be context-sensitive, using sensors to perceive the environment;
- The systems must be equipped with intelligence or action patterns, to adapt more easily to context changes.

The systems that satisfy all these features are endowed with intelligence, a quantum leap in terms of technology, and the easy access to the general public. All this helps to bridge the gap between man and machine. This accessibility fosters a massive deployment of equipment, rapidly increasing complexity of these systems. Socially, it also means an evolutionary leap in which the average person has access to complex systems in terms of features, but of easy operation.

Many people believe that there will be an evolution to what is called the information society. That is, the interaction between people and devices on a day-to-day basis is making a hybrid system, where the devices discreetly adapt to user preferences, providing focused services. The control of the embed devices is called middleware, since it controls the devices through simple operating system functions (Bavafa & Navidi, 2010).

In Figure 9, the representation of a generic architecture originally used in the development of Intelligent Environments is depicted. There is a cyclic process that starts in the Environment, goes through Sensing the environment, delivering the data to the Middleware (and devices) in order to make changes to the Environment through Acting, and restarting the cycle again.

These systems can be summarized as follows:

- The Environment is comprised by the ecosystem composed of house, devices and humans. It can be divided into actions and state. While the actions are related to the sensors, the state is

related to a set of variables, physical and conceptual. So, the state relates to the state of the house, which can be set by never-ending features (temperature, lighting, placement, weather, and the humans), which, in their case, are even more complex to grasp.

− The Sensing is composed of a myriad of sensors that deploy their information to the Middleware. Several different sensors can be used to perceive the Environment such as light, temperature, visual, audio, weather. More sensors mean more quality of information and, therefore, more accuracy in the gathered information.

− The Middleware is the software in charge of receiving the information from the sensors and provide actions to be delivered to the actuators. It controls the logical decisions and can be stated as an abstract of each connection between software and hardware, working as a controller and bridging the gap between the operating system and the user. It is usually limited to a set of rules and has no learning abilities.

− The Acting is the group of actuators that enable changing the Environment variables. They receive the information from the Middleware, which is usually a compound command, and proceed to execute their orders.
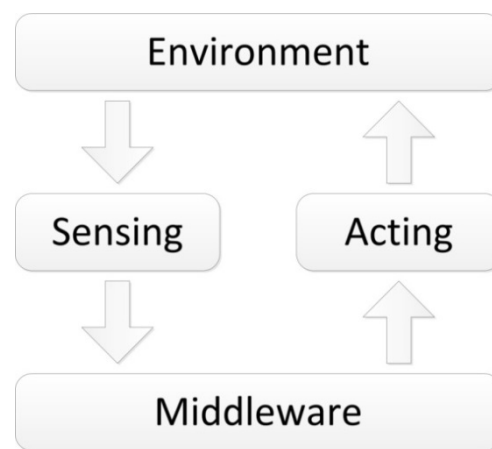
Figure 9: Generic architecture of Intelligent Environments.

This initial architecture was used to establish the base level of automation because of its simplicity and the number of available features (Augusto & Nugent, 2004). The human-machine interaction available as observed today began over the increase in home automation implementations.

Next, we will present the domotic, ubiquitous computing, context-sensitive computing, embed systems, Ambient Assisted Living, and the missing part.

2.1 Domotics

According to Pellegrino et al. (Pellegrino et al., 2006), home automation is the union of the automation and objects with the aim of endowing them with automatic features and network communication. With the constant miniaturization of electronic devices and the price reduction, the adoption by the production market was high, being new houses fully equipped with domotic devices.

The goal is to increase the level of comfort, safety and convenience, thereby increasing the user's quality of life. It is also the framework for major automated systems, providing the necessary settings for the hardware that will be used, and establishing connection and communication standards. The domotic supports all structures, serving as a column for all connections of devices, both cable or wireless networks and generating an array of interconnected applications.

The devices can be divided into groups that define the characteristics and operation mode. Each of these groups follows a well-defined list which rests on the entire structural concept of home automation, affecting how the system architecture in a home is compound. These groups are:

- Sensors: they capture the state of the environment like sentries, and communicates with the controller the state changes occurred;
- Actuators: act on the environment, executing commands supplied by the controller;
- Controllers: receive notifications from sensors, process that information in accordance with the internal rules and command the actuators to accordingly proceed.

The installation in homes depends on various variables such as weather, the house age, communication infrastructure or quality of building, among other features. The proper implementation of automation in homes should then follow these steps:

- Functional Specification: what kind of house to be implemented and the purpose of the devices;
- Selection of devices: considering the specification, which are the most appropriate devices;
- System Architecture: how to combine different devices and which roles and rules to be implemented;
- Control Interfaces: what more appropriate interfaces for end users in terms of complexity, quantity and positioning;

These steps cover the whole process, from the initial decision to the finished product, resulting in an effective implementation and design, and ensuring that everything fits perfectly at the end.

Domotic is currently widespread in most advanced countries, being used in private homes, schools, hospitals, etc. However, there is panoply of rules such that many of them are unable to communicate with each other. This fact leads to interoperability problems, flowing into an obstacle for developing and delivering services (DeLong, 2003).
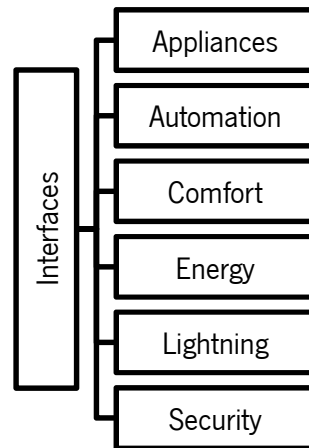
Figure 10: Different components of home automation.

Different solutions in terms of standards for establishing common interfaces (as those shown in Figure 10) have been proposed. One of the proposed solutions consists of creating a system of interoperable services based on the concept of "sensor fusion" (DeLong, 2003). So, the resulting system combines all the features of devices and sensors in order to generate a service environment shaped by their characteristics.

Communication Standards

As mentioned above, domotic provides the physical platform for implementing automated services, by allowing to set the operation and communication protocols. While the operation is established in several ways depending on the device and its features, the communication has to be very specific in the sense that the devices must communicate with one another. As the volume of devices present on the market, it is expected that several devices from different manufacturers can communicate with the available controllers.

Conceptually, it is split in the operation mode and communication type despite the fact that these two features are interconnected, enclosing some properties of each other. In accordance with the communication type, the use of devices is divided into wired and wireless. Within these groups there

are subgroups. So, for instance, wired devices can also be divided into the type of cable and the features, .i.e., intertwined cables and power network.

It is worth emphasizing the following communication technologies because they are the mostly used in the home automation market, and more developed, presenting new challenges and answers over the increasingly demanding user's requirements.

X10

The standard X10 (Pico Electronics 1989) was presented in 1974. Four years later, the first devices were launched, although now there are a large number of companies that manufacture devices with this standard.

The X10 consists of the use of the power grid to send communication signals between the devices and the control unit. The devices are easy to deploy and operate, and they can be used other control systems, such as infrared and radio frequency commands, to directly control the performed actions. The communication is achieved by modeling signal frequency of the power grid, sub-communicating with other devices constraint to an average speed of 1Mbps. Nevertheless, this velocity is conceptual as it must be considered unstable power lines and perennial noise from older appliances without signal correction.

In terms of operation, the signal is sent through phasing electric power. So, every device must be in sync with each other.

ZigBee

The ZigBee is a wireless communication standard used in automation and remote devices. It was developed by the ZigBee Alliance. The ZigBee Alliance is a consortium of companies, e.g., Philips, Samsung and Motorola, whose aim is to develop an open, flexible, robust and effective system that works seamlessly with a variety of different devices and manufacturers (Gislason, 2008).

Given that the communication standard is based on IEEE 802, it has the throughput of 20 Kbps, 40 Kbps and 250Kbps over the 868 MHz, 915 MHz and 2.4Ghz frequencies (Gislason, 2008).

The energy consumption associated with ZigBee is relatively low due to automatic switching between the active and inactive state (exchanged by means of a timer). They usually have an activation time of about 30 milliseconds and a battery that lasts at least two years, although some can be powered through a wall socket. A complete system has a control unit that coordinates all devices and actions, also serving as a signal repeater.

A ZigBee network is divided into two groups of devices: Reduced Full Function Function Devices and Devices:

— Full Function Devices (FFD): describes all devices that have memory and ability to compute. These devices are able to communicate with other devices and services, and to detect the network topology. These devices produce network consumption higher than the Reduced Function Devices. In this group the devices can take on the following roles:

  - Coordinator: assumes the role of functionality coordinator of all actions. It is responsible for booting the platform and establishing communication between nodes;

  - Router: in this role, the device relays the information between Coordinators and End Devices;

— Reduced Function Devices (RFD) - describes the devices that do not have memory and computing power, being equal to the End Devices. They are inexpensive and have small power consumption. They only receive and transmit information, exclusively communicating with the Full Function Devices.

  - End Device: this is the last device on the network, being a sensor or actuator.
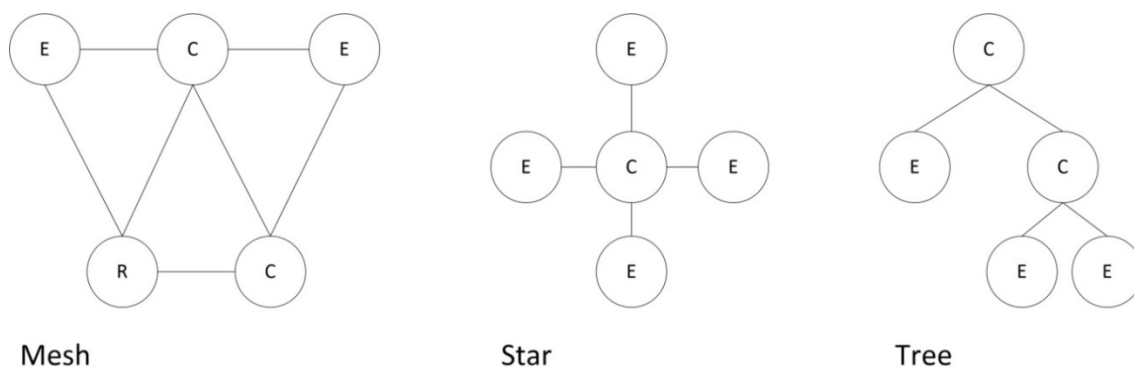
Figure 11: Mesh, Star and Tree network architecture

Network architectures featured by ZigBee are tree, star and mesh. Each one has its own features and serves for different purposes, such as the way of connecting devices. They can be summarized as follows (Figure 11):

— Tree: the core of this network consists of devices FFD and RFD edges. The main feature is its hierarchical organization. Thus, the FFD devices can assume the role of controllers and assigning for each level a new hierarchical structure, creating a line of highly structured operation. In that way, this network provides a high level of reliability and greater coverage area;

- Star: this network focuses all its decision on one control device. The main controller assumes all communication with other devices, which may be end devices or other controllers, thereby creating sub-networks. This network uses very little power and tends to be simple and economical, using more RDF devices that have low cost. This is the network architecture used in most house implementations;

- Mesh: this is a secure network, allowing duplication of information and data distribution. It usually consists of a controller and several repeaters, introducing redundancy. That is, the data will be always transmitted and received, adding organization ability and automated mapping. This network is a very robust but expensive, mostly deployed in industrial environments.

ONE-NET

The ONE-NET technology, initially developed by Threshold, is characterized by being open source and enabling widespread access by developers. In that way, innovations can arise from the user community. In addition, the rapid growth in the number of users attracts companies such as Texas Instruments, Silicon Labs and Semtech, among the most notable.

This standard is implemented in low-power wireless devices (battery-powered), making up a service platform for automation, security and monitoring. The devices are low cost, and different transceivers and sensors can be used given the system's flexibility in accepting different types of equipment controlled by software. The devices communicate via radio frequency using the Frequency-Shift Keying system to encrypt data, operating at speeds ranging from the 38.4kbits to 240kbits, and having operating frequency of 868MHz, 915MHz and 2.4GHz.

In terms of network, the topology can be a star, point to point, multi-hop and mesh. So:

- The star network excels in low complexity and cost, passing all communication by its main controller and taking all decisions in accordance with the scenario presented at that time;

- The peer network corresponds to a network of several layers where the main controller delegates functionality to other drivers. So, they go on to control simple devices and report the results back to the main controller. This network excels in functionality and effectiveness;

- The multi-hop network is outstanding for network deployment over large areas. The controllers are configured to assume the role of repeaters, with a cyclical repetition of message sending.

This network must be properly set, taking into account the distance radius supported by the devices to ensure minimum loss of data;

— The mesh network does not allow the inclusion of repeaters. In its place, communication is sent to all devices, creating large entropy. This kind of network is being somewhat belittled by the star and point to point networks. It has small effectiveness compared with the other networks.

The user can define his/her message protocols for functions such as temperature, energy, and/or state. Due to this feature, the changes done by the user community are significant and daily growing. The maximum communication distance is between 500 meters and several kilometers (adopting the appropriate type of network depending on the distance). The amount of microcontrollers which are supported by the system exponentially increases, too.

Unlike other standards and technologies presented, this is not easy to implement and configure. However, given the complexity and possibilities that this system can achieve and that it is an open source technology, it could be the next communication standard champion.

The domotic is used to the implement physical systems, such as sensor and actuators devices. Everything else, like processing, is performed by other platforms. In addition, features and actions can be implemented matching with the user expectations.

2.2 Embedded Systems

The Embedded Systems concept consists on the development and adaptation of common devices to be integrated into a communication network. That is, the devices are capable of communicating data captured by sensors and act over objects.

Embedded systems are researched and developed since a few years ago. However, due to technological and spatial constraints, some restrictions were present. Only recently has it really achieved full integration of computational features into regular objects.

The initial approach was applied to home appliances, due to their large use and common presence in every home. With the advance of computers it became straightforward to integrate them in refrigerators and televisions. Thus, it is possible to control and receive data from them, skipping basic function

middleware. Currently, computers come in form of mobile devices with enough processing power to control several domotic devices. Moreover, the advances in these devices were not only in terms of power but also practicality. So, these devices receive sensor systems (e.g. GPS, accelerometers, luminosity sensors) that helped in terms of everyday operations. This sensor information can be used in different applications like detecting movements from the accelerometer data.
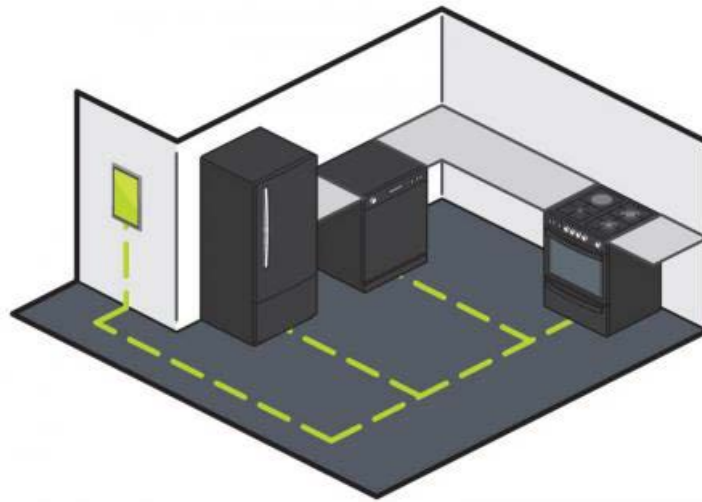
Figure 12: Home appliances embedded systems schematic.

An architecture of a home environment with embedded devices in the appliances and their connection with an wall-mounted controlling system, is presented in Figure 12. Although there are different ways of implementing this architecture (e.g. every appliance has a controller screen or one appliance controls the rest), the depicted one is currently the best because the user can control everything in a single place. That makes easier send all the information to other services and, in case of failure, the failed appliance can be replaced without suspending the whole system operation. The screen is typically an embedded device itself, namely a microcomputer, which receives all the information from the devices, takes actions (when planned) and presents useful information to the user.
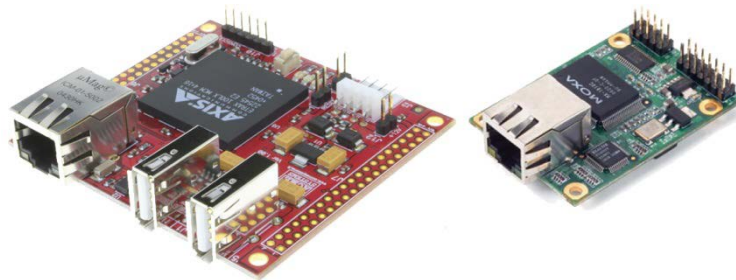
Figure 13: Microcomputers.

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In Figure 13 two microcomputers are depicted. These microcomputers have network connection as they cannot save any information. Consequently, a home server is needed. In this home server, applications that intelligently take actions, by using the information provided by the microcomputers and sending commands to the embed devices in the appliances, can be implemented.

These embedded devices, as expected, pass unnoticed by the user because they require no special attention and are easy to understand. Many of the devices can be already found in day-to-day life, proving to be ubiquitous systems. Thus, these devices generate a communication network that involves users resulting in an ecosystem of smart devices.

So, embedded systems are a critical part of the AmI when a smart environment is designed. Currently, it is verified the environment context and changes are done to meet the programmed rules, being these specified according the user preferences.

2.3   Ubiquitous Computing

The Ubiquitous Computing environment is composed of computer systems that collaborate with each other and interact with the user in a transparent and linear way (Weiss, 1999). When this concept was proposed, its implementation was very limited since no devices were available to cover the desired features (such as integrating micro-scale devices and appliances). On the contrary, thanks to the technological advances, this is something quite easy to accomplish nowadays.

The main goal of ubiquitous computing is to provide the concept and structure to develop devices. Those devices engage in everyday life in a non-intrusive way. This fact allows users to concentrate on their work rather than on the tools to use. This leads to a major change in nowadays lifestyle (Kim et al., 2006).

Despite being currently achievable, it is still difficult to find this concept effectively implemented. Part of this situation comes from the devices and appliances makers that do not yet bet in this type of integrated and centralized solutions. So, a set of integration rules should be defined. In that way, devices and appliances could be integrated into a system and can operate correctly. These features are:

- Memory: devices must have memory to store and share information about them and all previous platform interactions;

- Communication: the devices must be able to communicate with each other, providing information about their features and performed actions. They should also be able to receive information from other devices in order to contextualize the platform and determine what services can be used. They also have a communication standard, such as Bluetooth or Wi-Fi, to easily communicate with other platforms;

- Context: the devices must be able to perceive the environment and capture the changes in the context. In that way, they can adapt to the reality and correctly respond to those modifications. That is, they must take into account the changes in context along the proceeded actions for immediately adapting to them;

- Transparency: devices should be as invisible as possible (invisible in the sense of the least intrusive possible, not visually invisible). The user should benefit from the actions performed by devices, but without representing an obligation for him/her.

2.4 Context-Aware Computing

As the name suggests, Context-Aware Computing (CAC) consists of computational systems that are context-sensitive. That is, collecting data from the environment in which they operate enables them to interpret their context. In this case, the word context refers to "information which contains a detailed description of object features or environment state". This information is used to fully describe the object, which can be in terms of features such as functionality or method of operation (Schmidt, 2005; Fischer et al., 2004; Abowd et al., 1999).

Due to the AmI complexity, context is composed of different things (e.g. devices, environmental conditions, humans), each one with its individuality. Applied to humans, context is defined as the performed actions, location, interaction with other people and social status. In computing science, context can be defined as available resources, connectivity, bandwidth and results, among others. In home, context can be the features of an appliance or other devices, and their current state. So,

depending on the area that is observed, the context includes different elements and has different structure.

The CAC mainly hosts developing applications that use context characterizing information to optimize the functions to be performed. In practical terms, it results in two types of applications: the first ones directly operate on the environment according to the context changes, while the others act upon other applications feeding them with information about the context. There are numerous applications developed in each group. So, for example, applications whose performance changes when the user has a disability or even interfaces tailor to the user. Therefore, these applications are embroiled with the user profile context, using information such as age, eyesight and hearing or memory capacity.

From that, it can be concluded that the crucial issue is the context setting as well as the required contextual information for a given object. Additionally, other key issues are the connection between different objects, what properties they share and how they complement each other. Subsequently, the information must be classified to result in a format suitable for the system.

Thus, the aim is designing a system able to adapt to environment changes by considering user preferences and needs. To achieve that, sensors and user profile are used since they respectively provide information about the context environment (e.g. position of the wearer, room temperature, or luminosity) and user context (e.g. health conditions such as heartbeat). In that way, a system is designed such that it is in accordance with the response to be performed, while considering all involved contexts and the intended goal.

The context concept can be shaped to gather different types of information coming from static sensors, body sensors or the user's calendar. Given the flexibility concept and its ability to adapt, it is not difficult to realize its importance. Currently, the sensor fusion data is used to take advantage from the complete information. The sensor fusion concept consists of merging information of different sensors, that have little in common, but their data complement each other. So, for instance, joining data from luminosity, temperature and humidity sensors can result in information about the current and future weather and also lead to home climate control (Sanfeliu et al., 2010; DeLong, 2003; Ercan & Erdem, 2011).

All these differences arise the question what the definitions of context-aware applications are. The definition of context demands a rule to create applications. As incoming data is variable, the application is, too. However, ontologies serve as communication normative and can ensure interoperability between other systems platforms. In terms of the used devices, the system must have a detailed

characterization of them and be able to share this information with the other platform services. Thus, it is easier for the services to adapt to the devices and advantage from its features.

The CAC is useful for AmI because it defines the basic concept of intelligent actions and allows the use of devices with actions considered intelligent. These devices respond to the change of states, captured by sensors, ruled by the context in which they operate and how they are programmed.

Context-aware computing helping disabled people

The development of systems that help disabled people is being discussed by the European Community, resulting in several alternatives for such problems. Some alternatives are more complex and expensive than others, but undoubtedly the technological solutions are a viable alternative.

The CAC, with its features, is perfect for applying adaptive systems that respond to the users and their needs. The elderly are more susceptible to health problems, suffering from several constraints that limit their lives, being the most common limited motor skills, hearing or vision problems and cognitive impairment. The CAC can conveniently provide answers to specific user needs, taking into account user health problems, the environment and the objects that make it up. This can be achieved by means of a carefully built context concept, selecting what is really needed and what can be ignored. The features which should have access to these systems are:

- Emergency assistance: detects and accordingly acts when critical events occur;
- Greater autonomy: through domotic systems and applications that liberate the user from complex and arduous tasks;
- Increased comfort: providing safety, maintenance and house cleaning, as well as managing personal events and leisure time.

These systems keep a constant assistance to users. The scientific community has coined the ecosystems that contain CAC system working in favor of the user as Ambient Assisted Living.

2.5 Ambient Assisted Living

The new sociological structure and the progressive inversion of the age pyramid leads to social and economic problems. The younger generations will not be able to support the older ones, due to scarcity of resources. This reveals that it is very difficult to maintain people with special needs at home. One solution to this situation would be to leave people to look after them such as social centers, day centers and nursing homes, among other continued care institutions. These services are geared to provide help and assistance to the elderly, also providing activities to spend their time, making them more active and motivated. However, only few of these services are available to all people. Consequently, it is impossible to provide assistance to everyone. For that reason, it is urgent to rethink the services structure to make them accessible to everyone. A technological response can provide these services with greater efficiency and lower cost. Currently, technological solutions such as sensors and actuators can act non-intrusively, helping the user to feel integrated and valid (Novais et al., 2010a; Novais et al., 2010b).

The scientific community called Ambient Assisted Living (AAL) and is aimed to constantly monitor people through sensors, cameras and other devices, and act on the basis of the received data.

Therefore, the goal of the AAL is to improve the life of people with health problems and/or specific needs by helping them do everyday activities. That is, its goal is allowing a more independent and active life, avoiding the need of help, when possible.

The AAL spectrum typically falls on indoor environments, mainly places where people perform their routine and common tasks such as houses and apartments. So, its goal is equipped homes with a system to percept the environment and act on it. This can be achieved thanks to the following technologies:

- Domotics: designs and outlines all the necessary devices and strategic locations. It covers the implementation of the physical platform and devices necessary for operation;
- Ubiquitous Computing: conceptualizes how systems will communicate with each other and what level of sharing and collaboration they may have;
- Context-Aware Computing: adapts the existing applications to communicate with high-level systems. It introduces the functions managing context features to those applications that do not have them;

– Embedded Systems: provide common devices with advanced features. It transforms common objects with computer skills, so they can be connected with advanced computational systems.

The protection and user safety are also key points of AAL. These two features can be shaped into two formats, either internal or external. Internal safety means protecting the user in terms of activities and health status. With that aim, it takes into account the required amount of work to perform an action, or the user constraints which prevent action performance. As a solution, in those cases, the decision is left to the system.

Figure 14: Sensors placed at strategic positions needed to monitor different actions such as sleep, physical activity, medication alerts and open water taps

On the other hand, safety refers to the active surveillance of the user's health. In any emergency situation, the system can perform specific actions or connect with medical services. Regarding external safety, some devices are used to control the approach or entry of strangers into the home. For that, identification methods such as video capture or electronic identification card have been implemented. In that way, the system will check the authorization of the intruder at any time. Figure 14 depicts an initial conception of sensors placed in key points to monitor the activities and provide the required safety.

An example of an AAL system implementation, named VirtualECare (Gomes et al., 2010; Novais et al., 2010a; Novais et al., 2010b), can be seen in Figure 15.

VirtualECare Project

The VirtualECare project was developed at the University of Minho. It aimed to develop a user-centered platform with different services where sharing information between different services plays a main role to provide full medical assistance (Costa et al., 2009; Costa et al., 2008; Novais et al., 2010a).
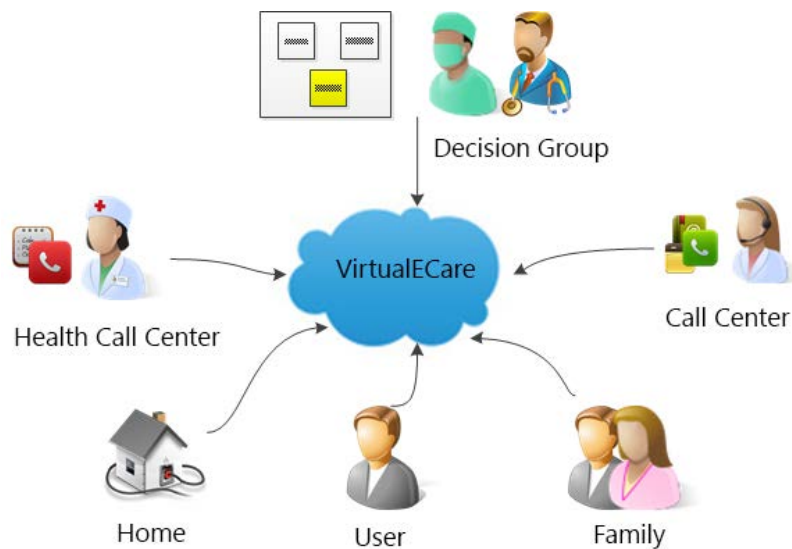
Figure 15: VirtualECare components

This project benefits from the use of different technologies and concepts, as shown in Figure 15, and their features are:

—   Group decision: decides on the user health state and if the provided services are the most suitable. They often review the services and decide what types of changes need to be done, approving activities that the user must practice;

—   Call center: receives all calls from users, doctors and family members, noting and reporting questions. It also makes the bridge between the user and the decision-making group, collecting their suggestions and valuable data to add to the user process. Additionally, it receives the data obtained from the environment monitoring;

—   Health call center: has specialized personnel in emergencies, able to receive clinical information and, if necessary, take the required actions. They can address emergency situations, redirecting to the emergency services more efficiently. In terms of data, it receives the information about complementary tests, incorporating them in reports forwarded to the group decision;

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- Family: is ultimately responsible for having active collaboration by supervising the user tasks. They also have access to the reports about the user health state;

- Home: is where the user is integrated. It is equipped with sensors and actuators which capture the environment status and report it to the group of decision using the reception call center and the call center health for this purpose. The environment must be in constant connection with other services in order to communicate all events and be available in case of emergency. The environment may take the form of a home, hospital or day center;

- User: is the core of this project and its services. Typically, the user is a person with special health care needs. He/she is surrounded by a technological environment to be constantly observed. The gathered data is delivered to other services, building a reliable clinical profile that can be used to respond to his/her needs.

2.6 The Missing Part

Upon presenting the previous concepts, it is clear that something is missing (Augusto, 2009; Aarts & Encarnação, 2006). For instance, every concept works for the benefit of the user, but the systems do not change, although the user does. The inflexibility of these concepts does not comply with evolution. So, they reach their purpose in a specific time period, but they are becoming obsolete. Certainly, the systems outcome from the previous concepts, do maintain working and doing what they are programmed to. Nevertheless, they do not learn or change and, therefore, they cannot adapt to a new environment.

Figure 16 highlights the integrating concepts of the AmI, but none of them has the capability of learning. Therefore, the question that arises is: **what is the missing part?** A simple answer is Artificial Intelligence (AI) since it provides the methods to implement learning capability. Thus, AI applications that transparently change the internal definitions of each application can be added to the AmI. In that way, the user will be better assisted due to the surrounding adaptation to his/her evolution, learning and conforming what was initially programmed to be performed.

In Figure 17 are showed the hierarchic layers of the AmI. These layers structure represent the information flow and importance to the user, attending to his/hers needs.
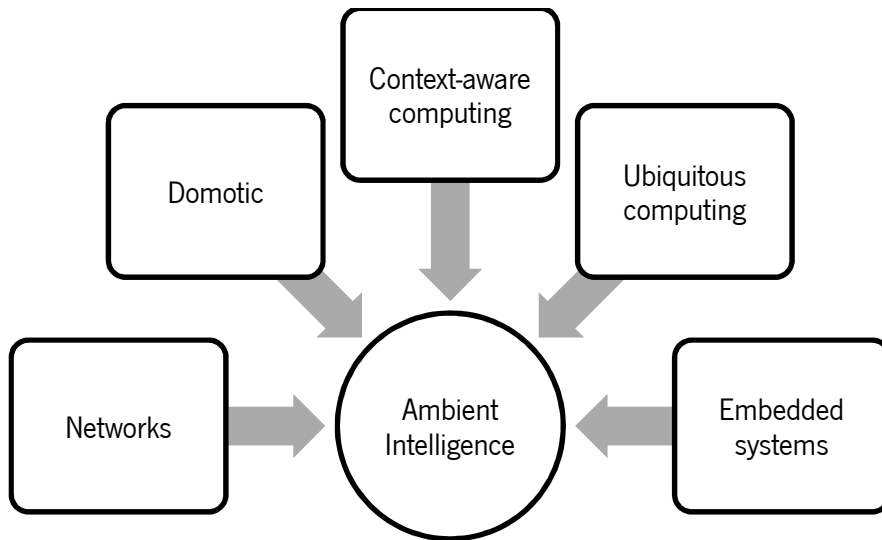
Figure 16: AmI integrating concepts.

Despite what the sensors capture today or tomorrow remains the same, information processing can differ. So, as assisting the users is primordial, learning what they want and what they need, can lead to a harmonious environment where users feel welcomed and accepted.
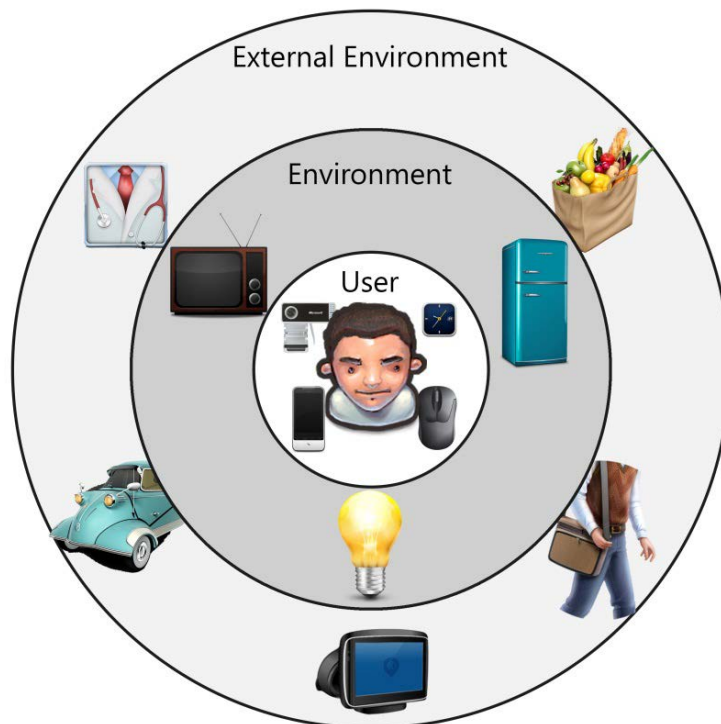
Figure 17: AmI hierarchic layers

2.7 Synthesis

In this section, the various constituent fields of AmI have been presented. Starting from the available devices, the various concepts covered by the AmI have been outlined. As described, the combination of these concepts results in user-oriented services, providing continued assistance in their daily tasks.

Domotic represents the different sensors, actuators, and communication networks. It establishes contact with a real environment, providing systems with perception and action. It is the lowest-level platform, which essentially consists of electronic systems.

The embedded systems are devices or everyday objects that have advanced features such as sensors or actuators. The difference lies in the automation scalability, mobility and processing capacity. These embedded systems can be found, for example, in home appliances or mobile phones, being really useful in notifying people of any situation that might be happening. However, without some kind of intelligence associated, these devices are held back because they are limited in terms of decisions.

In addition, the highest-level concepts, i.e., the ubiquitous and context-aware computing and the ambient assisted living, have been presented. These concepts pay attention to the context of objects in the environment given by domotic and embedded systems. These contexts take into account many variables like user preferences, and influence various objects in order to act in concert with a specific goal.

Finally, we have introduced the question that pushes the AmI concept forward, the Intelligence. Currently, the presented concepts and technology do not have much intelligence, or at least an advanced one. Thus, they do not provide the best solution to user problems. For that reason, we aim to introduce the ability to learn in these systems. In that way, systems will be sufficiently autonomous to suit user preferences or contour limitations from the devices in the environment. AmI systems have evolved over time with the purpose of being able to respond ever better to the people challenges, serving as a discreet but vital help.

In the following sections, an overview of projects approaching the AmI concept as well as solutions implementing learning abilities in AmI platforms is provided.

3 Related Work and Projects

This chapter will review several representative projects in the AmI and Cognitive Assistants (CA) areas. These projects have contributed to the scientific advance in their respective areas in some way, presenting innovation or the way to achieve it. So, it is assumed as a new idea that has not been covered by other projects or the development of platforms and solutions covering new areas. Therefore, they contribute to AmI knowledge development through technological advancements. Some projects are more successful than others. However, all projects should be considered as valuable assets simply because they contribute with knowledge. Successes and failures are sometimes more important than the results, providing the right and wrong ways to follow, very valuable for future developments. In the subsequent sections, projects that are relevant in the CA area are analyzed.

3.1 ACCESS

The ACCESS project (Assisted Cognition in Community, Employment and Support Settings) was developed by the University of Washington. It is a geo-positional platform aimed at helping people with cognitive disabilities, guiding them through a city without getting lost (Liu et al., 2009).

For that, ACCESS gathers information about the user's location and checks the reference points in the knowledge base with the purpose of correctly guiding the user to the next position. The reference points are usually photos of locations, such as residences or monuments, where the user has to go to receive the next indication as shown in Figure 18. This helps the user to get the right direction without resulting in a visual compass, which could be more complicated to the user. In addition, this system increases the indication accuracy, although the limitation imposed by the reduced available reference points. For that, it is crucial that the user complies with the indications.

Figure 18: Working example

Initially, ACCESS was designed for mobile platforms with low complexity and limited functionality and components (without compass, for example). However, its concept is very interesting even today. The graphical way the instructions are presented is interesting to people who have difficulties in using complex devices or do not remember how to operate them. So, one key of this project is showing photos overlapped with directions information. In that way, ACCESS overcomes the potential problems population normally have when they are lost or disoriented. Therefore, ACCESS helps those people to find their way to a safe place or to the desired location.

However, this design has many constrains. Firstly, the device must have enough capacity to store large blocks of information. Secondly, it cannot assist the user when he/she deviates from the indicated path (due to limited local information). And, finally, it does not support interactions with other people (e.g. caregivers). These constraints raise a barrier to use it, being the user forced to go only to the predefined

locations, as displayed in Figure 19. That is, the user cannot roam freely. However, if he/she gets lost, he/she may engage the application to lead him/her to a safe place (Liu et al., 2010).

Figure 19: Screenshots of the indications steps corresponding to ACCESS project
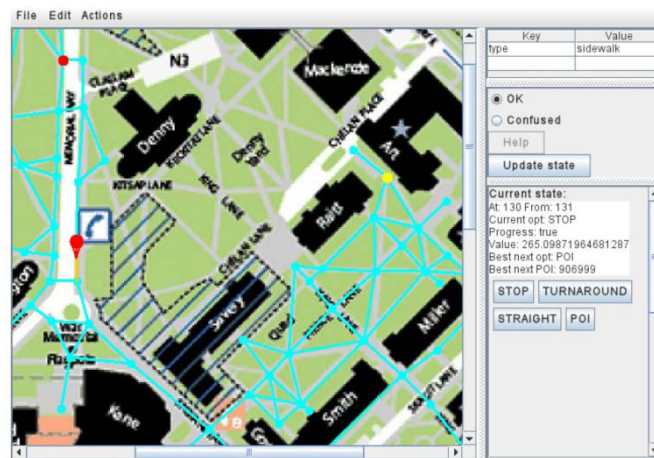
Figure 20: Routes definition application belonging to ACCESS project

Furthermore, due to the lack of flexibility in terms of discovering new routes, it is required to estimate all possible routes so that the corresponding photos are available for the user. Figure 20 shows the software enabling the manual insertion of points and directions and their association with the photos of the landmarks. This turns into a great amount of time spent by a technician to prepare the new route. Thus, if the user wants to change or add a new route, he/she has to wait until the technician develops this route package. Consequently, this system is unusable in our daily life and, therefore, not suitable to common users.

3.2 ALZ-MAS

The ALZ-MAS project was developed by Tulecom Group, with the purpose of implementing a multi-agent platform to coordinate and assist an elderly care service (García et al., 2009). This project focused on a controlled environment such as nursing homes, where elderly people with cognitive problems live. In that way, they can be constantly monitored and specialized features are provided to users and professionals.

Using the agent creating platform, FUSION@ (Tapia et al., 2009), a multi-agent system that supports real-time connection and removal of services, was developed. This system has a shared services system such that agents assume the roles of controllers and administrators in all services, intertwining by using the SOAP communication protocol (Adams et al., 2011; Englander, 2002).

The ALZ-MAS was implemented in a multi-level structure that differentiates between services and agents creating a hierarchical architecture. With this implementation, it is easier to distinguish roles and access and importance levels. This allows the deployment of AmI oriented agents, which lead to transparent and ubiquitous services.
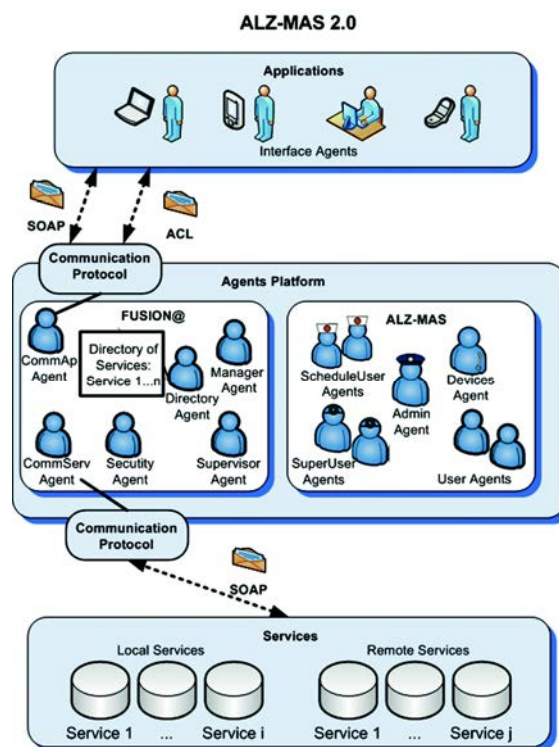
Figure 21: Architecture of the ALZ-MAS (García et al., 2009)

The ALZ-MAS goal is reached by optimizing both routes and the time spent by caregivers, such as nurses or assistants, thanks to the proper scheduling of activities. The optimization system takes into account the position of the caregiver and other individuals and estimates times, obtaining the briefest route from the user requirements.

In Figure 21, the different levels of division and execution of the application can be seen. The automatic planning constitutes the production rules, targeted by agents, to distribute the processing load and to manage other users and their applications. These rules are applied to the location, resulting in an optimized path that indicates the next task to be performed. The system is also dynamic and it may receive several updates to the scheduled events, providing a new route automatically optimized.

An interesting feature is the agents and services available in mobile devices. Mobility is an essential requirement today, providing quickly access to information and everywhere and freeing users from fixed terminals. Actually, mobility was one of the main reasons to work on this project. So, the constant connectivity context and events and routes changes in real time are key features of the project.

No further advances in this project can be found since 2009. However, this is a complex design and its findings may be retrieved from examples, characteristics and approaches of the produced results. In fact, some of the discussed solutions are interesting such as the scaling and platform used for the developing agents, the concept of mobility or the constant rescheduling.

3.3 Collaborative Memory Aids

The Collaborative Memory Aids (CMA) project, developed by the University of Toronto, was the result of combining several projects from the same research group. Its purpose was providing social inclusion of elderly people (Wu et al., 2004).

This project excels in mobility and adaptive interfaces. It was specifically developed to interact with the user by mobile devices such as Smartphones. In addition, it connects to a server that will safeguard data of daily operations and data transactions. It is aimed at providing users with a multi-user shared agenda platform that reminds them what to do during the day and what other people are doing at the same time.

Built keeping usability in mind, the CMA provided fine-tuned interfaces to match the user's expectancies. The use of advanced technological devices by older people entails variables that must be taken into account since learning difficulties and health problems could prevent the normal use of an application.
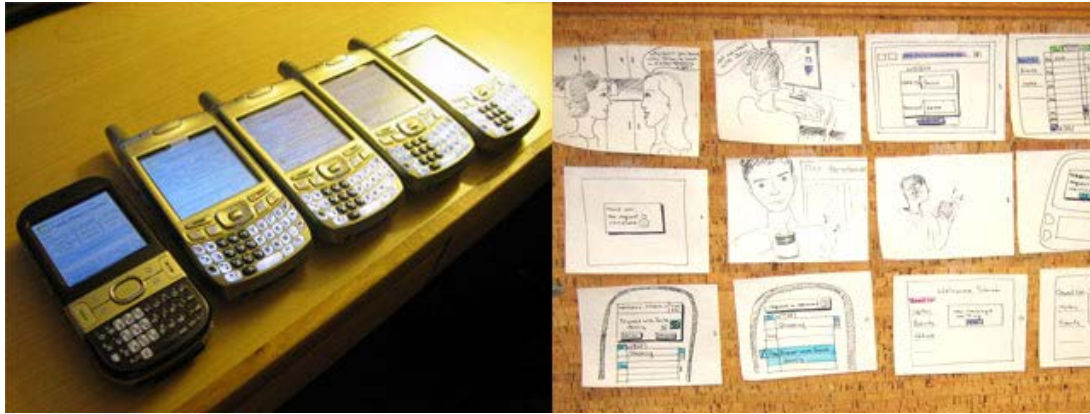
Figure 22: CMA development and storyboard design

The ease and intuitiveness provided by this project lead to an unprecedented concept, the proper application management for those who have little technical knowledge. Furthermore, the learning curve should be short such that the interaction procedures for users are very similar to their interactions with other objects.

The CMA enables events handling such as adding, changing, removing and sharing, proving that a calendar supplies a natural way of reminding tasks to be accomplished. An example can be found in mobile devices where calendar applications feature as providing a large storage capacity, different presentation formats and audible and visual warnings. The constant connectivity offers the ability to share events and contact with others, especially with family and friends. Figure 22 shows different mobile devices presenting the application in execution and the storyboard to the development of the interfaces.

The CMA success relies not on an intelligence-based system or event adjustment procedures but on interfaces. The lack of intelligence or any sort of automatic management leads to a rigid system, where the user has to manually insert all the events, requiring that he/she remembers to introduce them (Wu et al., 2008). However, the adaptive interfaces are very interesting given that older people have very specific constraints. For that reason, they are not inclined to adopt new technology, especially when it seems unnatural and difficult to understand.

3.4 CompanionAble

The CompanionAble project, developed at the University of Reading, is a synergy of robots, software applications and their semantic integration to build a caregiver assistive environment (Kessler et al., 2010; Guettari et al., 2010). It provides integration between the robot and the smart house sensor network environment, enabling the fusion of communications between the user (through the home TV screen), healthcare staff, medical professionals, and gerontologists.

From the user point of view, this project provides intelligent day-time-management, content generation for cognitive stimulation and training, medication reminder, analysis of acquired data regarding his/her health status, and efficient and natural social communication by means of audio-visual communication with relatives or caregivers.

As shown in Figure 23, the robot is large and tall, resembling a somewhat human form. This robot is provided with a set of cameras to enable visual perception, a screen to display visual information and to receive user input, and a voice modulation processing system based on the text-to-speech concept.

Figure 23: CompanionAble robot

The user's home must be equipped with several sensors to capture the environment and user's actions that the system could not have perceived. This becomes a "human" presence that differs from the user

interaction with a computer or a mobile device since this robot has no real action abilities due to the lack of actuators of any kind.

This is one of the few projects that associate an AmI home and a robot, despite the fact it is still at a quite early stage. Nevertheless, the developed system highlight that users accept the robot in their lives by integrating it on their daily activities and serving as a companion, relieving them from loneliness.

3.5 Hermes

The Hermes project (Jiang et al., 2009; Jiang et al., 2010) was developed by an association of entities such as the Center for Usability Research and Engineering, INGEMA Foundation, IBM Haifa Research Lab, University of Bradford, Athens Information Technology, TXT e-Solutions. Funded by Framework Programme 7, this project must follow the lines of development and investment in elderly assistance established by the European Union.

This project is based on the combination of visual, audio and reasoning information through the Sensor Fusion concept (DeLong, 2003; Sanfeliu et al., 2010; Atrey et al., 2010). In terms of workflow, Hermes uses mobile devices to gather information and a server to provide data processing and knowledge extraction. Objectively, this project attempts to create a digital brain of associations that effectively emulates the user, being lucid and coherent.

The aim is then to capture different parameters such as audio and video along with data such as where, who, what and why. These types of information result in events episodes that form a high stage of information. As a consequence, an event-relationship graph between different activities is generated. Representing people with whom the user interacts, and their impact on his/her life, leads to a mapping procedure that resembles a meta-associative brain.

Basically, the system is composed of seven blocks of logical information:

- − Sensing infrastructure;
- − Visual processing;
- − Audio processing;
- − Sensor fusion;

- Context modeling;

- Indexing and contextualization;

- Meta-data processing.

All these blocks contain several components that provide the appropriate response to recurring events. So, within the sensing infrastructure different components are included. As an example, as components we can find visual perception, which is capable of tracking and recognizing multiple objects; auditory perception, capable of identifying each sound and its spatial position; or speech processing, among others.

This project ended in March 2011, although it was partially developed. That is, the project results only cover the home monitoring concept, mobile games and cognitive architecture. The loss of the whole development (a cognitive emulation) greatly limits the actual impact of this project.

3.6   SenseCam

The project SenseCam (Hodges et al., 2006; Hodges et al., 2011) is developed by Microsoft. It is the first approach to personalize healthcare. Mainly, it consists of a camera attached to the user, typically around the neck or chest, which captures timed photos, thereby obtaining a photo timeline. Creating a photo album where the wearer has been, who he interacted with and what activities he/she carried out.

Figure 24: SenseCam device

The study that Microsoft conducted with an elderly population with memory problems had very important results. Most users improved their ability to recall memories about events, as well as their memory capacity in some cases, slowing the memory retention deterioration (Hodges et al., 2011).
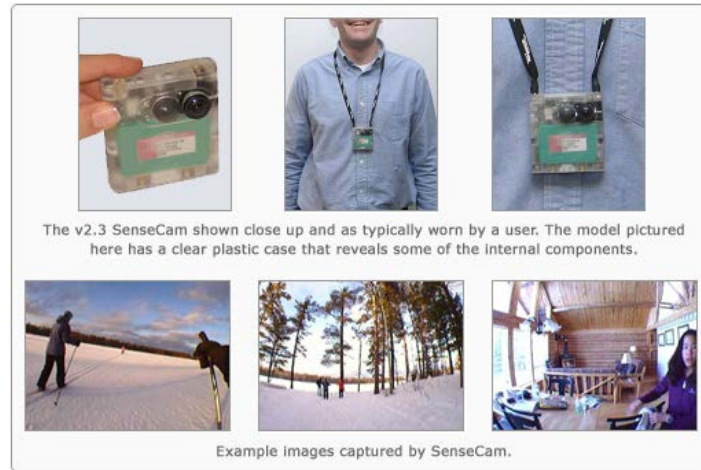
Figure 25: Device and sample taken photos

It is an ongoing project, but so far it misses user interaction features, and requires a great amount of attention from the user.

3.7 Critical Analysis

The projects presented in this section positively contributed to this PhD thesis, both conceptually and abstractly. For that, positive and negative aspects were analyzed. So, whereas the positive results can be obtained by the validation of the work done, absorbing the provided knowledge; negative results contribute to expose the wrong path and serve as example of what not to do.

After a failure, efforts must be focused on rectifying it. This results in different solutions and concepts than the expected ones. So, different approaches that were not initially expected can be integrated into other projects that are not directly related to the area. Consequently, this study about the state of the art saves time and effort to understand what the flaws in these projects were and how to avoid them, given their direct and indirect consequences.

The presented state of the art is along the concepts approached in this thesis. So, the presented projects clearly belonged to the AmI area. Currently, they change its initial state by contributing with their results, including technology and new concepts. These new perceptions opened a way to different developments, assuring some type of closures in matters left open. Therefore, some assertions can be done from their success or failure in the different projects.

Thus, the ACCESS project presents a tracking system and a guide for the user. This project pioneered by introducing images of spaces and landmarks to guide the user in a course. However, this design suffers from several drawbacks. Among them, the amount of information in terms of images limits the storage capacity of several routes, and the system is closed, not enabling connections to other types of services.

The project ALZ-MAS results in a system where the concept of multi-agent platform in AmI environments is introduced. It allows to creating agents that respond to the platform requirements, adjusting them to the environment within they operate. Nevertheless, it is a theoretical approach since it was not developed long enough to act in a real environment.

The CMA introduced adaptive interfaces to AmI systems. The typical user of these systems does not have great knowledge of technology and, therefore, intuitive interfaces, which are easy to understand, were designed. However, this design fails by having few features and no connection with other platforms. As a consequence, the scheduling functionality is the only available service, without being provided with some kind of intelligence or automation in the tasks management.

The CompanionAble robot and home are one of the most developed projects in introducing robots in an AmI environment. The results of test in a controlled environment were positive, being the users aware of the presence of a robot (and not a humanoid) and interacting with it. Nevertheless, its major problem is the high cost of technology since it resulted in a robot with very little features. The robot must be assisted by several monitoring systems that are in the user home. Thus, the home controlling systems do most of the tasks.

The Hermes project offers an important perspective in the sense of developing the architecture of an AmI project. It also established the basis of cognitive assistants' development by presenting an approach of user's profile emulation. However, this goal was too ambitious by that time given the lacking knowledge for the project development, producing no significant results.

As described, the SenseCam is a simple camera. Its simplicity made it very limited and required a large interaction with the user in terms of obtaining the pictures. This resulted in it not providing any sort of real-time interaction.

Next, the iGenda project will be presented as well as how the knowledge acquired by these projects helped find solutions to common problems.

4 iGenda: Technologies

The iGenda project is an AmI platform in its essence. Mainly, iGenda was built considering all the concepts previously presented, despite becoming modular and independent from other systems. To develop this platform, the multi-agent concept, where each agent is responsible of a specific task, was used.

With the purpose of satisfying user needs, two user systems were developed: a mobile application and a desktop one. So, each system covers different user specificities, despite their similarity in terms of core functionality. In the case of the mobile system, it can gather information from a sensor platform, which generates data of the user's health condition. So, both applications (mobile and desktop) have to be connected and exchange information with the iGenda master server, also acting as an interface to the user. The main reason for using the multi-agent paradigm is that agents help remove overhead in the

application execution and accelerate the execution of critical operations. This fact results in a tiered system that works on request, being optimal to real-time agent changes and deployment on a started platform.

Several concepts are within the AmI area and they can be used to provide user-centered solutions. In this section the concepts and technologies that made the iGenda possible are presented such that each one contributes to the iGenda functionalities and, therefore, it is crucial to its explanation.

4.1 Agents

By definition, an intelligent agent is an entity that perceives the surrounding environment and automatically acts within it (Russell & Norvig, 1995; Wooldridge & Jennings, 1995). In Figure 26, an information cycle concept is represented. Agents must have the ability to autonomously achieve a certain goal by using some of their skills such as learning or past knowledge. Wooldridge (Wooldridge, 1997) stated that an agent is a multilayered system present in a particular environment. This system is modular, flexible and autonomous to be able to achieve its goals.
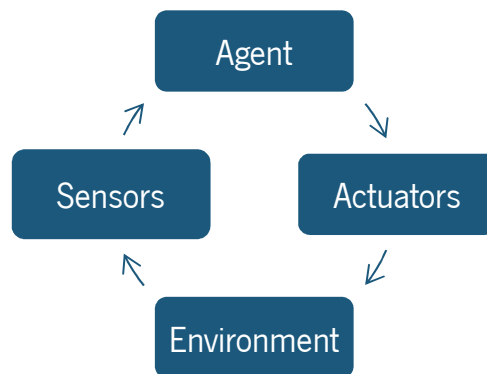
Figure 26: Information cycle concept

Agents must serve a purpose, a goal that operationally guides them (Maes, 1994). Agents, throughout their concept, can have many different roles and goals. In the AmI area, agents perform actions that usually benefit the user, helping him/her on what he/she needs. In particular, they may help users in various ways:

— Absorbing the complexity of difficult tasks;

- Performing user tasks;
- Teaching the user;
- Implementing collaboration systems;
- Overseeing events and procedures.

All these actions converge on the following agent definition: agents must have the ability to deal with unsolved problems, and to solve issues more efficiently (Jennings et al., 1998).

Agents can be divided into two types of notions: weak and strong (Michel et al., 2003; Vincent et al., 2001; Weyns & Holvoet, 2003; Axtell, 2001; Wooldridge et al., 1995). As the names indicate, they differ in terms of features and range of actions that agents are capable of performing.

The notion of weak agents does not depend on its action strength, but in the action and reaction capability. These agents have the following features:

- Autonomy: the agents do not depend on other agents for normal operations. Other agents have no knowledge of the internal operation of their peers;
- Reactivity: the agents perceive the environment and respond appropriately to changes in that environment;
- Proactivity: agents take initiative, and taking into account their goals, perform actions to adapt to the environment status changes;
- Sociability: the agents create connections to communicate with other agents, competing or cooperating to achieve their goals.

Additionally, strong agents must have the following features:

- Mobility: ability to move across a network formed by peers, performing the tasks assigned to it;
- Intentionality: ability to define objectives and strategies to achieve the goals;
- Learning: ability to acquire knowledge. The knowledge base update is done through the assimilation of behavioral patterns or preferences;
- Competence: finishing with success and efficiency of tasks that the agent is responsible for. Competence is related to confidence in the agent by third parties;
- Veracity: failure to (intentionally) provide false information;
- Rationality: non-acceptance of tasks that seem impossible or contradictory to its principles, when not compensated in terms of risk, cost or effort;
- Grace: adoption as their, goals of others, provided they do not conflict with its principles;
- Emotionality: adoption of human features.

Attending to these notions, agents can be divided into classes (Wooldridge, 2009), attending their goals and their features:

- – Simple agents (action-reaction);
- – Model-based agents;
- – Goal-oriented agents;
- – Utility-based agents;
- – Learning agents.

Simple agents (action-reaction)

These agents only act when necessary based on a set of rules without absorbing any prior actions. The functions are based on the action-reaction concept. So, after detecting any change in the environment (action), the agent behaves according to its planned program (reaction). This type of agents is suitable for environments where all the variables are known, and where solely simple actions are required.

Model-based agents

These agents can act on environments partially unknown. They keep the environment state and have a well-defined action framework, defined by a wide range of conditions and actions. The group of conditions and actions are named world model, and, from this prior information, the agent is able to perform actions, knowing only part of the current environment.

Goal-oriented agents

These agents are more complete than the model-based agents. They expand the capacity into the concept of goal. From the concept of a purpose, these agents have the description of the acceptable situations. Given that agents are enabled to choose between several hypotheses, they choose the one favoring the goal. Not being directly focused on efficiency, these agents are more flexible. That is, they can accept a set of unknown cases and achieve the desired goal using concepts such as planning and demand.

Utility-based agents

The agents previously presented can only distinguish between goals and non-goals. On the contrary, the utility-based agents use utility functions. That is, they define a state mapping to determine which states are more desirable to achieve the goal. So, the states provide the knowledge of relationships and paths that allows to achieving a certain goal. This leads to a system reaching a goal by adding the different

parts of the path, typically, choosing actions that maximize utility. Therefore, the utility-based agents have a sense of model as well as environment knowledge, performing tasks that involve logic, representation, perception and learning.

Learning agents

The learning feature provides agents with tools to work on unfamiliar surroundings. Moreover, the agents will be optimized depending on the circumstances and the received information. So the agent is divided in two: learning, where the agent is optimized, and performance, in which the agent chooses the best tool or way to perform a given task. These agents must have an external agent that determines the efficiency of their choices, creating a system of weighted procedures where results are transformed into a library of execution, calculating their impact on the environment.

Architectures

These concepts must then be gone with architectures to secure the agents' development. Thus, architecture is used to establish a normative, built from construction patterns enabling the agent operation scheme.

There are various types of architecture, although the mostly used ones are: deliberative, reactive, hybrid and BDI (beliefs, desires and intentions). So, any agent can be classified as one of them, depending on the followed operation process (Salamon, 2011).

Deliberative

The deliberative architectures mainly follow the classical Artificial Intelligence approach. The agents have little autonomy and are mostly static. They follow the logical-mathematical reasoning and have a limited ability to learn (Kubera et al., 2010) (Figure 27). Therefore, they must have a vast knowledge about the environment within which they act.

| Perception | ⟹ | Modelation | ⟹ | Planning | ⟹ | Execution |

Figure 27: Deliberative agent process flow

Reactive

This architecture defines an agent as basic automata. That is, it is only able to act according to its base of knowledge. Given its inability to solve problems out of context, these agents can only deal with

situations of low complexity according to what was set. In this case, the provided information is of type atomic, received from sensors (Kubera et al., 2008) (Figure 28).

Condition	➡	Action

Figure 28: Reactive agent process flow

Hybrid

It combines the two previous architectures. The goal is to build agents who are able to ponder the perception variables and quickly respond to events of low complexity. Being constructed hierarchically, this architecture initially addresses the reactive layer and then the deliberative layer (Panait & Luke, 2005) (Figure 29).

Deliberation planning	⬌	Task planning	⬌	Action execution
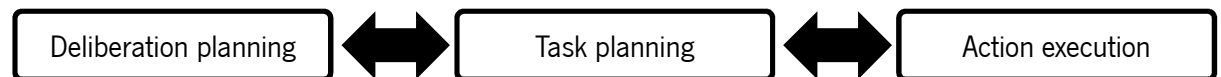
Figure 29: Hybrid agent process flow

BDI

This architecture is more complex and complete than the previous ones. It requires planning actions to build an agent that responds according to their goals based on previously defined procedures. The three aspects (i.e. beliefs, desires and intentions) serve as an abstract implementation of agents. So, beliefs are the aspect containing the knowledge about the agent environment. On the other hand, desires are the aspect storing the possible goals to be achieved; while intentions are the aspect retaining the agent plans of action, of potential situations and events (Singh, 1999; Guerra-Hernández et al., 2004) (Figure 30).

Knowledge	➡	Beliefs	➡	Desires	➡	Intentions

Figure 30: BDI agent process flow

The initial developed systems had very few agents, being common to have only one agent working. However, with the crescent complexity, more agents were deployed in a common platform. That fact has led to the development of the multi-agent systems concept. This concept states that the agents in the platform must communicate with each other and each agent can have different categories or

architectures. Also, along the structuring process concept, it was established that the agents would be deployed in an easy and transparent way.

4.2 Multi-Agent Systems

The development of the agents' concept has highlighted autonomous features like being able to make decisions without external revision. Keeping individual agents was counterproductive since some of them shared features and information. Therefore, it led to merging projects and agents, evolving to a state that sharing information between different agents is demanded. This advancement, i.e. the ability of communication, was noticed by the scientific community when analyzed the capabilities of an agents' platform. So, the multi-agent concept was born (Russell et al., 1995; Wooldridge, 2009; Wooldridge et al., 1995; Weiss, 1999).

Multi-Agent Systems (MAS) have provided new paradigms, especially the division and simplification of complex tasks over several agents. That is, each agent only had information about the area assigned to it, becoming an expert on it and containing all the information and procedures (Ramos et al., 2008). MAS also helped in terms of development and operation. Thus, in terms of development, the procedure distinction results in designing and building agents in a more easily way. In that way, future changes are easier reducing time-consumption and costs when introducing new features. On the other hand, in terms of operation, it meant the physical separation of agents and improvement in terms of modularity. The agents have the ability to communicate between each other and, despite being able to be separated in terms of location, they remain connected to the same platform. Adopting the concept of distributed computing, agents have the ability to be virtually and physically separated. Thus, agents can be on their own computer without being affected by the consumption of resources by other agents. In terms of communication, MAS can use previously established ontologies and protocols, providing scalability to the platforms and allowing developers to deploy their own agents.

MAS separation of agent concept translated to more robust and fault-tolerant platforms. That is, when there is a problem with an agent, it can be unloaded, repaired and loaded again without affecting any other agent in the platform. The ability to have replicas of the system means that downtime and major errors can be avoided by booting a new platform in other physical machines. This operation is a tight

MAS environment because it uses external agents to monitor the operation status, activating the rescue plans when needed.

With the aim of communicating efficiently, the MAS must have methods and protocols. They can be defined in terms of implementing the necessary functionalities (Andrew Brent Williams, 2000; Yuan, 1998) such as:

- Communication platform: physical transmission of information;
- Communication language: meaning of the individual messages;
- Ontology: communication model;
- Architecture and organization: determination of the connection between systems.

To implement MAS and their platforms, network organizations providing the structure to the physical network are required. So, there is a crescent complexity in terms of individual classification because of the number of agents. Therefore, they can be placed in a comprehensive organization group.

4.2.1 Organization

MAS must belong to one or more organizations leading to various ways of placing agents in a network, defining their position, hierarchy and communication network. Despite being highly modular, MAS are restricted in terms of interactions and communications and for safety reasons each agent only has a limited number of contacts. For their part, ontologies ensure the communication between peers, demanding the use of standards. Grouping all these constraints results in the need of defining rules to implement MAS.

MAS can be then arranged in various unique shapes or a combination of them. The most prominent organizations are presented below (Bond, 1988; Weiss, 1999; Ferber, 1999; Olson et al., 2001).

Hierarchical

The agents are hierarchically organized such that the top agent performs the most important actions and communication is vertical. The agent at each level can command the subordinate agents (those in lower levels). It uses a tree-like communication procedure, passing messages from agent to agent in order to reach the goal.

Expert

All agents have the same hierarchical level and communicate with all community, without having any priority. Predefined ontologies ensure communication between agents, being able to simultaneously receive and process multiple messages. Typically it uses direct communication resulting in a shared communication space.

Goal oriented

There are several agents that have the same features and functionalities, competing proposals with different goals. It is based on the concept of bidding markets. Typically there are one or more agents that communicate with a community, and the agents' community only responds to direct requests.

Tasks

The organization relies on a single agent to distribute and receive all messages and actions from other agents. It requires the managing agent has enough capacity and fault tolerance since all the other agents only communicate with the manager.

As abovementioned, a platform or agent is not forced to adopt any of those organizations. They may be in a complex system of organizations where agents have two very distinct classifications and specific approaches to each organization they are integrated into.

Those organizations can be implemented whether there is a real computational application that assures the creation and support of the agents' environment. Some applications support different agent concepts and architectures, which may be implemented in different programming languages.

Among the wide range of available designs, the main platforms for implementing multi-agent systems are chosen according to the number of people using them and the academic and commercial projects in which they are used.

4.2.2 Multi-Agent Systems Development

MAS can be developed using specialized tools and platforms. Once they are developed, they must be implemented in an execution platform. The platform should be able to properly perform the agent's actions as well as implement a communication system. By providing these features, the system can

ensure the correct functioning of MAS. In terms of execution platforms, each platform has its features and approaches that must be considered when developing the agent.

Some development platforms are (Argente et al., 2007; Becker-Asano et al., 2005; Gawinecki & Frackowiak, 2008):

— JADE: provides a very flexible platform for implementing agents built in JAVA. Agents only need the concept of behaviors to implement an operation structure that allows to freely developing its features. The registration and maintenance of the platform are strictly organized, allowing to only registering a single agent while avoiding possible conflicts. JADE is a platform that enables a quick development of agents, using the standard FIPA-ACL as the communication method. However, the lack of rules means that unknown faults can be easily introduced.

— JADEX: based on the BDI concept, it uses a custom implementation of the JADE platform, built in JAVA. Despite the requirement of BDI architecture development, it results in a very structured system but rather inflexible. Additions of new agents demand a deep change in the platform structure.

— Jason: uses Java based on AgentSpeak. Consequently, it is constrained to the contours of AgentSpeak, resulting in a robust but very inflexible system. Similar to BDI architectures, Jason only enables deployment of agents in logical language, making very difficult add new agents to the platform.

— JACK: is an agent platform built in JAVA based on BDI. It is robust and constructed to be implemented in industrial environments. Currently, among the presented platforms, it is the best developed and most advanced, targeted to develop commercial products. Unfortunately, it is a commercial product.

— SPADE: a development platform built in Python. It is the most similar to the JADE platform and can also connect to the JADE agents' platform. The communication method uses the standard FIPA-ACL, and has a graphical environment to manage the platform. Its great advantage is having its own way for publishing agents as webservices.

Taking into account all these platforms, JADE was chosen as the development platform for iGenda. The reasons for choosing JADE were: the ability to rapidly and easily develop agents, a robust platform, a communication system based on FIPA-ACL and being free of charge. Additionally, the JADE availability for the mobile platform Android and constant updates with new features were also taken into account.

JADE

JADE is the acronym for Java Agent Development Framework. As its name indicates, JADE is a development platform of Java agents (Gawinecki et al., 2008; Bellifemine et al., 2007), developed by Telecom Italia.

The JADE platform ensures the creation of supportive environments for agents, providing management and security features. In addition, it guarantees the creation of services that facilitate communication and registration of agents, being the AMS and DF proto-agents (seen in Figure 31). The AMS (Agent Management Service) is the authority system and ensures each agent has a unique name. In fact, names should be unique to avoid crossing information and ensure the agent uniqueness in the platform. Authority refers to be able to create and terminate agents, both locally and remotely, and it is responsible for the whole platform in which the agent operates. The DF (Directory Facilitator) is a service similar to the yellow pages. That is, it has all the information of the communication network and agents in the platform, containing their names and addresses. This data is used to find agents with certain features.
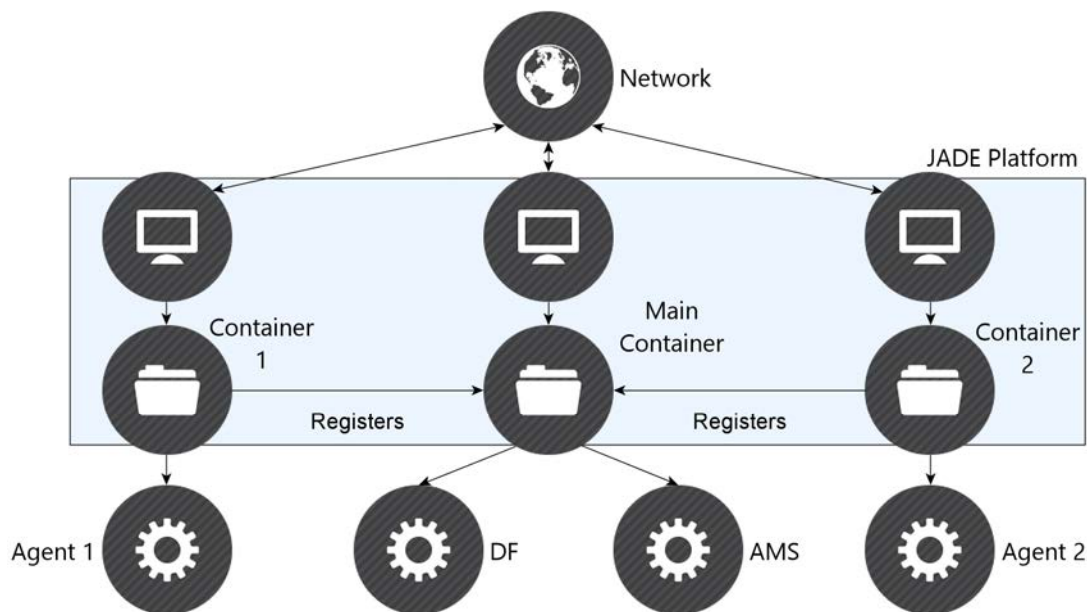
Figure 31: Example of the platform and containers.

JADE uses ontologies freely. Ontologies in this context are understood as the implementation of a communication infrastructure and protocols defining layers of understanding among agents. To enable communication between agents, it is needed more than a physical network connection that uses the same language, vocabulary and protocols. Therefore, the ontology is aimed at defining rules of communication where agents know how to communicate right from the start, what ensures the platform

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flow of information. The agents follow ontologies based on communication speech. They define the shape and the active fields that contain information relevant to the goal. The flexibility allowed in the agent building leads to relegate to the developers the implementation of ontologies specific to each project and/or agent.

In terms of the language of communication, JADE adopts the standard ACL (Agent Communication Language) (Foundation for Intelligent Physical Agents, 2002b; Foundation for Intelligent Physical Agents, 2002a), defined by FIPA (Laukkanen et al., 2002; Giraldo & Bonilla, 2011; Bahadori et al., 2005), which helps to succinctly define fields and structures of messages.

Agent building is highly-based behaviors. The use of these behaviors defines the role of the actions that allow the agent to achieve its goals. The most common ones are *cyclical*, *one-shot* and *simple*. These behaviors are what consign attitudes and operating models, hosting all the code to proceed as constraints and functions. In addition, JADE has composite behaviors that are composed of primitive behaviors. These composite behaviors are *parallel* and *sequential*. They define if the primitive behaviors are executed sequentially or in parallel. For that, it uses a tree system allowing composite behaviors inside composite behaviors, as shown in Figure 32.
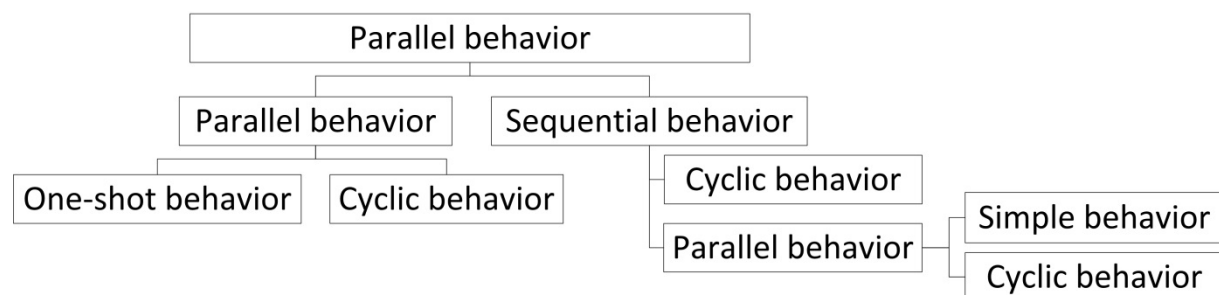
Figure 32: Example of behaviors structure

The system modularity developed using JADE is high, given the developer's ability to build and model any type of agent when implementing any kind of activity. The JADE platform ensures the communication between agents. UML can be used to formally design agents (Booch & Jacobson, 2005), using JADE API's to implement the functions necessary to the agent operation.

4.3   Mobile Systems

The mobile systems are now a major area where technology and applications are developed and used. It is assumed as mobile devices, all independent power source devices with some ability to capture, process and transmit data. This definition covers mobile devices from smartphones to sensor platforms.

4.3.1 Devices

With the advent of miniaturization and autonomy optimization as well as the crescent availability of mobile devices in the market, it was easier to develop cheap complex devices. Currently, some phones have more power than a 4 years old computer. Moreover, they come with several features such as GPS, accelerometer, luminosity sensor and compass, having also different methods of communication such as GSM, GPRS, Wi-Fi and Bluetooth.

In fact, smartphones can be compared to pocket computers. They are able to connect with other digital platforms like Arduino. This allows the extension of sensing ability to capture a multitude of physical inputs, analog or digital (Buechley & Eisenberg, 2008). The smartphone processing capacity is strong enough to receive and process data.

Projects such as the Amarino or the Micromouse Cheese Trophy already use this combination of mobile devices with sensors connected to platforms to interpret analog and digital signals. These projects promote the development and implementation of systems for home use. Companies like Phidgets (Greenberg & Fitchett, 2001) develop platforms supporting sensor connection, and providing drivers to connect to devices using Android operating system (Yu & Liu, 2010; Meier, 2009). The developer only needs to assemble the drivers in the operating system and then develops the code to process the received data. Devices like smartphones developed by different manufacturers tend to exhibit very similar hardware features, differing in their operating system.

Smartphones

There are several operating systems for smartphones today, although the most used ones are Android, Windows Phone and iOS. These operating systems have great similarities with personal computers, allowing installing new applications and customizing both interfaces and configurations. In terms of features they can summarize as follows:

- Android: developed by Google, is based on the Linux operating system and is free and open. So, development is free of charge and allows access to the operating system source code. It is fully customizable and makes developing applications easy. The development uses the JAVA language and adopts its programming methodologies.

- Windows Phone: developed by Microsoft, is installed in newer devices. The application development is done in C++ and .NET, using a specific platform for this purpose. Its market share is small, revealing fewer applications for this operating system, or much interest by developers. The core is closed and does not allow modifications. This makes it limited in terms of service implementation on the native operating system.

- iOS: developed by Apple, is only available in smartphones manufactured by this company. Its development is done by a specific platform. The core is closed and does not allow modifications since it is not allowed to install applications without Apple approval. The programming environment is commercially licensed, i.e. it has a purchase cost.

Figure 33: Smartphone sensor features

The iGenda project adopted the Android platform over the others for various reasons (depicted in Figure 33). Given that it is free of charge and allows full configuration of the operating system kernel, it is possible to build complex applications that can be freely distributed. Moreover, its use by a large number of people contributes a greater market spreading, and, consequently, it can have better chances to be used. The rampant growth of Android use is also a proof of confidence for user part (see Figure 34). Sustained growth annually results in a market share of 52.5% (Cozza et al., 2011), with an increase of 25% with respect to the last year. This statistics lead to manufacturer investment with the purpose of offering a wide variety of devices with different features.

In August, 56% of recent acquirers chose an Android device
Operating System Share – All Subscribers and Recent Acquirers
Aug 2011, Nielsen Mobile Insights, National
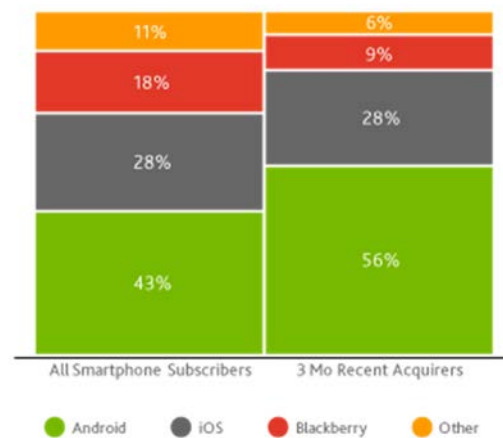
Figure 34: Sales growth of Android devices in August 2011 (available from Nielsen Media)

A large availability of device models results in potential compatibility issues that can be easily solved by switching to another device with disparate features. This cannot happen when devices are all the same. In the development phase, it is very important to know that hardware compatibility problems can be easily solved.

When considering smartphones as small personal computers, and having multiple communication standards, it opens the possibility of expansion. They can be connected to other devices using similar communication standards. In that way, they can connect with a sensor platform. The sensor platform sends data to the smartphone and it takes care of processing the received data. This grouping is called Body Area Network. Basically, it consists of a set of devices that monitor a user, and intelligently acts according to the received data.

4.3.2 Body Area Network

The Body Area Network (BAN) is a ubiquitous network in which portable and wireless devices operate that communicate with each other to share information related to the user (Latré et al., 2010; Waluyo et al., 2007; Jain, 2011; Wolf & Saadaoui, 2007).

This concept arises from the increasing development of personal mobile monitoring platforms. They started as large devices that were used on the medical area. From then, they have been decreasing in size and increasing accuracy. So, nowadays, there are already several alternatives that can be used by

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anyone. These devices are mostly available in the form of complex platforms that operate on proprietary protocols and interfaces. However, their connection with other devices is transparent and accessible, as seen in Figure 35.
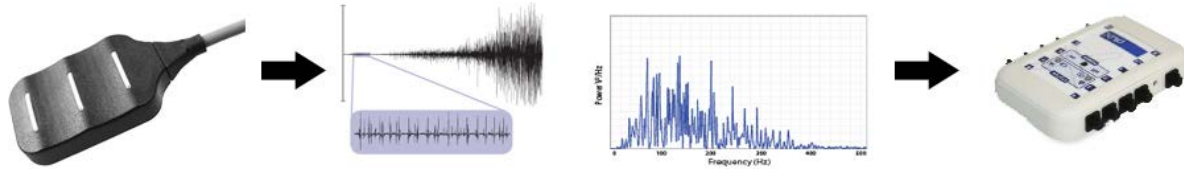
Figure 35: Example of sensor data that reaches the platform

The availability and the environment where these devices are placed, shape the way they communicate with the reception units. The formats are preferably wireless, prevailing ZigBee and Bluetooth standards (Gislason, 2008; Micallef et al., 2008). These platforms can be used by a common person with some training, being sensor placement and maintenance crucial tasks for optimal functioning. Information merging from the various sensors must be also considered. Note that information combination can produce results that would go unnoticed. For example, fusion information of an electrocardiogram (ECG) and the blood pressure value (BPV) may indicate potential problems that are normally undetected.

The most common portable sensors are:

- Electrocardiogram (ECG): a set of three sensors placed on the wearer chest. Its functionality is capturing his/her heart rate. From these sensors, information about the heartbeat, cardiac degeneration, impending heart failure, stress, among others, can be obtained;

- Respiration sensor: perceives the respiration cycles by measuring the rib cage expansion and contraction movements. The measurement is done by generating voltaic energy through body movement. This sensor allows to checking if the user is breathing and if he/she has any breathing problems or chest impediment;

- Electrodermal (EDA): measures muscles short pulses of energy. Small electrical sensors should be placed on the muscles such that this sensor provides muscles fault detection, and information of cognitive and emotional states;

- Electromyography (EMG): this sensor estimates the general muscle state. In sum, it can be used to assess fatigue, muscle twitches and instant responses;

- Accelerometer: This sensor provides information about the user movements and their strength. It can be used to detect if the user is moving and suffer from impacts like falls;

- Temperature: this sensor provides information about the user body temperature. The fluctuations in body temperature can indicate health problems untraceable by other sensors.

These types of sensors provide raw data to the reception platform. The platform takes into account all the sensors features such as voltage level, sensitivity and errors. Then, data is transformed into information. People cannot read raw data, thus they need to have some kind of discernible information.

Applications developed by the sensor manufacturers are responsible for the data processing. Thereon, the application provides a file or data stream to third party applications.

The union of smartphone platform and sensor platform enhance user mobility and monitoring. That is, the data is gathered and locally processed being able to immediately detect problems. The BAN can serve as a first stage emergency service, contacting medical services in case of emergency. Then, the BAN is a great solution for patients at imminent risk.

When coupled with other services, the BAN can become an AAL service. So, pairing it with other AAL services can result in appointment management, medical contact and a panic button connection with care services. The presented information is compact aiming to a general health projection, being the details only available to the medical personnel team.

4.4 Artificial Intelligence in AmI

An initial approach on AmI is presented in Figure 9. It was already a complete architecture but it missed the intelligence essence. By definition, intelligence is the concept evolving by learning achieved over time, which in the classical system does not occur. Figure 36 shows the inclusion of new concepts (Ramos et al., 2008).

Comparing Figure 9 to the Figure 37 it can be seen that four more modules were added. These set of modules are known as the platform artificial intelligence (AI). They provide the system with the features needed to perform as the classical notion of AI. Therefore, this representation shows an evolution from a static format to a modular format. This is reflected in the introduction of key components of artificial intelligence. Concepts such as Reasoning, Knowledge Learning and Decision Making provide the necessary modularity. In terms of workflow, it can be observed that it develops a hybrid architecture.

With the new components, the middleware becomes a connecting bay for all components, while the remaining components maintain their functionality. The workflow provided by the new components introduces intelligence capability, as depicted in Figure 37.
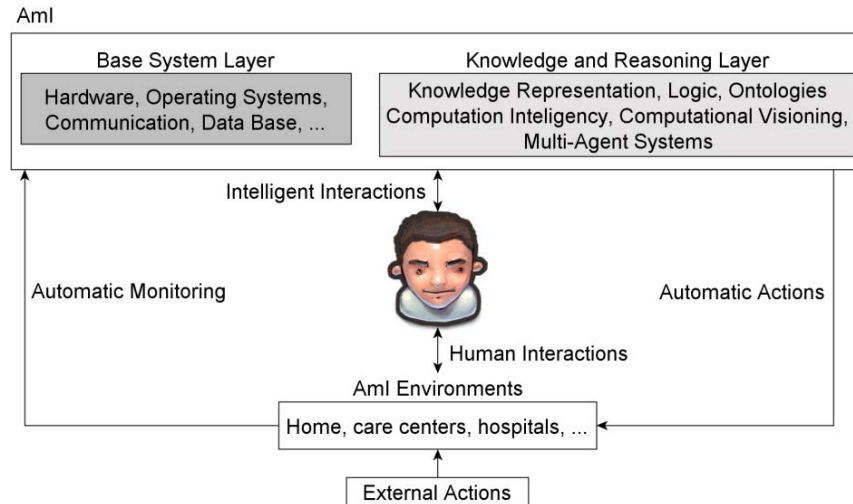
Figure 36: Artificial intelligence perspective on AmI
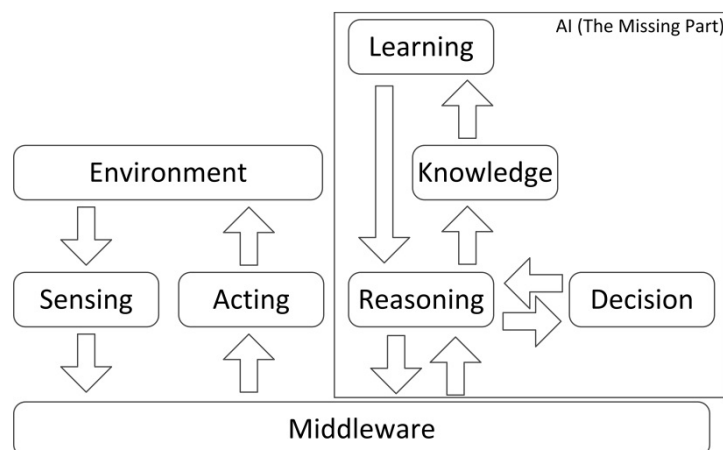
Figure 37: Generic architecture of advanced Intelligent Environments

Each module has a task, which can be explained in the following way:

  — Reasoning: bridges the gap between the middleware and the first layer of processing. After processing sensor data, the validity is checked in accordance with previous iterations and, then, data is transformed in Knowledge;

  — Knowledge: retains the information about the association fields. All data resulting from the learning are stored in the system;

- Learning: joins new knowledge with previous knowledge. The information from the Knowledge module is validated and new associations are then formed, extending or eliminating associations. Therefore, it helps the platform to keep the associations current;
- Decision: has several constrains that the information should comply according to being useful or not. If it is, is sent to Acting to be implemented.

On every sensing cycle this process is repeated such that it continuingly shapes the system knowledge and the action consequences. This leads to a perfect response system, which weights every decision according to what is used to do on other executions.

This is an optimal solution to the user since he/she is informed of each decision if wanted. Thus, the system learns what the user like/needs and adapts the next actions to the learnt information and fine tune the actions over devices.

We are firm advocates of this approach, opening the door to future advances since it enables more and better features to serve the user. Considering the number of successful projects, it shows that this system has continuity, making it the common approach.

4.5 Conclusion

In this section, we have presented various constituent technologies of the iGenda, starting with the multi-agent concept and their architecture. Then, the devices that can be used are discussed and, finally, the learning and intelligence attributes are introduced. The combination of these concepts result in user-oriented services, providing continued assistance in their daily tasks.

The multi-agent systems assure the construction of agent platforms in which each agent has different features and, therefore, different actions. The JADE agents exchange information between them, collaborating towards the same goal. The separation of features (or tasks) comes of a more flexible and fault proof system. By being threaded, each agent is an individual application and solely cares on its performance, being the agent platform responsible for the maintenance. Moreover, the agents can act over information in different ways, being able to process more information and extract more knowledge at the same time. It leads to more complex behaviors.

The sensors when properly combined with mobile computing systems can provide real-time information about the user health status, creating an efficient monitoring system. The BAN concept is recent but there are great advances in this field. Ensuring that devices used to collect and process information are reliable and meet the usability standards, serves as a basis for future application implementations in monitoring systems.

This type of solutions impacts on both health services and the daily life of a person. This balance is difficult to achieve, and with the proliferation of BAN's and subsequent services, it was composed as a viable goal, providing gains in each area. Health services goal is saving resources by freeing resources for other patients like beds, and releasing the clinical staff for other tasks. For the patient, the freedom allowed by the sensors to carry out their usual activities, and to release him/her from the hospital environment, where there is little human interaction and he/she is at risk for hospital infections.

Finally, the importance of intelligence in this type of projects is discussed. Drawing a parallel between the system and human beings, they learn every day from little things to great events. This shapes the knowledge according to his/her preferences. Moreover, it is very difficult to follow the human being preferences as they have certain vices and established preferences (such as favorite color or sport club). In addition, they have constant changes in preferences (comfortable room temperature, amount of light), but not to mention social relationships.

Going to the digital world, it results in a complex knowledge base with a large amount of single interactions and intricate connections between them. But, with help of learning and logic systems, the interactions can be provided with "importance", that is, what is really important to the user and how to achieve it. We therefore defend the adoption of artificial intelligence concepts in AmI. Their contribution is essential and the features they present push forward an area that was soon to become stagnate.

It is in our view that artificial intelligence was the missing part, and its inclusion was imperative. Static systems only provide solutions that have solely one propose, and do not change over time, meaning that eventually the solution will become obsolete. The artificial intelligence can provide, trough learning systems, more guided responses and adapt to the user changes, being updated at all times.

All of these technologies are then working for a common goal: providing the user with a better, more interesting, and more active life.

5 iGenda: Cognitive Assistant

People, mainly older ones, suffer from something that silently limits them: forgetfulness. The lack of memory is something related to all human beings, some with greater incidence than others. So, with ageing, it happens more frequently being able to reach extreme cases as the Alzheimer's stage. The scientific community has determined that it is not yet possible to heal this loss of memory, being the best alternative exercising the mind with specific exercises and recalling past activities and events.

Technology can be a good assistant in terms of the availability and support it can provide, revealing itself as a platform for multitudes of services aimed to people. Recently, projects more oriented to the user were developed. In that way, services specifically designed to address user problems and personality, are provided. Indeed, entities like the European Union (EU) begin to realize that the human being, as a person, has been neglected. On the contrary, technology has reached a satisfactory level of

development to be used by ordinary people. Therefore, the EU supports projects that develop technological applications to assist people in need. For that, scientific community establishes the application core in people. So, they lay the foundations of the advancement and construction of future applications that use services as standards for community use.

These developments are part of ongoing efforts that have recently proliferated, giving birth to an AAL evolution. So, new areas of development emerge, stating as goal the delivery of applications that assist people in their daily routine. In addition, it outweighs the common flaws to propose easy and achievable solutions. The AAL applications that care for the user memory and abilities are called Cognitive Assistants. They help the user by providing suggestions about tasks and different tools to help the user do his/her tasks (Costa et al., 2012a; Costa et al., 2011b; Costa & Novais, 2012b; Gomes et al., 2010; Carneiro et al., 2010).

Cognitive Assistants

As abovementioned, Cognitive Assistants (CA) are a relatively new concept, in which each approach may be quite distinct from the others. In short, the CA can be guidance systems, several procedures for an activity or photo album reviewers. Essentially, they are focused on people and their disabilities, providing the tools that best fit them. This also opens the door to a concept usually disregarded offering personalization. The AAL has been prolific in providing solutions to assist the user. However, the personalization has not been widely addressed. In the case of CA, it is a theme that should be essential since each person is different. Therefore, "one size fits all" type of solution is unacceptable. In fact, adding all the nuances of possible users is necessary to have a good customization system to properly respond to users' expectations. The interfaces, amount and types of warning notices, are just a small sample of essential services and which should correspond to the best user's interests.

The iGenda is user-centered since it provides services that intelligently help to achieve tasks or recall an activity plan. For that, it takes constant contact with the user social sphere. Collaboration with other people is essential for helping them to be active and connected. The key issue is creating interest and relevance, even when people are not physically present. This fact also enables active participation in monitoring user's health, given that it provides the current state to user relatives, alerting them and enabling to participate in the user's recovery.

On the way to achieve all these features, it is clear that the iGenda must be composed of a multitude of modular services, which can be visible or invisible to the user.

5.1 AmI Structure Models

In terms of the AmI structure, there is a need to establish some connection layers between the different areas AmI comprises. In Figure 38, the system models and information flow are depicted. They represent the different worlds composing the fields where the AmI retrieves or deploys information. In this project, three worlds are considered: real, context and services. Being each world composed of modules containing the features of the interest areas. With the purpose of designing a complete AmI system, the following models must be included:

- Environment: it contains the features defining the environment surrounding the user. Mainly, it contains a detailed description of all objects concerning the user. In addition, due to the heterogeneity of AmI environments, this model needs to be flexible, configurable and extensible.

- User: it describes all the users within the environment, focusing on their personal features and objects such as their profile and other generated information. Despite its crucial importance, it can be considered as a subset of the environment model.

- Context: it covers a wide area since it encompasses very different objects with distinct features. Basically, it can be defined as any relevant information from the environment entities which allows the system to adapt to the demands and changes of both the user and the environment. Its content can range from the processing models of each user appliance to the user preferences. Most of all, it bridges the real word with the services world such that it provides important information that has a meaning, or a purpose, to goal-oriented services.

- Modules: it defines the integration and common services of the system. The specification of the possible implementation of new services, and the existing ones, are in this model manifesto. Rules and guidelines are the main core, establishing the basis for developing and deploying the services in the platform.

- Services: it defines what type of services and their features are used. The service duplication can be a problem due to conflicts of resources sharing. Furthermore, choosing what services matter the most, and which services conjugate better with others are crucial. The future development must also take into account the current available resources and service consumption of them such that the system keeps working at the bare minimum. Moreover, it

does not forget that this model is responsible for the information about the middleware available.
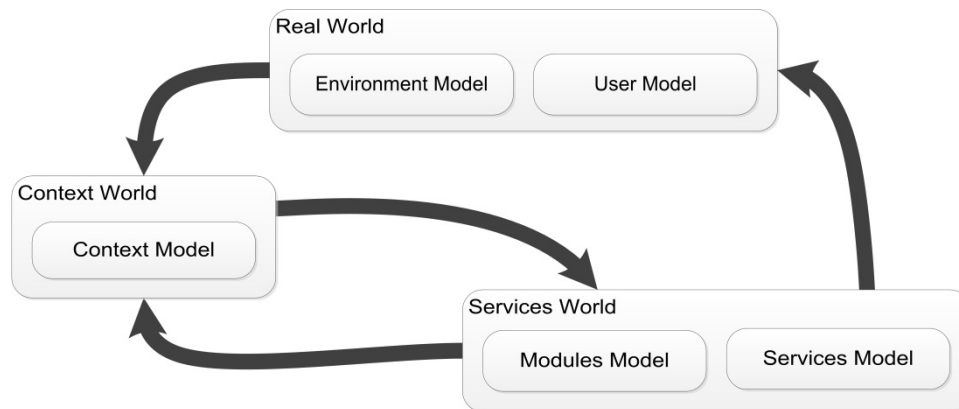
Figure 38: AmI system models and information flow

The five aforementioned models cover the components of a complete AmI system. Despite that, the high variety of AmI scenarios, heterogeneous devices, sources of information, contexts, transparency, intelligent user interfaces and the rest of constraints provided by AmI makes developing these systems a hard task.

One of the most common solutions for the design and development problems in AmI systems consists of the use of Living Labs. That is, smaller real environments, in which systems can be tested and validated, are implemented (Gabel et al., n.d.; Mulvenna et al., 2010; Mulder et al., 2008). The main disadvantage of the use of Living Labs is their constraints with some scenarios, like environments with a large amount of users, with privacy concerns or emergency systems.

Other solution could be the use of simulation platforms. But, as described, no solution or simulator in the literature covers all the requirements and needs of an AmI system.

Nowadays, because of the novelty of the CA area, a framework allowing to test and validate the resulting systems, covering all the features in AmI environments, has to be provided. According to this need, we present an architecture for CA, iGenda. It uses all the above mentioned models, what confirms it is an AmI system. The main strengths of this architecture can be summarized as follows:

    — iGenda has a multi-layered structure which completely covers the four models. In that way, it includes all the components and achieves all the requirements of AmI systems. In addition, it has the ability to easily change a module without interfering in the system performance;

- iGenda enables developers to design and integrate real and simulated elements. This integration results in more realistic models due to the injection of real features;
- iGenda is based on a modular decoupled architecture. This kind of architecture presents several advantages in the AmI context as modularity, portability, flexibility, easiness of deployment, heterogeneity among devices and online restarting of services.

The iGenda architecture is then a proof of the CA concept. Its technological goal is providing a structure concept that states how the CA systems should be developed. Four case studies presented in the following sections, validate the proposal of the iGenda architecture. In addition, its insertion in the AmI concept confirms the usability in a real environment with real users, that is the true test of these architectures.

5.2 General Architecture

Given the features previously highlighted, the design we present is highly modular. This means that, unlike integrated applications, the iGenda comprises independent modules with different functionalities. This type of architecture favors the implementation of new features and, in robustness terms, is fault tolerant. The block-based architecture denotes the simplicity of developing and adding new blocks, as well as updating (or refactoring) the existing ones.

On the way to achieve this goal, we assumed the MAS concept as an optimized form of modular system implementation based on independent agents. According to this concept, the agents uniquely implement the actions to be performed. Moreover, they may collaborate with other agents to engage their goal. For that, they follow a set of rule-based models standardizing the communications and operating procedures.

In terms of the iGenda base platform, JADE was chosen. The JADE, as explained in section 4.2.2, is the most appropriate tool for the project implementations. The freedom of implementation, in terms of procedures and communication support, was a decisive factor of choice to the iGenda. Furthermore, the agents follow a highly hierarchical organization. In that way, they respond to a coordinator agent, who starts the platform and handles all the external communications. According to this format, its

deployment is very straightforward to perform since the only requirement is just executing the controller agent and registering it on the platform.

Actions are split into two stages and two systems: functional and logic, Java/JADE and Prolog, respectively. Java/JADE assures the agent platform, file reading, temporal calculations and connection with web services. On the other hand, Prolog ensures the performance of logical decisions which model the results.

The modularity and connection format of the iGenda architecture allow the development of different blocks and features. In this regard, as examples we have:

- A fall detection system;
- A localization and orientation system.

The lack of advances in the development of a structure concept defining CA systems is problematic because validating the developed CA platforms is a hard task. That is, there are no guidelines to develop CA platforms. Therefore, proposed approaches tend to fit with the CA projects using their own methods. While they can work well by themselves, it is almost impossible to combine the resulting products. This fact results in a divided group of services that do not collaborate with each other. Consequently, having different products do not provide any advantage.

Figure 39 shows the complete CA archetype. This archetype encompasses the necessary features to build a CA platform as well as a real implementation of it, the iGenda. This validates this proposal, and shows up the possibility to develop a modular system that can be connected with other systems, advantaging from information fusion and services completion.

Starting from the lowest-level layer, it shows how a project (i.e. the CA platform) should be structured. Then, the rest of the features are integrated in a higher level providing the core implantation and the developed modules validating this concept. The archetype was the first step towards the correct development of structured applications. So, building new items and features that coadunate with the rest of the platform is allowed. In addition, due to its communication features, this project is easily integrated with others via free and open web-services and the available API.
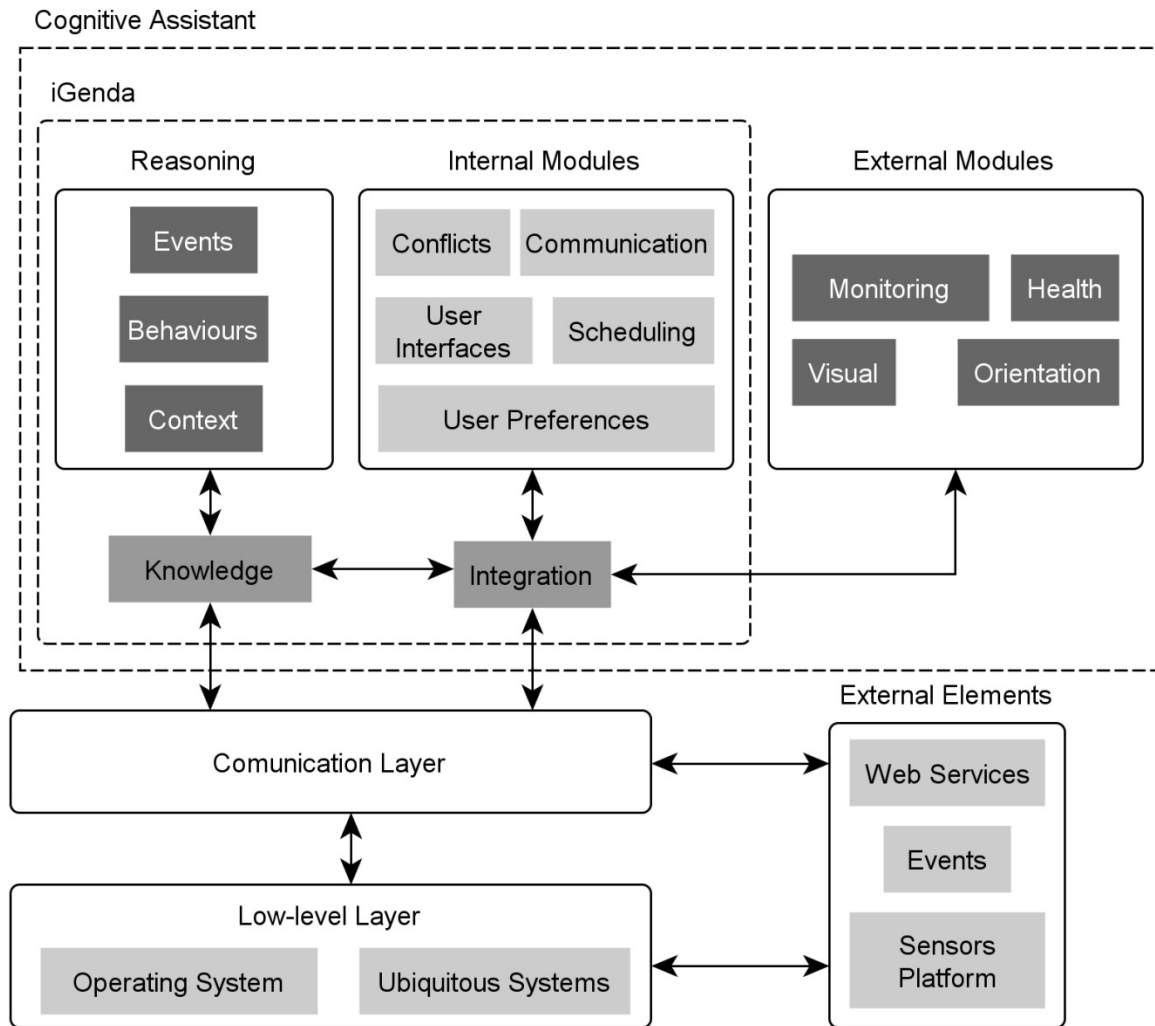
Figure 39: iGenda archetype

The archetype depicted in Figure 39 can be explained as follows:

Low-level layer

This layer contains the systems enabling the setup of the CA platform. Due to the agent use, some kind of operating system must be available. Both modular operating systems or, the more rule-base, ubiquitous systems serve as the structure or connection systems;

External Elements

This layer consists of a group of elements (or services) that are not part of the low-level layer, but they are not in a higher layer. It is usually composed of web-services from other platforms such as external events fed to the system and hardware-like services (e.g. sensor platforms). The CA system must be able to gather the information they collect by the direct way (through the communication layer) or by system drivers (through the low-level layer).

Communication Layer

This layer comprises the services in control of all communication ways (both ubiquitous and operating system). Therefore, it generates the information necessary for the knowledge module. Additionally, it is able to receive the information from external modules, guaranteeing the legibility and right format of the gathered information.

Knowledge

As above described, the knowledge contains the data to be sent to the modules for further analysis or to be directly used. It is the first stage of the AmI platform, by introducing the artificial intelligence in the CA system.

Integration

As previously introduced, the integration assures that all the system nodes are coordinated in terms of the communication. In addition, it contains the communication normative to be followed by the new modules in order to properly interact with the rest of the platform, passing by the communication layer. In this way, the new module directly accesses to reserved information flowing in the system, as well as it has communication priority over the external elements.

Reasoning

It groups the events, behaviors and context. These elements define a first stage of the high-level processing. By receiving information from the Knowledge, it filters and learns from the information, distinguishing between the important content and the non-important one. For that, the first step is verifying the context of the information received. With that aim, the information is compared with the rules and the previous system interactions, validating it and its importance. The behaviors are then triggered to choose the appropriate processing method. Note that not all messages are information of new events to be scheduled, but they can be, for instance, control messages, system updates, or internal agent communication, among various others. In this way, the behaviors are used to implement action methods that process the incoming information according to its context and pass it to the specific element in the system. The events are the last element to be used. Due to performance requirements (i.e. events must be processed as fast as possible), the information about a new event is reformatted according to its content and the correct module to be sent to is chosen. Consequently, the events do an initial processing of the content in terms of importance and context and send it to the appropriate agent for further processing.

Internal Modules

It implements the required agents to provide the core iGenda features which are the scheduling actions. So, it includes conflict management, communication, scheduling, user interfaces and user preferences such that each agent is responsible for a part of the system scheduling. Thus, the conflicts are responsible for matching events with time frames, dealing with all types of conflicts. On the contrary, the communication is responsible for establishing internal message trading pipelines and communication with the external agents and modules, providing integration methods. On its behalf, the scheduling is responsible for the aggregation of the different calendar sources (offline and online) and to retrieve and save events. The user interfaces are responsible of presenting to the user an interactive and simple interface that provides only the information important to the user. And, finally, the user preferences are responsible for shaping the system according to the user personality, what conditions how the events are processed and how the information is presented to the user. These agents will be presented in more detail in the following sections.

External Modules

These modules are composed of systems, considered as agents, which provide the system with additional and useful information. That information is retrieved from the iGenda information that they require to operate properly. Up to now there are four developed systems: the monitoring, health, visual and orientation. Each system is user-centered, following the iGenda hypothesis, and provides the user with complementary services that help him/her in his/her life. These systems are deeply analyzed in the Case Studies section.

Due to the modularity and hierarchy required to this project, some elements of the archetype are represented as agents. Although they are conceptually sound, their behavior requires them to be included in agents. In that way, they guarantee the proper system placement and the information flow. In the following sections, the most important agents are explained in detail as well as how they work and their fundamental features. These agents outstand the rest by being part of the iGenda core, and by being the gateway agents of the case study development.

5.2.1 Agenda Manager

The Agenda Manager (AM) is an independent agent that serves as a gateway for other agents and web-services. That is, the AM acts as the agents' controller since it initializes other agents, implements message context filtering, sets the receiving behaviors, and serves as system security.

```
{
        "firstName": "AAA",
        "lastName" : "BBB",
        "adress"    :
        {
                "city"   : "GGGG",
                "street": "YYYY",
                "gps"    : "11.111111",
        },
        "phone"     :
        [
                {
                        "type"   : "mobile",
                        "number": "253 676767",
                },
                {

                        "type"   : "home",
                        "number": "253 313131",
                }
        ],
        "key"       :
        {
                "internalKey": "123456789",
                "externalKey": "987654321",
        },
        "agent"     :
        {
                "agentName"        : "WWW",
                "agentDescription": "QWERTY ASDFG",
        }
}
```

Figure 40: Snippet of a data structure (JSON) with the user and agent features

This agent contains information related to the features of the remaining platform, containing data about the user and the people who interact with him/her in form of a user customization. So, all that is about people is kept in a database. That is, the system database has the description of different user's features.

The AM also saves personal details about the user such as their name, location and contact. In addition, the AM contains information about itself, such as name and features, which will be used to register it in the network (Figure 40).

For that, the AM internally has a data structure saving all interactions with other users and agents resulting in a daily record for further analysis, if necessary.

The AM includes a message context filtering that optimizes platform performance and security. Mainly, it is achieved by implementing message filtering models that use performative, ontology and protocol. These fields help to quickly detect the agents' intention, by annunciating them ahead in specific fields, and leaving the details in the content field.

On their behalf, the communication protocols are managed by the FIPA-ACL standard. Its use is a requirement for all the agents with the aim of ensuring communication compatibility and uniqueness. In that way, all the agents use the same standard what means that messages will be always received by the destination agent.
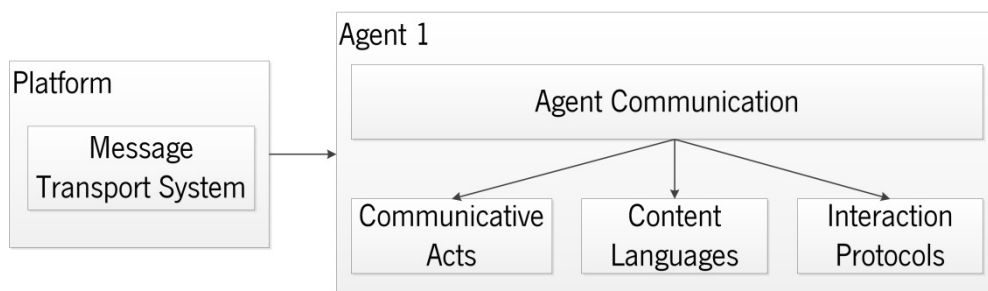
Figure 41: Representation of the fields involved in the communication process

The message arrival is guaranteed by message buffer offered by the JADE platform. The reason lies in the fact that it manages the message send and receive process. This buffer, provided by the Message Transport System (MTS) agent, retains all messages that do not reach the destination agent for a specified time until the receiver agent becomes active, in which case it delivers them, or until the delivery time is exceeded, in which case it rejects the messages (Figure 41). Consequently, messages should have a time stamp or a conversation handle since they are not synchronous and could cause an erroneous conversation session.

In terms of overall performance, Figure 42 illustrates the process from the reception of a new message to its sending to the appropriate agent by means of an activity diagram. As shown, the AM agent is in charge of initializing the Conflicts Manager and Free Time Manager. In section 9.1.1 is show in greater detail the agent classes and structure.
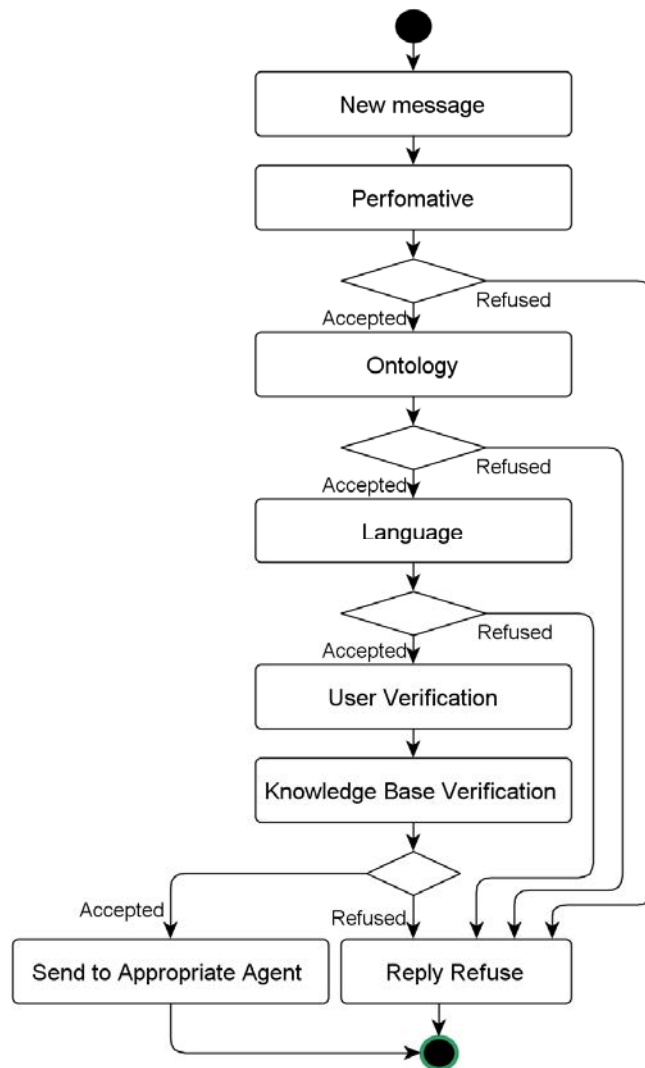
Figure 42: AM activity diagram

Services

Currently, the progress of applications and services provided by companies cannot be denied. A case in point is the products offered by Google (www.google.com). Products like Gmail and Google Calendar (GCal) are booming, as being used by 155 million people (Nielsen Wire, 2011). Thus, it can be considered a synergy between these services and the iGenda.

GCal is the product that most closely resembles the iGenda features. It may be more advantageous for this project. Hence, the connection with this product is of utmost importance. Also, the API from Google Calendar is freely available. Thanks to that, developers are able to build an application that bi-directionally communicates and can import and export the data contained in the web platform.

With that purpose, a web-service that communicated with the GCal was built. Thereby different services are integrated with iGenda. The aim was to take advantage of using a platform commonly used. In

addition, it can be used as an event aggregation service, having the events remotely and locally saved. Hence, the system creates an event list always active and updated, taking the advantage of symbiotically integrating it with mobile devices working under the Android operating system (Ughetti et al., 2008; Canalys, 2010; Meier, 2009). Since Android was also chosen to implement the iGenda interface, it represents a system integrator of the various available services.

A bidirectional web-service has been implemented on the AM. It can get the events from the user's account as well as send new events, being able to change and delete data from calendars. This data capture is triggered when an event is received such that it gathers all the information, checks its consistency and delivers it to the appropriate agents. So, once all agents notify to the AM that the calendar is consistent, two replicas are saved, one locally and other in GCal.
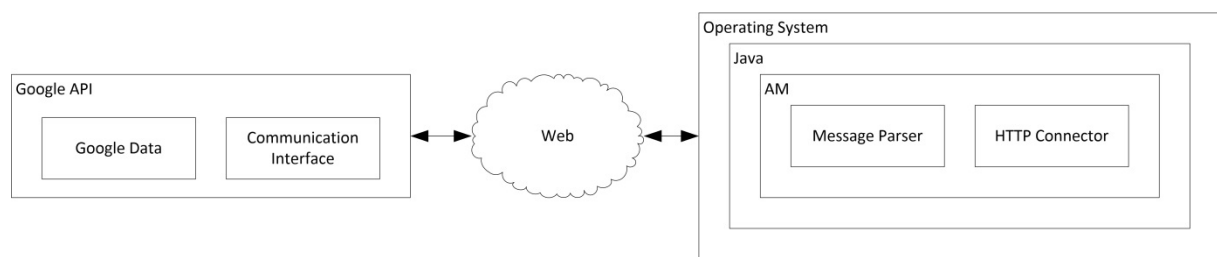
Figure 43: Communication relationship between the GCal and the AM

GCal provides the users with a web-based visual environment, allowing the use of interactive elements like the ability to drag an event to another day, the creation of events and its placements, and the variation of descriptions beyond the date and event title. Due to its API, GCal offers the possibility of recovering online information in a simplified way, being able to import common formats such as iCalendar (RFC 5545) and without resourcing the visual interface.

In terms of web-service communication, JSON format (RFC 4627) is used to transmit internal data fields related to an event. This means that events are not necessarily constrained by the base structure, what offers flexibility to add new fields containing residual or contextual information. JSON is a good alternative to XML (Sporny, 2010; Crockford, 2006; Nurseitov et al., 2009) because of its highly serialized format. That is, JSON has a structured system of identifiers, distinguishing between the several types and their content.

The GCal service together with the email service becomes a powerful communication system of daily management. In the context of iGenda, they mostly act as remote storage and a compatibility bridge. In terms of storage, it uses the cloud service, which has the ability to integrate simple events and save

them on the data communication load. In addition, it provides flexible data storage in terms of event fields. This is very important because iGenda needs reserved fields for extra information regarding the event. In terms of compatibility bridging, it spreads the information between all the used devices.

Storage

Regarding storage, iGenda makes local copies of data in the iCalendar format. These agendas are divided into months. The search and data delivery are performed in a simple and immediate way, being possible to view the calendar without any additional processing. The monthly schedule is used to optimize the way iGenda processes the calendars such that it does not overload the system when rescheduling. Hence, the iGenda uses load balance of resources, given that the less data is used, a shorter response of disk drive I/O is required. Moreover, the communication load is very small since data strings are simple and short in size.

This process takes into account the events that may span for more than a month or even those that may be divided into several days. Thus, iGenda detects that span and loads all the necessary calendars to change that event as only one. This is necessary because iGenda considers events as time frames, i.e., blocks that span over an amount of seconds on a seconds calendar.

5.2.2 Conflicts Manager

The Conflicts Manager (CM) is an agent validating the events in the user calendar. Due to life events, the appearance of new events and/or change or deletion of defined events, are usual. In fact, people are constantly scheduling and rescheduling activities on the basis of event importance, its association with people and its impact on people's life. In addition, new activities may overlap the existing ones, forcing to reschedule some previous events when the new event is more important. In the day-to-day life, managing activities is something that is constant and typically takes little attention, except for events of extreme importance or interest. Eventually, overloaded schedules make it increasingly difficult to appoint new events.

Something similar happens with people with cognitive problems as their memorization capacity deteriorates. So, a complex situation can take place: they forget scheduled activities.

For this case, the CM can be useful. Mainly, the CM is an agent capable of receiving messages containing an event, and checking collisional events with it. When detected, it makes the necessary

adjustments in the schedule or notifies the AM with the purpose of replying to the sender that the event cannot be scheduled.

To solve this kind of problems, events are hierarchical and highly structured. This results in the assessment of a rating system, where each event has a level of importance. So, a message is received by the AM agent and verified by the latter. Although this message already has a level assigned by the sender, the system cannot consider it as a final classification. Obviously, the event may not be so important to the user, and something must be done to gauge its level. Therefore, the AM retrieves the sender importance from the users' database and weights the messages as follows (1):

30% - Level of importance of the message;

70% - level "Clearance" of the user in the database.

$$p(m_p, u_p) = \frac{1}{m_p * 0{,}3 + u_p * 0.7} \bigwedge m_p, u_p \geq 1 \qquad (1)$$

Where m_p corresponds to the priority value contained in the message, while u_p refers to the priority value of the sender in the database. Clearly, the lower p value is, the lower the priority is.

After processing the values the message reaches the CM with this new value, estimated from the real importance to the end user. Thereafter, events can be processed and placed on the agenda.

The action models structure the next phase. They provide the actions to be followed by the system to manage the events received. This process is done by attending to the best interest of the user. That is, it tries to solve any conflicts intelligently, querying the user or refusing to schedule if it is unable to resolve the conflict. The Figure 44 shows the several stages of the action models process, presenting the activities schematic and highlighting the main actions each model follows. In section 9.1.2 is show in greater detail the agent classes and structure.
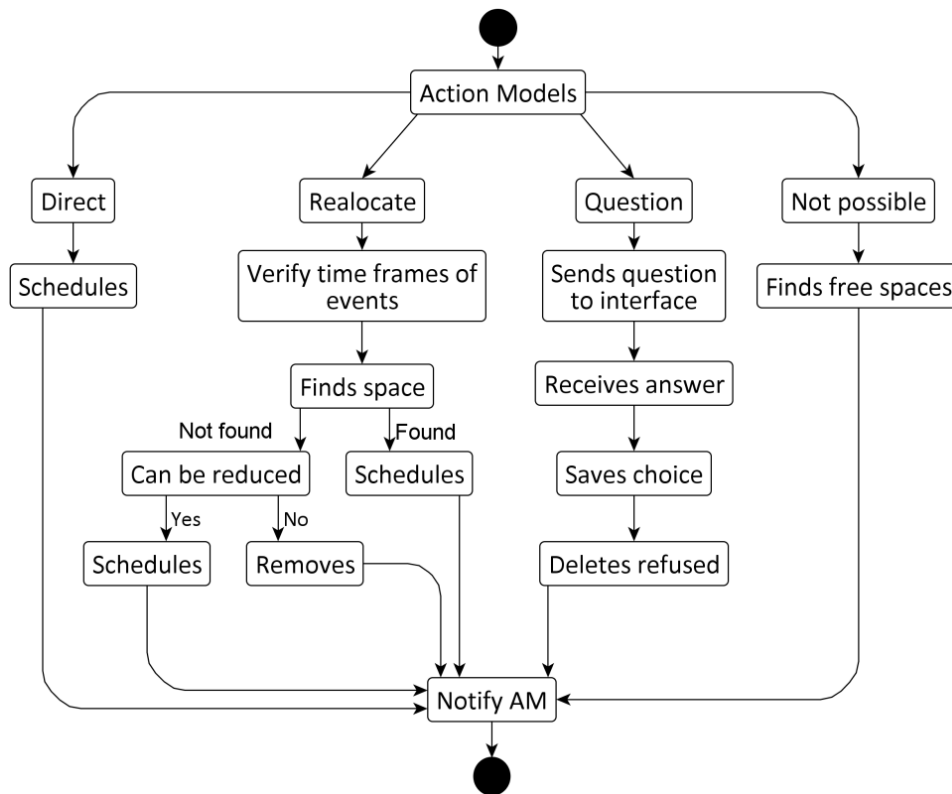
Figure 44: CM activity schematic

As shown in Figure 44, the possible actions to be taken are:

Direct

When there are no conflicts with other events. The CM saves the event in the calendar and notifies the AM to make the remaining notifications.

Relocate

When a new event conflicts with events present in the calendar. In this case, two situations can outcome: the event has a level above all the conflicts or the event has a lower level. What then happens is space verification such that free spaces are searched for the events that did not prevail. If compatible free spaces are found, then events are temporarily saved in the calendar. The AM is notified. So, it can verify if other people are involved in the events, asking them if they agree with the change to make the event definitive or to remove it, if they disagree. Otherwise, when no free space is available, the event will be excluded and all the involved people will be notified.

On the other hand, when there is a spare event resulting from a reschedule, it needs to be reallocated such that the process is set to the beginning but including the spare event and the next time frame.

Although this spare event can exchange with another, the system only accepts a time frame leap of four events in order to keep the system free from cycles.

Question

The inquiry procedure provides a set of options in terms of decision and response. So, in case of event collision on the basis of importance to the user or from user specification, the CM sends a request to the AM. It sends the request to the interface for getting the user answer to be sent back to the AM. As an example, if two events of great importance are competing for the same space without a possibility of amendment to another location, the system proposes a question to the user about his/her preferences. Thus, according to the reallocation procedure, when an event results in a movement of another event, all the participants of the moved event are notified. CM is notified, checking if this user has the possibility to move that event to the new time and, if it is, proceeding to ask the user if he/she is sure to move the event.

Not possible

If it is impossible to schedule any event, free spaces are searched. Then, the AM is notified of the refuse and the possible times where it can be scheduled, and it can relay this information to the sender.

Communication

In terms of communication, all the available information, that can be quite complex in case of event transmission, has to be considered. As all internal platform agents, the CM uses the standard FIPA-ACL for system messages. Internally, the message contains most of the information necessary for the agents operation. Moreover, exchanging calendars handles a large flow of data, which is deterrent in terms of performance, relegating to each agent to get the contents directly from the files. Regarding message content, XML is used. So, the use of markup resembles that it is used by the standard iCalendar file type, using the same concept of structure and can be easily interpreted as either algorithmically or by humans.

The response system can also take several forms, although all of them are highly structured and planned. Among the simple notifications of the successful performance, response answers containing the possible spaces and specific errors can be sent.

Focusing on the content, Table 1 summarizes the fields containing information about the specifics of any event to be scheduled.

Table 1: Fields of the message's content

Fields	Description
DTEND	Date of the event ending. In YYYYMMDD
DTSTART	Date of the event beginning. In YYYYMMDD
TMEND	Time of the event ending. In HHmmSS
TMSTART	Time of the event beginning. In HHmmSS
TIMEZONE	Difference to GMT (in minutes)
PRIORITY	Event priority
GEO	GPS location of the event
TITLE	Event title
SUMMARY	Event description
TIMEREDUTION	Event possible time reduction
USERS	Users sharing the event
ALARM	Event notification time
ALARMTYPE	Type of notification
EVENTTYPE	Type of event
ALLDAY	Event all day flag

Some fields are directly in line with those used in iCalendar standard, visible by calendar applications, while others are specific fields of the iGenda. However, both the iCalendar and GCal are able to save the remaining extra fields.

The iCalendar naturally stores the fields since they are delimited by tags in the text iCalendar file. The information can be stored with own unique tags along with other information about the event. This type of files is highly structured, ensuring that all event data are contained and encapsulated within the event delimiter.

Event processing has to take into consideration the fact that events can last more than one day. The solution used to manage this constraint was to retrieve a month (or even a longer period if needed) and to process it as a whole, refraining from limited time frames.

The base 10 was used to ease the processing in terms of accuracy and computation, whereas the milliseconds were used as the basis for all temporal systems. Consistently, the millisecond format has as unit 0 the date of January 1st, 1970 at 00:00:00.000 GMT. This means that the value will never be less than the current date and it may be directly converted. The ability to directly add and subtract values eliminates the existence of "pitfalls" where errors could be induced in the calculations. So, the

conversion into milliseconds is directly done for all the events such that they are more easily delivered to the Logic Module.

```
BEGIN:VCALENDAR
VERSION:2.0
PRODID:-//hacksw/handcal//NONSGML v1.0//EN
BEGIN:VEVENT
UID:189654774
ORGANIZER;CN=José Manuel:MAILTO:j.manel@example.com
DTSTART:20111231T230000
DTEND:20120101T060000
SUMMARY:Ano Novo
ALARM:10
ALLDAY:NO
TIMEREDUTION:0
END:VEVENT
END:VCALENDAR
```

Code 1: Snippet of an iCalendar file with extra fields

Logic Module

Java is a powerful language that has great community support and interesting temporal manipulation and definition libraries. However, this was waived for another language in terms of temporal manipulation (Neves, 1984). What happened was the choice of language Prolog, being SICStus (www.sics.se/sicstus/) the tool chosen to perform calculations involving time. This choice is based on the fact that it is a functional language, with low complexity entropy, quick and efficient operation as in encoding. Given that it is a functional and highly recursive language, the process of implementing functions, comparisons and cycles and providing full stops is simplified.

Regarding its application, it is in the Conflicts Manager Logic Module (CMML) which actually performs temporal operations such as comparison, addition, subtraction and movements, ensuring its accuracy in terms of execution. The only items delivered to the CMML are: the event id, the time in milliseconds, priority and time to cut. Recursion and low resource consumption are crucial for rescheduling operations. Moreover, multiple comparisons may be a common scenario, whereas the design of constraints for all possible scenarios is unrealistic. Thus, the concepts of recursion and negation by failure are used to efficiently encode the functions necessary to obtain the expected result.

Figure 45 depicts the schematic execution of the CMML. So, CMML is initiated by the agent that integrates Java with Prolog by means of the Jasper library. Jasper ensures that the operating system

runs the Sictus Prolog application and creates a transparent bridge with Java, being similar to Sicstus queries for the input method.
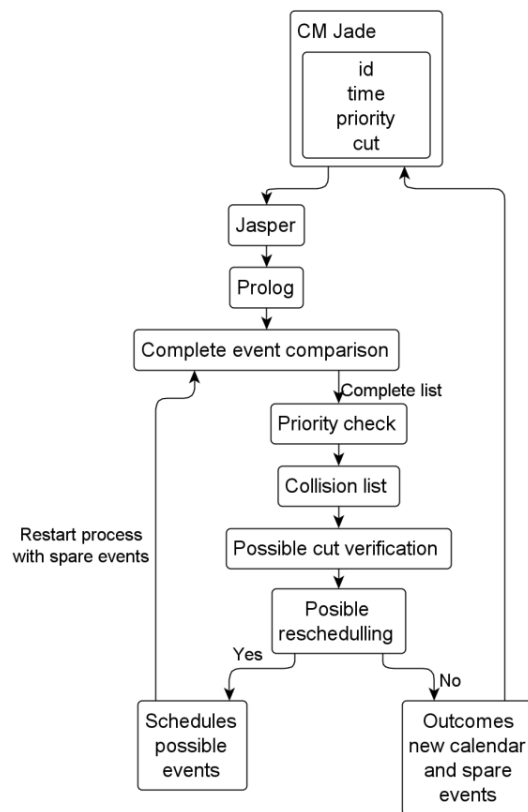
Figure 45: Execution scheme of the CMML

The CMML process flow can be summarized in the following steps:

1. The CM agent joins all calendar events for the day in question as well as for the following seven days. These events are stored by the CM in its original format and converted to the format of the CMML for being later converted back.

2. The CM includes a class for initializing the logical module, that contains the queries necessary for data input and processing functions.

3. The CCML receives the data, composed of the calendar and the new event. This data is compared with the received data in search of collisions in a cyclically recursive way. If there are no collisions, the new schedule is delivered to the CM. Otherwise a list of all events that collide with the new event is created.

4. All the priorities in the list are checked with the purpose of verifying the existence of any possible exchange and/or relocation. Therefore, this step results in a list of possible exchanges.

5. Then, it is checked if one event can be reduced in terms of time in an attempt to minimize the modifications.

6. The resulting list may lead to three scenarios:

    a. It is possible to shorten events to accommodate the new one. Thus, a new calendar is created, cleaning the list of collisions and transferring the schedule to the CM without any error.

    b. When there is a failed overlap, it results in the immediate termination of the execution, reporting to CM the unchanged calendar and the error code. This happens when an event is immovable and/or when there is a collision of priorities of the same value.

    c. In case of success in relocation, a new list of events that need to be relocated is generated and the process is restarted from step 3. However, it is worth keeping in mind that the goal is to allocate the event as closely as possible to its former position. Consequently, all events are checked to find a consistent space for this event.

7. Finally, when there are no more possible exchanges, the new calendar and list of unallocated events are reported to the CM to be processed and to update the user calendars.

5.2.3 Free Time Manager

People tend to become increasingly inactive when they go into retirement, entering a cycle of stagnation that might lead to various physical and psychological problems. Some studies (Walker, 2002) demonstrate that elderly have various risk situations associated with their inactivity. Excluding people with serious health problems, it is recommendable to perform activities of playful nature, involving the person both physically and psychologically. Physical problems arise in many situations and they usually involve bone and muscle deterioration and/or obesity progression. Psychological problems stem from the sense of abandonment and isolation, elements that lead to clinical depression and pathologies inherent to physical problems.

This type of problem is imminently social, revealing that a large portion of elderly community suffers from the same problems. These situations can be reversed by promoting interaction between people by means of activities requiring commitment, what connect people to a structure of goals and actions. This creates a cycle that forces interactivity and a continuous effort of involvement. These activities can vary from several levels of difficulty and commitment. So, they provide the necessary stimulus for the user to feel challenged and be attentive to what is happening around him/her. Moreover, there can be a joint

effort involving several people in the same situation when they participate in group activities, where sharing and recognition of common factors provides an inherent psychological boost.

Apart from solidarity activities, there are groupings of people such as a club or association, which promote activity exchange and co-work between multiple users. One of the most notorious is the Time Bank which, as explained above, promotes the exchange of specialized work among multiple users. That allows saving costs in terms of labor work as well as creating a cohesive group of people who share their day-to-day with other people and result in bonds of affection and interest.

The Free Time Manager (FTM) agent was developed to have a notoriously social nature. It was consigned through analysis and research of different available designs with the aim of introducing the features that provide an active life to the user. One way to make changes in the user life, being discret but effective, would be the introduction of tasks suggesting single or shared activities.

With regard to flow operation, the FTM is similar to the CM. This is an independent agent, built over the JADE platform, that implements the concepts contained therein. The FTM is initialized by the AM in two situations: by request or timed. The timed option consists of a time trigger that activates the FTM. A weekly or biweekly timing is more appropriate to schedule some activities. In that way, the user has time to verify what suits him/her and what not. The request means that the FTM is launched when any person (typically the user) requests it.

The number of scheduled activities is a key point for any system. So, with the purpose of not exacerbating the user, not too many events should be scheduled. Otherwise, the system would lead to opposite result to that intended.

Another important issue is that the system proposes different activities on a regular basis, with the highest incidence on the preferred ones. Hence, the data structure contains the user's preferred activities, structured by importance, mirroring the user tastes.

The referred variance on which the system depends is mathematically obtained as:

$$A_{ij} = \{(id_{00}, prio_{00}), \ldots, (id_{n0}, prio_{n1})\} \tag{2}$$

$$A_{i1} = \sum_{k=0}^{i} 1 \bigwedge i \leq |A|, i \in \mathbb{N} \tag{3}$$

$$A_{ij} = \{(id_{00}, 1_{00}), \ldots, (id_{n0}, n + 1_{n1})\} \tag{4}$$

$$B \sim \mathbb{N}(0, |A|) \tag{5}$$

$$f(i) = A_{i1} * B * -1 \tag{6}$$

$$result = (id, prio) = \max(\{f(i) : 0 \le i \le |A|\}) \tag{7}$$

Such that A_{ij} corresponds to an ordered pair of the array that contains the id and priority pair, that is, the unique identifier of the activity and the amount of importance for the user (2). These pairs are removed from the previously chosen database events. In that way, the database only contains the events that fit within a defined time. The importance value vector is normalized according to its position in the vector (3). This normalization is done in the way that they have no large discrepancies in estimating the chosen event. So, the events are separated by a priority value to derive a great possibility for them to be chosen. Thus, it is a linear approximation to the priority field (4). After linear normalization, a factor is introduced by the diffusion function $f(i)$ using a random variable (5) and making the product between the component and the random variable priority resulting again in a new priority value (6). The nonlinear function is set with the purpose of introducing variance in the priority estimation. In that way, the previous priority value is updated, allowing other events to be able to nominally have a lower priority. Finally, the event with greatest priority is chosen.

Let's put into practice these calculations with an example:

After (2)	$A = [(\text{‘id2’},4)(\text{‘id60’},60)(\text{‘id68’},100)]$
After (3) and (4)	$A = [(\text{‘id2’},1)(\text{‘id60’},2)(\text{‘id68’},3)]$
After (5) and (6)	$f = [(\text{‘id2’},-3)(\text{‘id60’},-2)(\text{‘id68’},-6)]$
After (7)	$result = (\text{‘id60’},-2)$

The chart corresponding to 100 iterations over an array of three activities is depicted in Figure 46. This demonstrates the exponential format, tending to be picked activity A about 75% of the time, while the remaining activities (B, C) are chosen less often. This reveals that there is a clear trend towards the most preferred activity, while the others are less chosen, although chosen enough to introduce some variance.
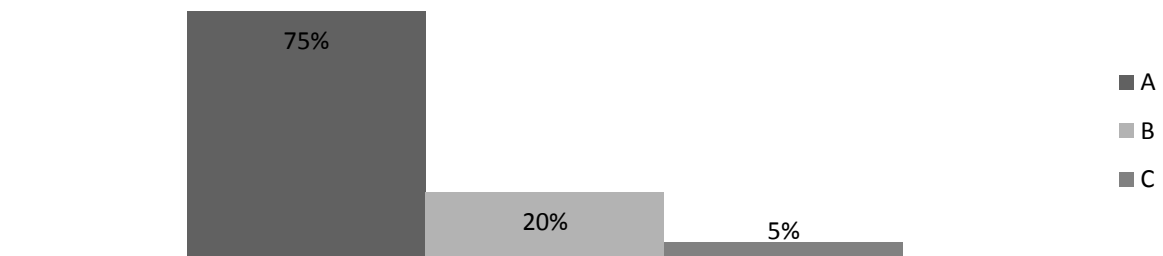
Figure 46: Graph of the event distribution over 100 iterations

On the way to choose the spaces and activities competing for these spaces, FTM relegates to its logic module (FTMML) to perform the required calculations.

Logic Module

As CM, the FTM has a logic module to perform the calculations and make the decisions crucial for working in harmony. This logic module is in charge of receiving calendar events from the database, searching for free spaces, selecting the event and scheduling it in the found free space. The volume of tasks assigned to FTMML is still extensive, having the most fundamental FTM tasks. The whole calculation process presented above was implemented in FTMML and is used to make the decisions about the activity to be chosen. In section 9.1.3 is show in greater detail the agent classes and structure.
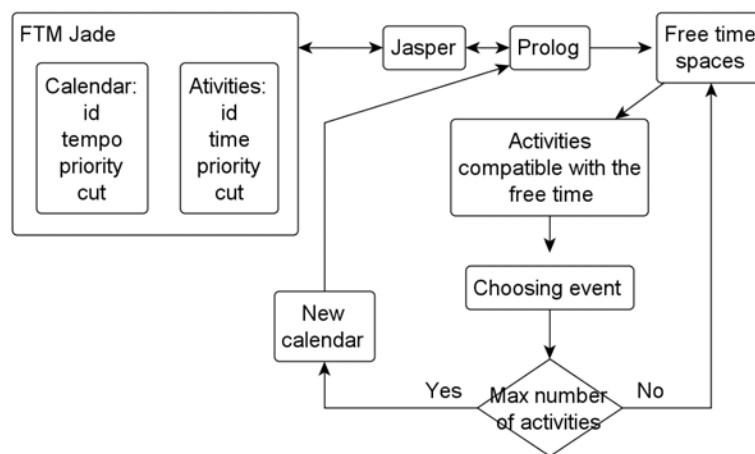
Figure 47: Schematic of the FTM operation

In Figure 47, the broadly operation of FTMML is shown. It is divided into five main parts of operation:

1. Initially, FTM delivers the calendar events and the available activities through the Jasper interface;

2. Once the system is initialized and the data is entered, the cycle starts to search for all the free spaces and incorporating them to a list;

3. For each free space, the event selection process is initialized. So, all activities that have the maximum time for fitting are initially separated, and then the choice function to select the winning activity is used;

4. It is checked whether the maximum saturation choices of leisure activities is reached. If achieved, the final schedule is reported back to the FTM, otherwise it goes back to step 2.

The type of help this agent can provide is interactive and silently enables activity suggestion such that some activities the user would not be interested in, expecting the user compliance.

In terms of communication, this agent is closed and only communicates with the AM. So, it contains all the information necessary for the operation, which is stored in databases, and it is only accessible by the AM.

Regarding the activities related to multiple users like a book club, they can be configured to send multiple connection requests in order to contact all the involved users. However, this action is formatted as a standard event, given that the FTM does not have any kind of conflict management and/or event handling activities. If involved users cannot attend the activity, the CM will complement the activity following the natural operation process

5.2.4 Interfaces

In terms of communication with the user, it is necessary to have a communication way that is palpable and that provides a natural method to functionally connect with the user. Moreover, too much automation causes user alienation. Of course, it is required to distinguish between what is automated and what is manual, providing the tools and resources necessary to respond to urgent needs.

However, this issue does not have a simple or simplistic solution. The trap that often appears is the development of products by engineers and for engineers. With this, the usual interfaces are generated to directly respond to the features and functions provided by the software (Chiara et al., 2004), creating dense systems that require a vast knowledge on computing. Even the way humans perceive the world and how they use these perceptions to interact with the surrounding elements modify how they can work with computerized applications. The interfaces should be designed to be naturally absorbed by any type of user, providing an environment to what the user is familiarized. That is, the interfaces must include both a beginner and an expert option, positively responding to different needs that may arise. To answer these questions, the scientific community has developed adaptive interfaces.

Still in development, adaptive interfaces consider usability firstly such that their goal is to cover a wide range of situations with interfaces fitting the user's profile. Of course, it is clear that an interface for elderly people and another for teenagers are completely different. On the other hand, it is possible to completely change the interface by limiting the amount of information available. In this case, the

nominal level of demand is not excessive. Thus, the problem lies in choosing the information be provided and the most suitable usage profiles.

The iGenda needs user interaction. Therefore, the type of interaction is decisive, usually requiring the user makes a choice that radically changes his/her day. To make this possible, two interaction interface platforms were developed: desktop and mobile. In this way, the user can choose the method mostly preferred. At the beginning of this project, an initial version for desktop was developed. However, with the growth of mobile systems capable of supporting the main features of this project, it was crucial to start a line of development of the mobile version. Actually, given that the functional paradigm changes, there are currently a large number of mobile devices available in the market and, consequently, more and more people tend to use them in a natural way. Mobility also represents a new approach in terms of connectivity being in constant connection. It allows the modification of events with greater ease as well as it allows to providing new features that would not make sense in a desktop version.

How it works

Technically, the mobile and desktop versions provide the same type of functionality to the user. The elderly and general users were taken into consideration. So, the amount of information and the ability to change the possible options were adjusted to fit these profiles. The number of interactions which the user can perform is limited, and the platform is adjusted to conveniently make decisions that respond to the user considerations. The platform has the ability to change the environment and responds to the arisen issues regarding the resolution of potential conflicts that need supervision.

Simplicity is the goal such that the users are not alienated. For that, the way the interface is operated is simplified by providing a smooth operation.

In terms of deployment, only the connection with the iGenda platform was considered, maintaining communication and messaging. Thus, the whole process of viewing calendars is provided by the operating system. There is no type of interest in re-implementing a complex visual environment since there are already alternatives for this. In fact, both local and online calendars have good visualization tools.

As the platform is constantly connected and has the ability to check their local and online calendars, it is understandable that the platform is able to verify the changes and to correctly match them, as previously stated (see section 5.2.2 Conflicts Manager). Notwithstanding these facts, the interface

provides the functionality to schedule events directly on it. That is, it has the ability to schedule directly with the desired user and to have access to his/her information.

Figure 48: Mobile iGenda scheduling screen

For this project, the chosen operating system is Android. Recent developments in JADE agent platform allowed the inclusion of support for Android, enabling the creation of agents on mobile devices. The agent support is crucial to maintain the connection flow with the iGenda platform. Thus, the platform can communicate correctly without resorting to the systems integration, but possessing the same security systems and communication protocols. Therefore, developing platforms for data integration is unnecessary.

In Figure 48, the events scheduling is shown. This interface integrates the following fields:

- Recipient: this field is described as a dropdown menu which contains people in the users' database. The database is frequently updated, and the AM sends the information about the new fields. In addition, it is available to manually place the user's address.

- Time and date: it represents the time of the beginning and ending of the task. These values should comprise all the time used to perform the task, including the travel time and overhead preparation time.

- The priority value: this value corresponds to the event priority. This value will be fixed later on the normal procedure of AM.

- Content: this field contains a task description. It serves to notify the recipient of the task intention.
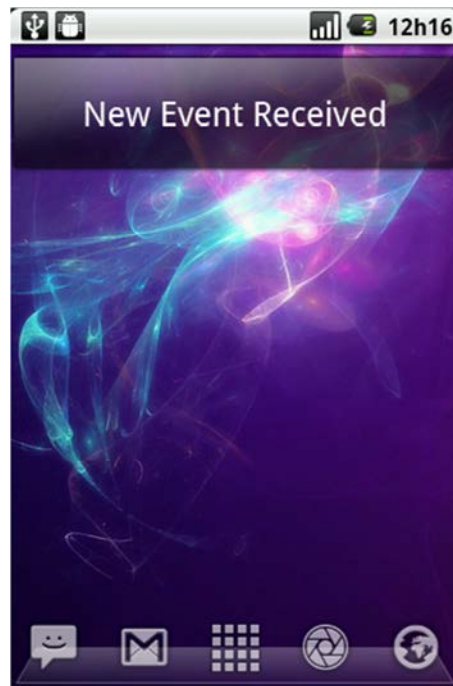
Figure 49: System widget

On the way to facilitate interaction with the user, a widget displaying the latest notifications directly on the desktop of Android was developed, shown in Figure 49. When selected, the application is launched. This service has been taken into account to cover the concept of usability and to provide maximum information with the minimum interaction possible.

In Figure 50, the screen listing the communication with the central server is shown. This screen provides all the information related to communication and notifications between the mobile device and the AM. The information is presented in the list format where the user can comprehensively view the notifications, being provided with information on the time reference, according to the local time. The buttons provide the access the calendar or to make a new appointment.

As previously mentioned, the iGenda makes use of existing tools in the operating system like the calendar representation. Android already has a good calendar application with native integration to GCal service. In terms of notifications, the user has access to the Android calendar app or through the iGenda application. The iGenda has the ability to regularly verify updates done on Google Calendar, notifying the user and saving changes locally in order to update the local calendar.
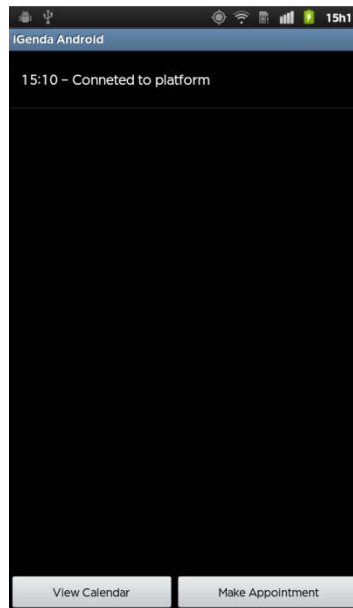
Figure 50: Screenshot of list of notifications

Social Profile

With the purpose of better serving the user in terms of complementary services, we developed a social profile what aimed to introduce or establish connections with other people by means of using social networks. This profile is embedded in the user local information, corresponding to his/her tastes and friendships. Regarding availability, this profile is connected with the other services on the mobile device, providing a constant connection to services and web sites. In the future, it will form the profile that will establish and modify the iGenda settings. The demand for full integration with the personalization services is one of our future goals. In that way, a uniform environment in which is contained all the options, presented in simple and functional way, will be created taking into account the user and the operating system used.

5.3 Conclusion

More than a project, the iGenda states a concept. That is, the approach used for this project has opened a new approach regarding the classical models of CA in AAL. For that, an archetype that established the validation for CA platforms was built and a platform validating the archetype was developed. With this development, it was found surrounding areas and other natural extensions or

developments that also lacked development or what was available were weak, paving the way for the iGenda modules.

The provision of a management system that intelligently schedules by establishing complex communications implemented on a structure of agents makes simpler to set common points between fields and services that heretofore were distinct. Integrating different aspects of user's life enables the centralization of many services in one place in the form of temporal appointments. It eases the work and reduces user frustration by doing a careful management of his/her time.

Socially speaking, an elderly user can advantage of this system not to only organize his/her life, but also advantage from the leisure manager, which streamlines his/her life by providing a more active and cheerful environment. The kind of help provided by iGenda is consensual and discreet, as well as has an impressive result in the lives of people who may use it. The reason lies in its features because they are built in a way that it requires minimal interaction with the user, although he/she can see the events changing to match his/her needs.

In the next section it will be presented the case studies that validate the archetype and architecture. They are intrinsically connect with the iGenda, taking advantage form the CA created and by the information and services available.

6 Case Studies

During the development of the iGenda project, several other modules have been implemented. These modules have resulted in projects that are closely related to iGenda and its features. The development of these projects resulted in a complete platform of modules integrated at the iGenda as a sphere of services. This provides the user a complete and integrated platform of services targeted directly at him.

Among the compendium of all the developed projects, the most interesting ones are:

— A sensor system with intelligent data processing, integrated in a BAN;

— A clinical decision support system oriented to medical staff, implemented in a web environment;

— A localization system with augmented reality;

— A profiling system using learning to generate dynamic content;

Each of these modules is different from the others. However, there is a link established by iGenda to provide all of the modules with the features of the others. Each module covers a different area and

components, providing a comprehensive service-oriented to the user and operator. Bearing in mind the user, this development corresponds to a range of services directly or indirectly developed under the tutelage of AAL, providing a helping environment to assist the user.

6.1 Sensoring System

The Sensoring System (SS) (Costa et al., 2011a) is an application that uses the sensor data and processes that data intelligently. By obtaining information about the health of the user, it proceeds according to action guides to report an imminent emergency.

The evolution of sensors has been steady. Actually, there is currently research on device miniaturization and reliability improvement of the gathered data. From this data it is possible to obtain information taking into account several factors of the different sensors available, like body temperature and electrocardiogram data. The sensor fusion results in more reliable information about the global compendium that is observed (DeLong, 2003; Ercan et al., 2011; Sanfeliu et al., 2010).

The SS uses sensors that are worn by the users in contact with their skin, gathering information in order to process the data. After obtaining the data the SS verifies its validity, checking with a guide that contains standardization values. Using the same data the SS can obtain a reading of the health condition, and imminent deterioration of the user. The main sensors are:

- Electrocardiogram (ECG): This sensor obtains the electric potential generated by the blood flow inside the heart. Each event corresponds to a sample of the cardiac cycle and may provide information about the general operation of each artery and ventricle;

- Blood Pressure Value (BPV): This sensor captures blood pressure, providing information on hypertension/hypotension and other vein problems and circulation such as venous constriction;

- Electromyography (EMG): This sensor verifies the muscular activity through the uptake of electrical impulses, resulting from muscle contraction, being able to detect muscle problems such as spasms;

- Temperature: this sensor verifies the user's body temperature, detecting various problems and diseases in a quick and efficient way.

The combinations of these sensors result in a system capable of capturing and checking the health condition of the user.

Architecture

The SS was developed under the Body Area Network (BAN) premise. The BAN is generated by the group of the sensors and a receiving platform. The sensors are attached to the body of the user and send captured data the receiving platform. An application on a mobile device is performing the initial processing of the captured data and sending it to a dedicated server to complete the data processing.

The goal was to be integrated in the platform iGenda to obtain benefits in terms of automation and scheduling under a mostly clinical spectrum.
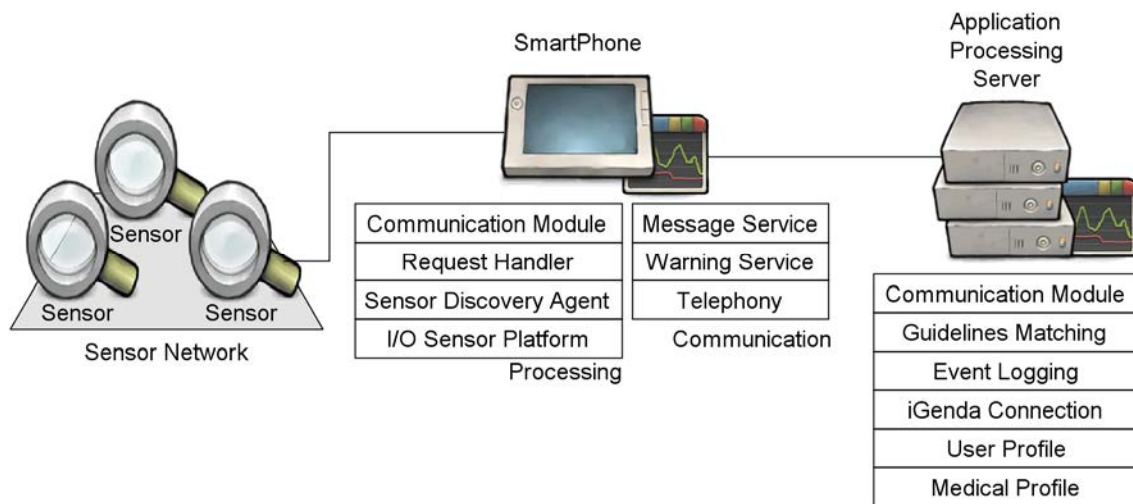
Figure 51: Architecture of the Sensoring System

Figure 51 depicts the platform architecture, including the different internal components and their connection. The Sensor Network is the sensor platform that communicates with the Smartphone, delivering the data through the ZigBee protocol. This sensor platform is external to the SS, being the product not developed in this project.

Regarding the Smartphone project, we can find the following agents:

— Processing: agents responsible for providing an initial processing, checking if there is a health problem with the user;

    o Communication Module: the communication module establishes the communication between all the systems integrating the platform;

    o Request Handler: handles all requests like a stack manager to suit all applications.

- o Sensor Discovery Agent: this agent is responsible for processing all corresponding events of sensor connection in the sensor platform, so the system can capture all data gathered;

- o I/O Sensor Platform: maintains all records of the sensors and their features, with the aim of properly comparing them whit the gathered data.

- – Communication: establishes communication with the other services, providing the bridge between the Smartphone and the Server;

  - o Message Service: responsible for making the connection with the message service systems present in the Smartphone operating system;

  - o Warning Service: provides a mean of notification to the user, both visual and auditory;

  - o Telephony: responsible for making the connection between systems of telephony services on smartphone operating system and application.

The platform is aimed at integrating all services. In that way, work is processed in a distributed way, considering the typical features of Smartphones and their resources such as their battery capacity and/or processing speed, among others.

Data

The sensors used in this work were developed at University of Minho (Gama et al., 2009), and market-driven by Plux (Silva et al., 2011; Silva et al., 2009).
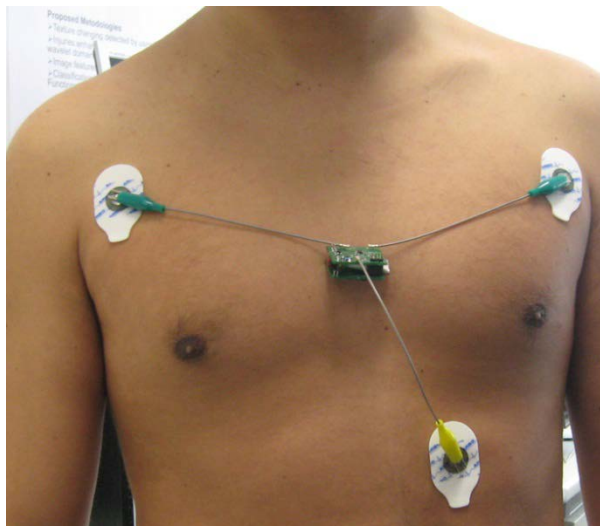
Figure 52: ECG sensor developed by University of Minho

Figure 52 depicts the used sensor in detail. Note that, from the development stage, sensor precision was high in terms of signal capture and data transmission. An example of sensors capture is depicted

in Figure 53 such that the red line represents the cardiac frequency of the user. From the data representation, it can be concluded that heart rate is normal and stable. However, these are not the kind of situations to be expected, but readings displaying serious or imminent heart problems. With the goal to obtain that information, it was also used the information provided by PLUX sensors. It is worth noting that the crucial difference between the two sensor platforms is that the SS platform provides a wider range of sensors and a greater number of captures due to its broad use.
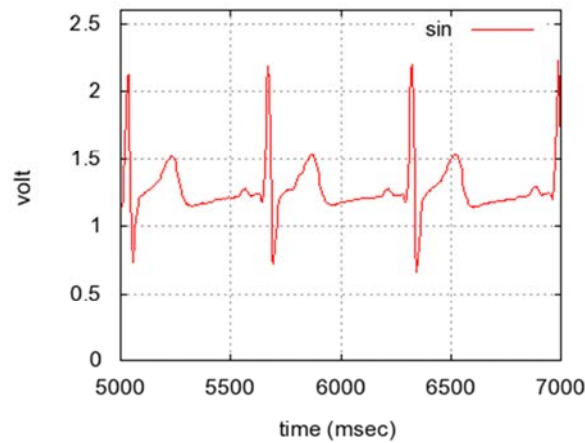
Figure 53: Visual Representation of the data capture by the University of Minho ECG sensor (volts over time in milliseconds)
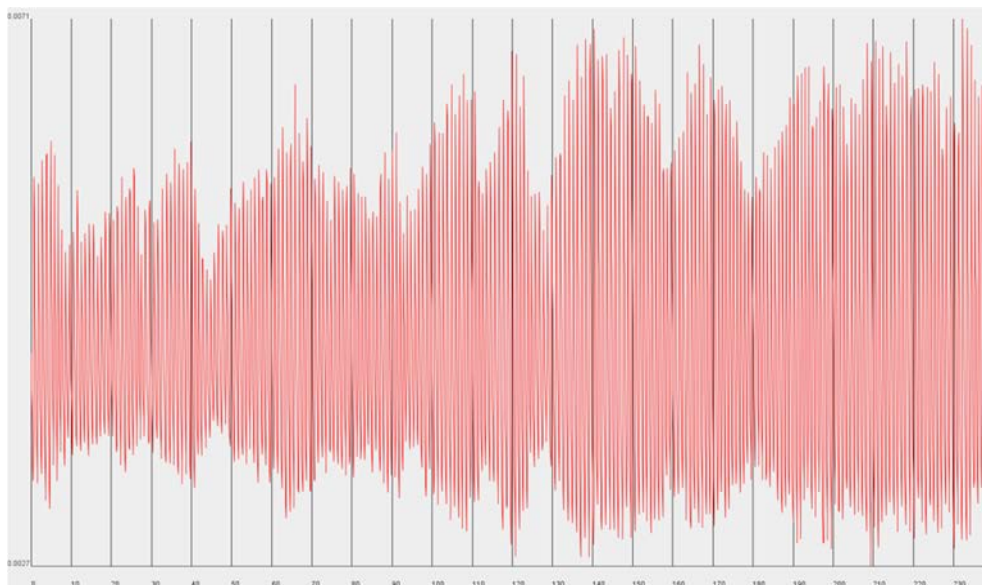
Figure 54: Blood Volume Pulse data capture

In Figure 54 shows the graphical representation of the Blood Volume Pulse sensor capture sample. Sensor captures are processed from data trained through PLUX datasets that include several cases of

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health complications/problems. This intermediate development phase serves to obtain the fine tuning before experimentation with real sensors, providing more stable foundations.

Afterwards, the data are processed following the sequence:

- Receiving data in raw format: receiving data containing the time interval stamps and the voltaic differential;
- Interpreting the data to obtain information and suppressing the common noise from an analog reading;
- Check and adjust the information with a filter;
- Alarm and notification if the values are differing by 5% of the model.

The SS serves as a data gathering service implemented in a mobile system, enabling the detection and identification possible problems. Thus, the SS can notify the problems detected to a help center or to an emergency service. For future data mining, all the data collected is kept for verification by specialized medical staff that can provide meaning and verify errors.

The reason for developing SS under the iGenda project lies on being consistent with the services provided by iGenda. Thus, the use of the scheduling and interface system enables the users with interactivity and medical staff with stats. In the short-term period the SS makes use of the visual environment and connection to communication systems, taking advantage of the iGenda implementation on Android. When any emergence is detected by the sensors attached to the user, it is communicated to iGenda. At this moment, iGenda will make the proper decision from the received data (commonly, it implies to contact an emergency service). In the long-term the SS makes use of the ability of the iGenda scheduling system. When sensing a steady decline of the user health condition, the SS communicates with the iGenda to contact the user caregiver to make an appointment. The iGenda processes this request by the AM and does a follow up to the CM in order to mark the event on the caregiver and the user, creating a shared event.

In short, the SS is an important addition to the iGenda, serving as an invisible bridge between what the user feels and thinks, opening the door to a medical application development where sensitive data is used and the health of a real person is at risk.

6.2 Clinical Guidelines

Medical errors are frequent cause of misdiagnosis, leading to future problems and even deaths (Studdert et al., 2005; Hampton, 1997; West et al., 2009; Farquhar et al., 2002; Maslach et al., 2001). The medical services are often overwhelmed with complicated cases and there is even a bigger pressure because medical staff is being cutting due to our current difficult economic situation. In fact medical practitioners are working more hours without any rest in a high stress environment. The medical staff can reach fast to a mental burnout by using only their deductive capacity and knowledge (Maslach et al., 2001), due to constant mental pressure.

Currently the stress and practicing mistakes are closely intertwined such that a stress increasing results in a higher number of clinical mistakes. This is especially important since a small mistake can cost a human life. For that reason it is necessary to address these issues, by promoting evidence-based medicine and disseminating standards for a good clinical practice (Ten Teije et al., 2008; Mead, 2000; Ibáñez Pradas & Modesto Alapont, 2006; Sackett & Haynes, 1996; Woolf et al., 1999).

The Clinical Guidelines (CG) is a platform for implementing digital clinical guides to be used when performing a differential diagnosis or a triage (Oliveira et al., 2012; Oliveira et al., 2011). Paper clinical guidelines are evidence-based statements that provide recommendations to patients and healthcare professionals about the suitable clinical procedures within specific circumstances. Currently, there are procedures in terms of the admission process and consultation in hospitals and clinics, based on digital clinical processes or basic screening systems. These processes serve only to keep patient history and to make very simple assessments. With that purpose a known schema based on sensor readings and the patient description are used. The lack of any intelligence, constrains the system facilities in terms of efficiency and usability for the clinician responsible.

The clinical practice is already done with the use of computer systems. They serve as support in terms of procedures and exams. They are key tools to carry out implementations of more complex systems and are fully integrated into a medical environment.

Unfortunately, most paper clinical guidelines are long textual documents with a high degree of complexity. This makes it difficult to use and update. In addition such static documents are unable to keep up with the fast growth of scientific knowledge.

Also they are unable to handle Incomplete Information, especially that concerning the patient condition. As a solution the Incomplete Information handles situations where there is an impediment because of missing data, incomplete answers to requests or multiple conflicting data. Providing a tentative solution (or an array of solutions) determining a degree of confidence confirming if the information is valid and secure.

Thus, with the purpose of overcoming all these situations as well as providing a working environment, a model and interpreter were designed and implemented.

Clinical Guidelines Model

The proposed symbolic formalism takes its inspiration from PROforma (Fox et al., 1998) that represents guidelines as flowcharts. Its goal is to offer an intuitive representation of clinical concepts and procedures. Tasks, decisions, actions, enquiries, and plans are the components of this formalism (Oliveira et al., 2012). The model is depicted in Figure 55. Each primitive has a set of attributes, relevant to the type of task to which they stand for. These attributes are aimed at controlling the execution of such tasks (e.g., time constraints, clinical objectives).
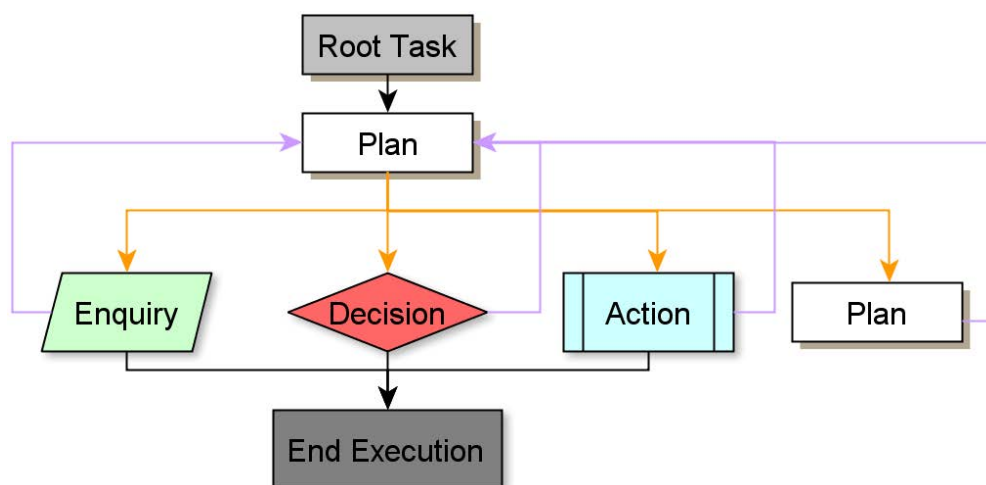
Figure 55: Schematic view of the primitives of the representation model, where each primitive denotes a task of the clinical process

The case study depicted in Figure 56 corresponds to a fragment of the ATPIII Hypercholesterolemia Guideline. It refers to the selection of the appropriate treatment for high levels of cholesterol, from the presence of coronary heart disease, risk factors and a ten year risk of coronary heart disease.

Going from the up to down, the guideline is the input for the Root Task for the management of guidelines and the guideline itself is represented as Plan P1. Note that Plan P2 is part of Plan P1 such

that Plan P2 embraces the enquiries necessary to obtain the parameters used in Decision D1. On the other hand, D1 is responsible for choosing the appropriate treatment based on the current state of the patient. The details about making decision process will be discussed in the following sections of this manuscript. Plans P3, P4 and P5 hold back the procedures for treatment, being their execution bounded by clinical goals expressed in terms of blood levels of LDL. The support format for the guideline model is based on the XML. The structure of the XML files is described in XML Schema Definition (XSD).
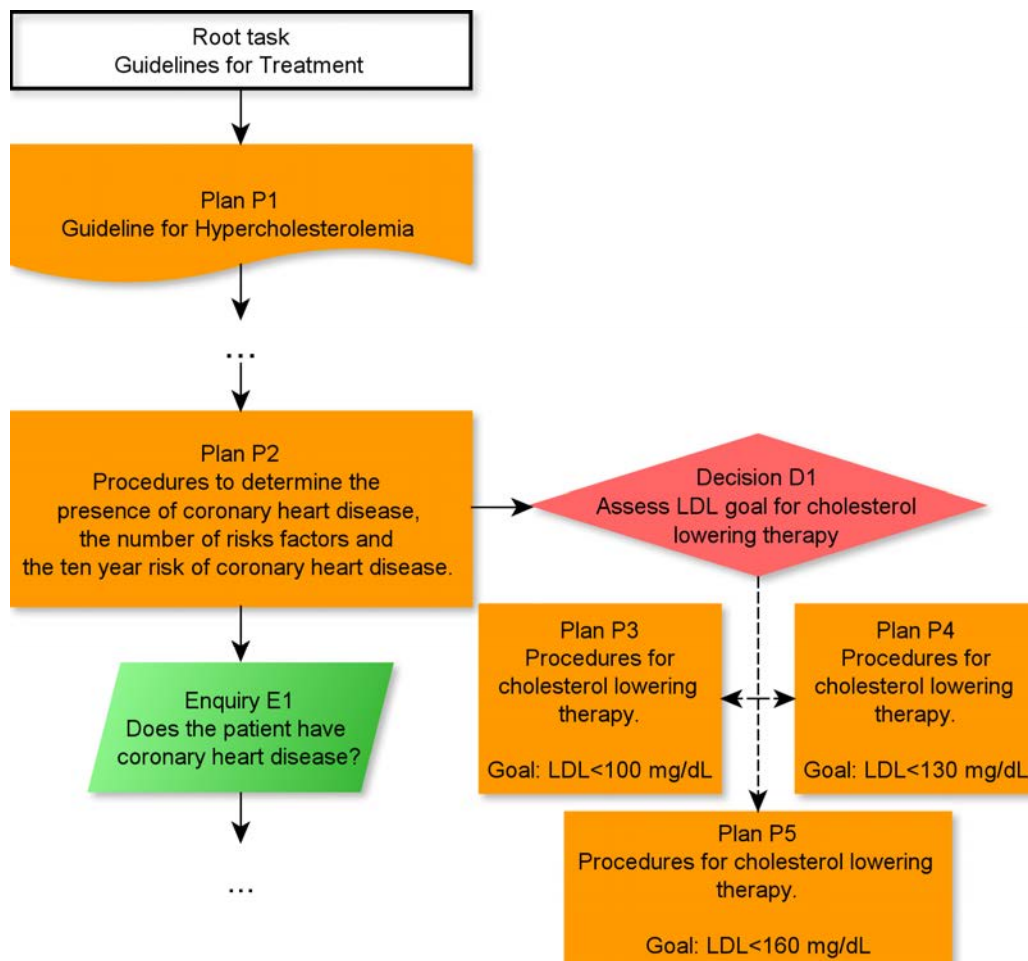
Figure 56: Representation of a fragment of the ATPIII Hypercholesterolemia Guideline in the proposed model

Knowledge Representation and Quality-of-Information

The image of the state of a patient within the clinical Decision Support System (DSS) resorts to Extended Logic Programming (ELP) (Neves et al., 2012; Neves, 1984). ELP encompass one of the few account mechanisms that cover the classic cases of Incomplete Information, such as uncertainty, incompleteness, inaccuracy, and incoherence. ELP uses default negation *(not p)* along with classic

negation *(¬p)*, to explicitly represent negative information. It is useful to distinguish between the cases that are false because they cannot be proven, from what are false because their negation can be proven. Indeed, many approaches for knowledge representation and reasoning have been proposed using the Logic Programming (LP) paradigm, namely in the area of Model Theory, and Proof Theory (Fitting et al., 1992; Neves et al., 2007). Our starting point is the proof theoretical approach and an extension to the Language of Logic Programming, being knowledge representation and reasoning. An ELP denotes a finite set of clauses in the form:

$$q \leftarrow p_1 \wedge ... \wedge p_n \wedge not\ q_1 \wedge ... \wedge not\ q_m$$
$$?\ p_1 \wedge ... \wedge p_n \wedge not\ q_1 \wedge ... \wedge not\ q_m\ (n, m \geq 0)$$

where ? is a domain atom denoting falsity; the p_i, q_j and p are classical ground literals. In this representation formalism, every program is associated with a set of abducibles. They are here in the form of exceptions to the extensions of the predicates that make the program. To reason about the body of knowledge presented in a particular set let us consider a procedure given in terms of the extension of a predicate denoted as *demo*. This meta predicate is given by the signature *demo:T,V →{true, false, unknown}* , according to the following set of terms:

$$demo(T, true) \leftarrow T.$$
$$demo(T, false) \leftarrow \neg T.$$
$$demo(T, unknown) \leftarrow not\ T, not\ \neg T.$$

Indeed, under this scenery we can assume the following:

− The first clause establishes that a theorem to be proved is put to a knowledge base of positive information returning the truth-value true (1);

− The second clause denotes that the theorem to be proved recurred to the negative information presented in the knowledge base, returning the truth-value false (0);

− The third clause stands for itself, associating the theorem to be proved with a truth-value in the interval]0,1[, i.e. a measure of system confidence in the proof process.

As an example, let us consider the model shown in Figure 56 when a patient does not have coronary heart disease. Suppose that the clinical staff is unable to detect exactly how many risk factors the patient shows, although they believe the number to be in the set {1, 2, 3}. Similarly, the risk of suffering a coronary heart disease in the next 10 years is also impossible to determine with accuracy, due to the risk factors. Even the healthcare professionals know it is either 19% or 21%. In the context of ELP, the

information about the presence of coronary heart disease, the number of risk factors and the ten year risk of coronary heart disease can be represented with the following extensions of predicates *chd, risk_factors* and *ten_year_risk*, in the form:

$\neg chd(X) \leftarrow not\ chd(X), not\ abducible_{chd}(X).$

$abducible_{chd}(X) :- chd(unknown).chd(unknown).$

$\neg risk\_factors(X) \leftarrow not\ risk\_factors(X), not\ abducible_{risk\_factors}(X).$

$abducible_{risk\_factors}(1). abducible_{risk\_factors}(2). abducible_{risk\_factors}(3).$

$\neg ten\_year\_risk(X) \leftarrow not\ ten\_year\_risk(X), not\ abducible_{ten\_year\_risk}(X).$

$abducible_{ten\_year\_risk}(19). abducible_{ten\_year\_risk}(21).$

$?\ (ten\_year\_risk(X) \vee ten\_year\_risk(Y)) \wedge \neg\ (ten\_year\_risk(X) \wedge ten\_year\_risk(Y)).$

where the first clause of each predicate denotes its closure. The hypotheses in terms of the number of *risk factors* and *ten year* risk are represented here as *abducibles*. The last clause in the extension of the predicate *ten_year_risk* stands for an invariant, denoting that the abducibles are not disjunct. So, *ten_year_risk* can be set to 19 0r 21, but ont both at the same time. On the other hand, the *abducibles* for the predicate *risk_factors* denote a disjunction, such that its values in the set *{1, 2, 3, {1,2}, {1,3}, {2,3}, {1,2,3}}*. With the purpose of establish a link between the parameters of the patient state and the ones of the guideline recommendations it is necessary to properly set the attribute named *Argument Rules* for each *Decision Task*. *Argument Rules* point to production rules sating the conditions to be held to choose one or more of the treatment options available at a given *Decision Task*. The use of production rules confers transparency to the clinical process, since they are interpretable by both people and machines. That is, they stand for themselves. For example, the set of rules that may enforce Decision D1 can be given in the form:

if chd(yes) or ten_year_risk(X) > ten_year_risk(20) then ldl_goal_less(100).

if ten_year_risk(X) =< ten_year_risk(20) and chd(no) and risk_factors(X) >= risk_factors(2) then ldl_goal_less(130).

if (risk_factors(0) or risk_factors(1)) and chd(no) then ldl_goal_less(160).

Then, the reliability of the available information used in each rule, is measured. In that way, it is possible to make a decision about the LDL goal of the cholesterol lowering therapy from Incomplete Information.ELP appears here associated with an Quality-of-Information (QoI) evaluation method, which is defined in terms of truth values taken from the interval *[0,1]*. If the information is *known*, the QoI for the term of predicate extension *p* under consideration is 1. For cases where the information is *unknown*, the QoI for a term in the extension of predicate *p* is given by:

$$QoI_p = \lim_{N \to \infty} 1/N = 0 (N \gg 0)$$

(8)

where N is the number of terms for p. This is the case in the extension of predicate chd abovementioned. For cases where the predicate extension is unknown, but can be taken from a set of mutually exclusive values (e.g. extension of predicate ten_year_risk), the QoI is given by:

$$QoI_p = 1/Card$$

(9)

where $Card$ corresponds to the number of abducibles of p. If the set of abducibles is disjoint, the QoI is defined as follows:

$$QoI_p = 1/(C_1^{Card} + ... + C_{Card}^{Card}) = 1/(\sum_{j=0}^{Card} C_j^{Card} - 1) = 1/(2^{Card} - 1)$$

(10)

where C_{Card}^{Card} is a card-combination subset with Card elements.

The next element to be considered is the relative importance assigned to predicate attributes under observation. That is, w^k which refers to the relevance of attribute k in the extension of predicate i.

The reason lies on the fact that some guidelines used in diagnostic situations, consider several weighted symptoms for disease detection. Note that these weights are normalized in the following way:

$$\sum_{1 \le k \le n} w_i^k = 1, \forall i$$

(11)

where $\forall$ denotes the universal quantifier. It is now possible to define a predicate's scoring function $V_i(x)$. So, for a value $x = (x_1, ..., x_n)$ in the multi-dimensional space, defined in terms of the attributes of predicate i, it can be expressed as:

$$V_i(x) = (\sum_{1 \le k \le n} w_i^k \times QoI_i(x))/n$$

(12)

It is now possible to visualize all the possible scenarios denoting the universe of discourse, in terms of the extensions of the predicates chd, $risk\_factors$ and ten_year_risk given above.

Last, but not least, it is worth paying attention to the fact that all terms will contribute to the score. On the other hand, if we are faced with a disjunction of terms, only the term with the highest *truth value* will get a higher score. However, this is not always the case, since a symptom can be more denotative of a disease than others that can also occur along with it. The evaluation scheme may evolve towards distinguishing conditions in terms of the symptom relative weight, which is the case when a profound knowledge of the clinical domain is shared with its part-owners.

The Decision Model

With the purpose of reasoning about patient background, a logic inference engine mimicking the diagnosis procedure was developed. So, once a given assignment is required to be executed, the engine must consider the guideline recommendations for that particular patient. Such model is depicted in Figure 57. Initially, the Formulation of Hypotheses is considered. At this stage, a survey on the available options with respect to a Decision Task, is performed. Subsequently, for each rule, there is a Voting Stage. The Voting Stage starts with the Evaluation of Conditions, at the knowledge base level. Under a successful outcome, the rule is considered inferable and the QoI Evaluation is the next phase in the decision process. Otherwise, the process goes back to the initial phase and a subsequent rule will be considered.
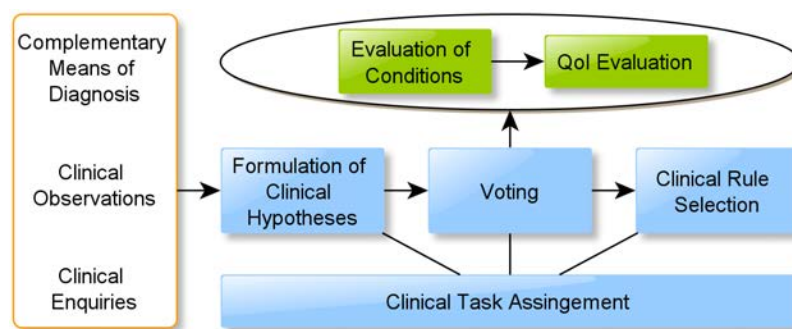
Figure 57: A schematic view of the decision model based on the CGs recommendations

Indeed, in terms of the scenarios above described, and according to the rules of Decision D1, we may come to a conclusion. At the Evaluation Stage, the QoI method is used to determine the truth or falsity of the logic conditions and the scores of each rule.

The Clinical Rule Selection stage requires that all the scores of the valid rules have been evaluated. The options are put in a preference list, according to the decreasing order of their scores and an information dashboard, containing the contributions of the conditions of each rule to the scores, and this list is shown to the user. The chosen rule is the one with the highest score and will determine the next task in the clinical process at the Clinical Task Assignment stage.

iGenda Connection

This case study connection with the iGenda is maintained at the information level. This means that the clinical guidelines module retrieves and deploys information over the iGenda core modules. The integration of these models generated features that are more hospital-oriented (Costa et al., 2010). Therefore, it becomes more useful in a direct doctor-patient interaction.

In terms of connection, the CG current development establishes the communication with the AM. This connection exchanges information about the user, his/her general health condition and as other important information. Similar information will be deployed over the iGenda databases, therefore, the user medical information will be updated and the iGenda will have a better perception of the user and its conditionings.

Further connections are being studied. As an example, the integration with the calendars of the physician and the user, proceeding to better GC post-procedure follow-ups, is under structuration. So, in terms of integration, the iGenda is opened to possibly integrating more medical services, thus creating an extended CA environment.

6.3 Orientation System

The introduction of mobile devices in iGenda development highlighted several features to be harnessed. For instance, user localization was always a thought and consequently developed under the iGenda Core Modules. It could become a real service since mobile devices are provided with GPS, Wifi localization systems and cameras. So, a combination of these features results in a personal guiding system. This new system provides knowledge about user whereabouts to both iGenda and user (Ramos et al., 2012).

The current trend is to provide high usability applications resourcing to augmented reality. This provides improved interaction applications to the user, displaying on the screen simple and useful information. Since 1988 the interest and the attention on how assisted technologies can improve the functional needs of people with cognitive disabilities have grown. The interest level has been increased thanks to the development of related projects and the public awareness of the technology use as assistant for people with cognitive disabilities (Alper & Raharinirina, 2006).

Like an ordinary person, individuals with cognitive disabilities leave their homes, but once outside, the security and automated actions of their smart houses are unviable. In the last years the interest and technology improvement has turned people attention to assisted technology outside home and not only inside.

System Description

We propose a system aimed at satisfying the needs of people with cognitive disabilities and at keeping their caregivers more informed. This system is developed for Android Operating System and uses mobile device GPS module to retrieve user outdoor location. However, GPS does not properly work or does not provide enough accuracy when the user is indoors or in a denser environment (e.g. big cities with tall buildings, dense forests, etc.).

Therefore, our proposal of only use GPS to retrieve user location does not work in indoor environments. We overcame this handicap by integrating GPS with an Inertial Navigation System (INS) (Anacleto et al., 2011).

Figure 58: Screenshot of the user visual system, overlaid with the next instruction

Consequently, our goal is to accurately retrieve user location in indoor environments without using structured environments and in a non-intrusive way. For that, the designed system consists of several sensors (Body Sensors Units), attached to person's clothes and shoes, such that sensors spread over the person lower limbs. These units are then connected to a Body Central Unit (BCU), which receives the sensor data and, from them, it estimates user location which is sent it back to the user's mobile device. One problem is that INS can have a drift due to sensor's thermal changes, which leads to erroneous location estimations. However, we are implementing a probabilistic algorithm that learns the user walking behaviors to correct the sensors data.

The orientation system consists of a mobile application, presenting several landmarks (in form of pictures) along the user path. In that way, the user receives information about the next direction to be followed, as shown in Figure 58. During the user movement an arrow will appear and indicate the

correct path. This information is given real-time and includes directions (e.g., turn left) or reminders to keep the user attention in the present action.

These directions are given by the localization system, which retrieves the person location and verifies if the person is doing the correct travel path. If, for some reason, there is an emergency or the user gets lost then, the user only has to press a simple panic button in the smartphone home screen. When activated it initiates a call and/or sends a SMS to the caregiver providing the current user location.

Figure 59: Web and mobile caregiver applications

In addition, a web application presenting the current route (together with a route history) is built for providing further information to the caregiver. Thus, this application has the ability of monitoring several different users, as depicted in Figure 59.

Figure 60 presents the framework of our system. With user current location, the smartphone will process the necessary data to present to the user the correct landmark for his location. Besides showing to the user this information, the mobile application sends (every 5 minutes or 200 meters) the current user location to the system server. The server communicates in a standard way, supporting SOAP (Englander, 2002; Ramos, 2007) and OAUTH (Recordon et al., 2011). It also integrates a database and decision engines that can send a message to the caregiver if the sensor platform detects a user emergency, as seen in Figure 60. Finally, the caregivers can connect to the server, through the web application to retrieve the user's current location, especially when the user is a person with cognitive disabilities.

A direct connection between the user and their caregiver can be established since the system provides notifications and profile updates about the user whereabouts. So, the server and constant connection to the internet enables this type of interaction between all the participants.

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When the user moves outside their home notifications are pushed to the caregiver application, providing full interaction between them. Also, the multiple possibilities of user monitoring empower the caregiver to follow different people. This means that health service providers can actually follow different people. At the same time, they rely on a system to monitor and be warned when a user requests for help or when the user went to an unknown or unfamiliar place. Devising attention to multiple people is very difficult for a single person but not for a computer. In case a user indicates their destination to the system and, at any time, he/she starts following a wrong path, the system would warn the caregiver about this situation. So, the caregiver can call the user to verify if everything is right.
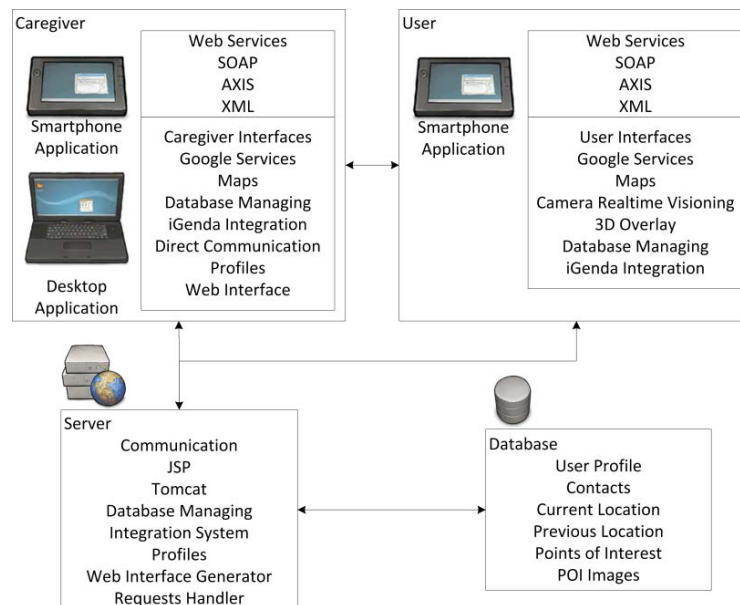
Figure 60: Orientation System architecture (simplified)

6.4 Visual Fall Detection System

A deep state-of-the-art analysis in AAL systems has revealed that fall detection systems and visual monitoring are growing in popularity nowadays (Felisberto et al., 2011). The reason lies on the easy user home support they can provide. So, a module to monitor and visually track any user, has been developed and integrated into the iGenda project. Although there are many sensor applications and localization systems that are discrete and ubiquitous, it is clear that image capture and visual detection is the most reliable and the most versatile service. Due to this fact, a group of the detections

accomplished by the visual monitoring and the iGenda modular platform, it can provide an enhanced pre-detection and detection of emergency and intelligent automation. The user benefits of security in case of emergency and intelligent actions, such as automatic scheduling or automatic domotic control, on his everyday life.

Multiple Spectra Monitoring

Multiple spectra monitoring consists of a series of object detection, tracking and activity interpretation techniques that, working with different spectra video cameras, are able to detect people's current position and movement. In this way, the system obtains the involved events and activities (Serrano-Cuerda et al., 2011).

The monitoring component of the system is focused on obtaining the current status of the people inside the monitored environment. This status means actions such as standing, sitting or lying (with impact whether it is on a bed or on the floor). The system detects if a person has already fell down, minding the fact that it is difficult to establish differences between tripping and falling. Two different kinds of cameras are used, i.e. colour and infrared cameras. Each one of them is used in different circumstances with the aim of fusing their data.

For standard circumstances colour cameras are usually a good choice, being suitable for a standard monitoring system. However, these cameras have two main drawbacks: on the one hand, this kind of cameras needs good visibility to provide successful results. Thus, they are not suitable for night-time surveillance or scenarios with low visibility conditions (Fernández-Caballero et al., 2011), on the other hand, privacy is an issue to be considered since people can feel that their privacy is invaded in certain scenarios such as bedrooms or bathrooms.

Therefore, an alternative must be proposed. Taking into account that humans usually are warmer than the remaining objects in the scenes, infrared cameras would ensure a good detection independently from the lightning conditions, whilst keeping privacy in some *delicate* areas. That is, infrared cameras are suitable for performing human tracking and activity recognition also in places where privacy must be preserved, since they provide enough information to the system, without providing further information about the person's identity. However, these cameras are prohibitively expensive. For that reason, other options must be analysed to monitor less critical environments.

Upon the consideration about the cameras, features and price, the conclusion achieved is to use infrared in places privacy should be assured, and/or environmental conditions are not good; while

colour cameras would be used whenever there are no privacy constraints and the environmental conditions are optimal.
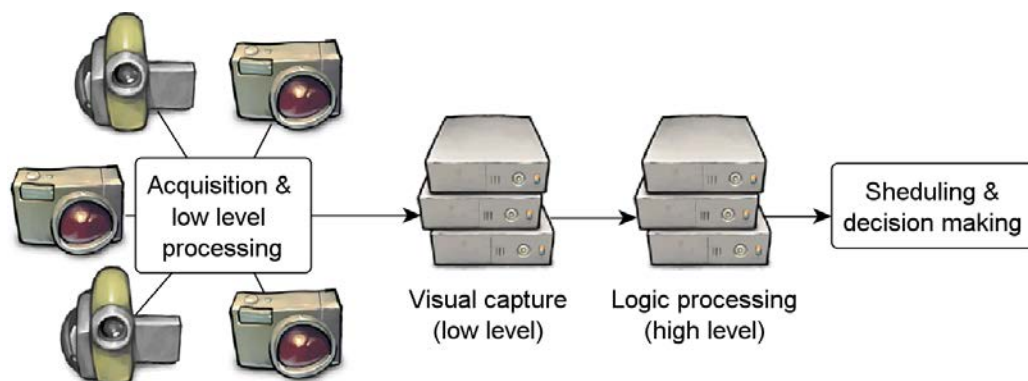
Figure 61: System components, showing the involved sensors and modules

System Overview

The system is composed of two different levels. The levels are arranged through three modules, going towards a higher abstraction degree (i.e. from the raw data to logic decisions). The high-level module consists of a scheduler that sends notifications to the emergency services when a dangerous situation is detected, serving also as interface to whole the platform. The lower-level modules perform the common tasks of a monitoring system, that is, gathering data from cameras, processing them to detect and track humans, and identifying the activities they performed (see Figure 61).

The iGenda manages the logging system, it can take intelligent decisions. Therefore, it immediately calls the emergency services and/or analyses the overall status to take proactive actions. As the surrounding environment can be analysed, events can be perceived. In addition, actions regarding the perceived scene can be used to prevent further problems and act over the current ones.

The idea is using both mobile and static sensors to perform constant monitoring of the user and his/her environment, providing a safe environment and an immediate response to problems that may occur. With all these premises, the highest processing level follows the intelligent ambient paradigm, whilst the lower processing level is implemented in C++ due to the intensive calculation especially in the image processing levels.

Acquisition & Low Level Processing

The module of acquisition and low level processing is designed to work on both visual and infrared spectra. Its main goal is to detect the humans within the observed scene, providing this information to the higher levels. As abovementioned, two different algorithms are used at this level. An "accumulative

computation" approach (Fernández-Caballero et al., 2003; Moreno-Garcia et al., 2010) has been chosen to work in the visual spectrum. It is used in the main monitored rooms. On the contrary, human detection algorithm is based on a single frame is used for infrared cameras and will be applied in rooms with special needs such as bathrooms or bedrooms.
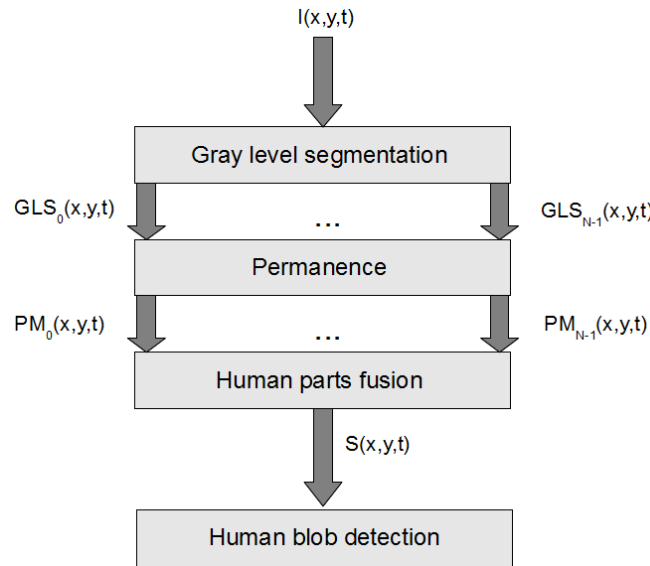
Figure 62: Accumulative computation approach

In great detail the algorithms are:

- Visual Spectrum Processing: The accumulative computation approach is used for human detection in the visual spectrum. Motion estimations allow to gradually obtaining all moving human shapes. The different stages of the algorithm cover the main features of the proposed approach. These stages are (see Figure 62):

  o Gray Level Segmentation: the module segments the original image (named as $I(x,y,t)$) into a preset group of N bands. Each of these bands corresponds to a different range of gray levels from 0 to 256. At the end of this stage there are N binary images. The pixels with a gray level value belonging to the band are set to the maximum value; while the remaining pixels are set to a minimum one.

  o Permanence: an estimation of increase or decrease in pixel value due to target's motion is performed. The module has been designed to obtain the accumulated charge on a quantization basis. It will memorize the value of the accumulative computation present at time scale t for each pixel (x,y).

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- o Human Part Fusion: during this step, the maximum values of all outputs of the N bands are considered. In that way, blobs representing a moving person are obtained for each colour component.

- o Human Blob Detection: this module performs a binarization based on thresholding. So, values greater than the threshold are set to the maximum gray level (255), while those values lower than the threshold are set to the minimum gray level (0). Once the image is binarized, a series of erosion and dilation operations is performed with the aim of suppressing image noise. Finally, spots are filtered based on human characteristic features, such as height, width and compactness. A sample of the obtained output of this stage is depicted in Figure 63.

- Infrared Spectrum Processing: our proposed infrared-based algorithm uses a single frame for the human detection.

- o Human Candidate Blob Detection: This stage of the algorithm starts with the analysis of infrared input images, taken at any time. Initially, a scale change is performed to normalize the image. Then, a threshold is used in order to perform a binarization whose goal is the isolation of the human candidate blobs. This threshold is estimated using an adaptive threshold method (Shapiro & Stockman, 2004). Thus, the warmer zones of the image are isolated, with the assumption that they belong to humans. At this point, the content of each blob must be validated in order to establish if one single human candidate or more than one are contained in the blob. Thus, the algorithm processes each detected blob separately.

- o Human Candidate Blob Refinement: After detecting human candidate blobs, it is necessary to analyse them to avoid common segmentation problems like erroneous grouping. Moreover, the following steps help to obtain a more accurate scene of the monitored scene, which will improve the performance of the higher-level modules. The first step is human vertical delimiting. The presence of warmer zones is used as an indicator of human presence since heads are normally warmer than the rest of the human's body, covered by clothes. Regions of the image where the sum of heat sources is below a threshold are also identified. Because these regions are supposed to correspond to gaps between two humans. So, a human individual is defined as a warmer zone (head + torso) limited by two gaps. Possible grouped humans are split

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into sub-groups, containing human candidates at the end of this process. Secondly, it is necessary to perform a horizontal delimiting. The height of each sub-image obtained in the previous stage must be fitted to the real height of the human observed. The computation is applied separately on each sub-image to avoid the influence of the remaining image on the result.

o Human Confirmation: Finally, it is required to confirm if the potential human candidate contained in each sub-image is actually a human. For that, we check the size of the sub-image as well as its standard deviation and area ratio with respect to the original infrared image. These evaluations discard possible false positives such as fuses, radiators, and other heat sources whose heat distribution can be confused with a human being. The result of applying human detection based on a single frame at a sample image can be seen in Figure 64.
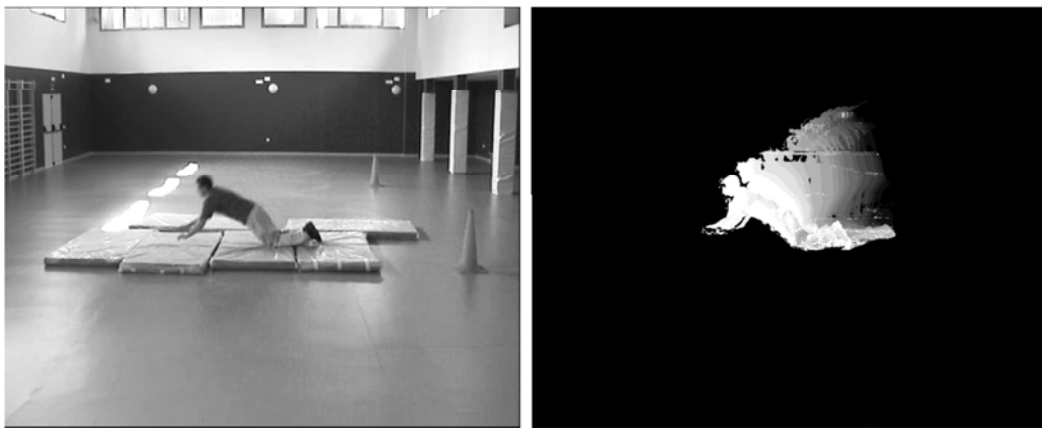
Figure 63: Accumulative computation result. Left: input image; right: motion detected at different time instants

Figure 64: Infrared spectrum detection. Left: input image; right: human blob detected.

Fall Detection Mechanism

Our approach is based on the idea of combining fall detection with an inactivity monitoring model. In this case, inactivity monitoring is thought for checking human inactivity after a fall during a predefined period of time. On the contrary, fall detection is focused on the geometrical analysis of visual human representation (introduced in the previous section). For analysis issues, "fall time" is defined as a time interval between 1 and 3 seconds.
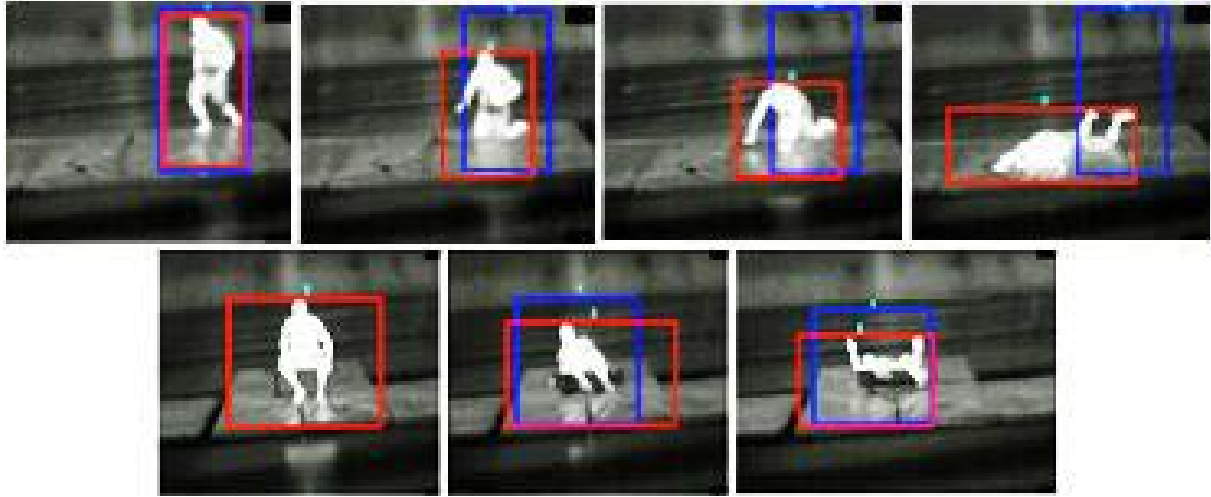
Figure 65: Representation of fall detection and inactivity monitoring, the blue square represents the previous state, the red square the current state

Figure 65 graphically summarizes the performance of fall detection and inactivity monitoring. In brief, during "fall time", fall detection is triggered. Once a fall is detected, inactivity monitoring is activated. If the fallen human stands up before a pre-established time interval called "monitoring time" (typically 30 seconds), inactivity monitoring is stopped and fall detection is launched again.

Figure 66: Detection corresponding to a false fall (kneeling action)

In detail, after "time fall" passes, the joint static and kinematic analysis corresponding to humans is performed. The static analysis corresponds to the study of a single (and current input) segmented

image, whilst kinematic analysis is based on a sequence of segmented video images. After estimating image parameters, fuzzy logic is used to determine the ranges for the fall indicators.

Integration With The iGenda

The iGenda receives the data from the other lower-level modules. It is a "high level processing" module to bridge and process the visually acquired detected falls. This fact leaded to an "Early response manager". This agent, working with the rest of the platform, is capable of making intelligent decisions such as immediately calling the emergency services or analysing the overall status and taking proactive measures. In terms of execution, the "early response manager" agent is continuously checking inputs from the "fall detection module". Thereon, the system provides information of valuable data such as intensity, post fall responsiveness, time and place, among other information. By using an established network connection, messages are sent to the user's smartphone asking whether the user is injured or not, and, finally calling the emergency service when a response is not given in a period of time.

Experiments

Several experiments were performed to validate the proposed system. The experiments were carried out on a personal computer equipped with an Intel Core i7 processor with 3 GB of RAM. The video sequences were recorded with a FLIR A320 infrared camera at a resolution of 720×480 pixels and a SONY fcb-ex780bp colour camera at a resolution of 704x576 pixels.

Experiments were aimed at three different situations:

— Fall from the standing position;

— Fall from the sitting position;

— Distinction between real and false falls.

For that, six image sequences (three sequences taken by the infrared camera and three ones provided by the visible camera) containing a single person, were used. Note that, as there are not image libraries available in public datasets containing falls, actors simulated the situations to be analysed.

Figure 67 shows resulting images where falls are foreseen in the experiment. There are red and blue bounding boxes on the images. A red box shows the rectangular bounds of the last detected blob position, whereas a blue box encloses the first detected blob of the fall presumption. Thus, fall indicators are estimated using the red and the blue bounding boxes.
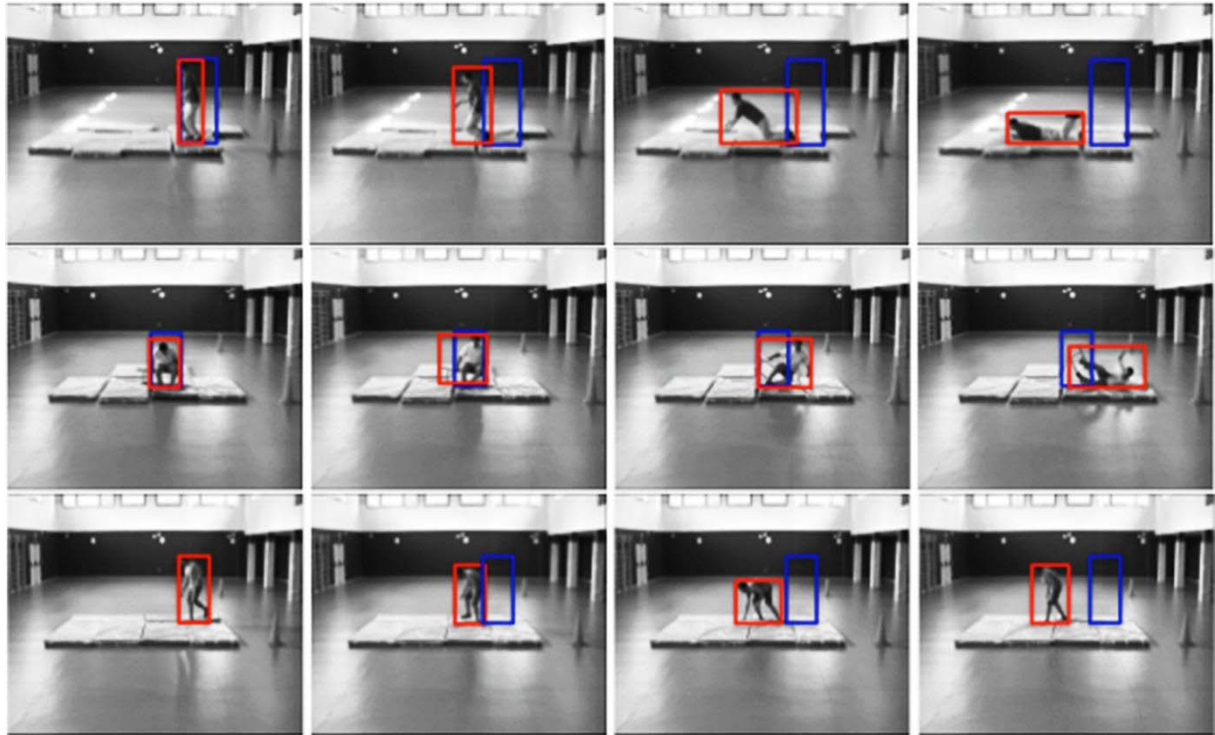
Figure 67: Visible spectra fall tests. Upper row corresponds to a fall from a standing position; middle row corresponds to a fall from seated; and lower row corresponds to a false fall (kneeling action)

The integration of the fall detection system into the iGenda platform allows to complementing each other in terms of security and user interaction. The system is neither full automatic, automatic, which could lead to a large number of false positives, or fully manual, relying on the user to perform all the tasks.

6.5 Conclusion

The iGenda development highlighted the need of implementing new functionalities in form of modules. These modules complement the core actions of the iGenda, extending it in some way. That is, they cover very different aspects belonging to the initial iGenda scope. In that way, the resulting integrated platform is able to work in different environments, providing different solutions to critical AAL issues.

Consequently, the user can take advantage of a large number of services centered in their health. It is worth taking into account that complementary services can also take advantage of that. So, for instance, the Clinical Guidelines and the Orientation System were developed to encompass the use of caregivers and medical staff. Consequently, although the provided sphere of services is not limited to

the user, it affects them in a direct or indirect way. Given that the system complexity and requirements are in upward trend, new features will be developed and integrated in the future.

The iGenda is then the base structure for the case studies, meaning that the development done on the case studies presented used several features and/or information of the iGenda platform. Moreover, it was one of the aims to build a CA ecosystem, where the user could use only one application and enjoy several services that minded very different aspects. The archetype presented relied on this concept, more specifically a module deployment concept. So, the main developed architecture would not have to change radically, but only to provide connection to new added modules. Likewise the AAL4ALL project is infused with the same concept of plugin systems. The iGenda is providing the templates to the standards and rules definition. This shows that the iGenda core modules and the case studies serve currently serve as the example to other large implementations.

7 Conclusions and Future Work

"We need to accept that we won't always make the right decisions, that we'll screw up royally sometimes - understanding that failure is not the opposite of success, it's part of success."

- Arianna Huffington

The evolution of digital systems as known today is revolutionary allowing large technological leaps. However, there is still a gap between what is developed in terms of state of the art and what actually is within the reach of an ordinary person. Most research and developments are focused on professional and industrial systems, relegating technological benefit of those who really need it.

Governmental and scientific organizations denoted a wide gap in humanitarian and social services in terms of technological solutions. The European Union, under the European Commission entity, is the main investor in projects aimed at population, having a strong focus on the elderly population. In recent years, there has been a great development in Ambient Assisted Living (AAL). The results of the initial projects are already being noticed and there is a great investment for the improvement of life conditions of elderly population. So, the combination of circumstances and desires lead to products that will help the individual to have a better daily life, being safer and more comfortable.

Under this perspective, the work presented throughout this document was developed. In fact, the belief in assistive systems, virtual organizations and collaborative medical communities were what potentiated the motto and stated the starting point of the iGenda project.

The iGenda development evidenced various situations that contributed to a sustainable platform for the current needs, and opens new lines of research. Adopting the cognitive assistant theme was based on the fact that other developments were too focused on performing a limited number of tasks. This results in a specific service where the user only benefits for what the service is specialized. With the aim of completing different tasks, a myriad of other products/services, which can lead to unaffordable costs for the user, is required.

Therefore, the goal was to develop a modular system addressing the problem of integration and interconnection with other services. This research highlights that modular systems are indeed the best solution for the implementation of AAL services and products. In that way, a new vision about how CA platforms should be built is provided and methods for integrating it with other systems are proposed. The containment of complex structures and function distribution in specific modules, translates into a platform for easy maintenance and updating, allowing future integration of new components.

The research hypothesis were attained with the development of a CA modular platform with core functionality, and validated by means of case studies, in form of external modules proving its modularity. At the same time, the possibility to effectively and innovatively respond to several questions from the scientific community was real. Keeping the end user in mind, all the developments done in this manuscript were designed to have the least possible cost. In addition, the used devices and services are those the user already has, being fairly inexpensive. Finally, a robust and integrated home environment, ubiquitous and transparent to all potential users, is presented. It provides a response to the question: "how to increase people's quality of life".

7.1 Contributions

In order to achieve the initially stated goals, the following contributions were fulfilled:

— A study of AAL systems and their components (see chapters 2 and 3):

- This allowed to identify gaps and aspects of the system that could be improved or implemented. In addition, it resulted in an exhaustive study of the state of the art pointing to future developments;

— A study of the computer systems supporting the development of a modular platform (see chapter 4):

- The interest in this kind of platforms relies on the facility of adding new components, which makes it robust to perform continuous and uninterrupted tasks; and
- It allows the design of a multi-agent system that supports a modular structure;

— The development of a multi-agent architecture (see chapter 5)

- It allowed the implementation of the core platform, its behaviors and communication processes, that heavily rely on ontologies;
- New communication terms are obtained with the addition of new components, without interfering with both the existing and future modules;

— Drawing an archetype platform (see chapter 5):

- It allows for the development of the cognitive assistant archetype and subsequent architecture;

— Development of the iGenda platform, in terms of an agent-base methodology for problem solving, leading to modularity and ubiquity (see chapter 5):

- The development of a cognitive assistant ;
- The consideration of intelligent scheduling systems to avert conflicts in terms of events. It presents also the ability to communicate between multiple users and bilateral scheduling. In addition, it provides a mobile format and customized alarms;

— Design and development of service complementary structures (see chapter 6):

- This allows for the integration with the iGenda core modules, establishing the required communications services;

— Testing in different scenarios the developed archetype and platform (see chapter 6):

- The development of a system supporting a sensor platform.

Placed in a mobile device, this system is responsible for receiving data from a sensor platform and to run an analysis software to detect latent or emerging problems. Then, an communication protocol is appropriately chosen depending on the kind of emergency. So, it is able to carry out complex orders, like scheduling events, which is the case when there is a deterioration in an user's health;

- The development of a system for clinical aid based on clinical guidelines.

   This system aims at helping clinicians and patients by providing a better clinical service. Therefore, it integrates their agenda with the purpose of linearizing task scheduling and communication with portable sensory systems;

- The development of a guidance system based on common preferences.

   This system provides augmented reality to guide the user to places where a specific event may be taken place. Indeed, it has the ability to engage with healthcare providers and presents them with the user's current location. The sites may be drawn from events belonging to the user's calendar;

- The development of a fall detection system using visual input.

   This system uses normal and thermal cameras to visually capture the location and position of the user's body, checking whether he/she is laid down. It also uses mobile devices to communicate with the user or, a more severe case, to call for assistance.

7.2 Relevant Publications

This document has highlighted the significant work done in terms of scientific projection. There is an enrichment of knowledge trough the contribution of effectively implement solutions, represented in terms of publications and projects. Regarding evolution and distribution of knowledge among peers, it resulted in 25 international papers, 3 of them in international journals, and other 4 in international book chapters. A selection of which is presented in the next subsections.

Parallel to this work, it was developed the projects TIARAC and AAL4ALL. The project TIARAC - Telematics and Artificial Intelligence in Alternative Dispute Resolution (http://islab.di.uminho.pt/tiarac), funded by the Foundation for Science and Technology, is a project aimed at developing negotiation support systems focusing on argumentation, artificial intelligence, game theory and human interaction. Decision systems of a court order can be implemented in functionality and interaction provided that involved people are not injured. However, the current decision support systems lose their sense of communication and negotiation between users. That is, the users do not interact directly with each other and cannot make a proper negotiation. So, along the process, the mediator does not get realistic reactions of users. In the context of the Portuguese law, there is also a large gap in terms of laws and legal limitations. This project, intended for creating systems supporting the users in legal negotiation (mostly in terms of divorces), results in a virtual negotiation room that provides data to ponder the best solution in terms of user's goods and properties. Hence, this project contributed with a portal that provides all the features above mentioned like the development of platforms implementing multi-agent systems for calculation and decision.

The project AAL4ALL (www.aal4all.org), funded by QREN and ADI, pretends to develop AAL systems that provide the user with a home cluster of services and devices to improve the user day-to-day. Aimed at the elderly people, the AAL4ALL is a project encompassing a large number of partners and it is responsible for research, development and manufacture of products that can be included in an AAL ecosystem. Currently, its goal is the development of standards that regulate current and future products. In that way, consistency for all products and market product adaptation for matching the standards set, are properly managed. Although the project is focused on the elderly and/or disabled, it is extended with the services provided, being possible to find products and solutions for care providers and medical personnel.

In this project, knowledge about agendas and communications systems between agents on mobile devices was used. As part of the development of an application providing communication between the user and a healthcare provider, it serves as a platform for data reception from a home server and for receiving common messages or alerts from sensors. The application also uses some concepts of scheduling and timetabling.

7.2.1 Scientific Journals

– Ângelo Costa, José Carlos Castillo, Paulo Novais, Antonio Fernández-Caballero, and Ricardo Simoes. 2012. **Sensor-driven agenda for intelligent home care of the elderly**, Expert Systems with Applications 39(15): 12192–12204, ISSN: 0957-4174, DOI:10.1016/j.eswa.2012.04.058.

Impact Factor: 2.203. Q1 in Computer Science, Artificial Intelligence.

Abstract: The exponential increase of home-bound persons who live alone and are in need of continuous monitoring requires new solutions to current problems. Most of these cases present illnesses such as motor or psychological disabilities that deprive of a normal living. Common events such as forgetfulness or falls are quite common and have to be prevented or dealt with. This paper introduces a platform to guide and assist these persons (mostly elderly people) by providing multisensory monitoring and intelligent assistance. The platform operates at three levels. The lower level, denominated "Data acquisition and processing" performs the usual tasks of a monitoring system, collecting and processing data from the sensors for the purpose of detecting and tracking humans. The aim is to identify their activities in an intermediate level called "activity detection". The upper level, "Scheduling and decision-making", consists of a scheduler which provides warnings, schedules events in an intelligent manner and serves as an interface to the rest of the platform. The idea is to use mobile and static sensors performing constant monitoring of the user and his/her environment, providing a safe environment and an immediate response to severe problems. A case study on elderly fall detection in a nursery home bedroom demonstrates the usefulness of the proposal.

– Ângelo Costa, and Paulo Novais. 2012. **Mobile Sensor Systems on Outpatients**, International Journal of Artificial Intelligence 8 (12): 252-268, ISSN: 0974-0635.

Abstract: Society walks towards a massive aging phenomenon. It is estimated that in 50 years the elderly population will surpass the young population. This means that two major problems will arise: social and economic. The active population will not produce enough wealth to support the elderly population and the problems that elderly person usually have will be growing exponentially, being the health services provided today unable to respond to such demand. Technology and the ever-growing evolution of it can be a possible response to both problems, providing an initial assistance and remote monitoring. This project enables elderly people to have an active life, by providing freedom in form of monitoring the user health state and providing tools to help them overcome daily tasks. In this paper it is presented a remote body sensoring that paramount with a cognitive impairment helper, present in a mobile system, to provide constant monitoring of the users' health condition, enabling proactive actions and medical reports to the user physician.

– Ângelo Costa, Paulo Novais, Juan M. Corchado, José Neves. 2011. **Increased performance and better patient attendance in an hospital with the use of smart agendas**, Logic Journal of IGPL 20(4): 689-698, ISSN: 1367-0751, DOI:10.1093/jigpal/jzr021.

Impact Factor: 0.931. Q1 in Logic.

Abstract: The world is walking towards an aged society as a consequence of the increasing rate of longevity in modern cultures. With age comes the fact that memory decreases its efficiency and memory loss starts to surge. Within this context, iGenda is a Personal Memory Assistant (PMA) designed to run on a personal computer or mobile device that tries to help final users in keeping track of their daily activities. In addition, iGenda has included a Centralised Management System (CMS) on the side of an hospital-like institution, the CMS stands a level above the PMA and the goal is to manage the medical staff (e.g. physicians and nurses) daily work schedule taking into account the patients and resources, communicating directly with the PMA of the patient. This paper presents the platform concept, the overall architecture of the system and the key features on the different agents and components.

7.2.2 Book Chapters

– Ângelo Costa, Juliana Teixeira, Nuno Santos, Ricardo Vardasca, José Eduardo Fernandes, Ricardo J. Machado, Paulo Novais, and Ricardo Simoes. 2013. **Promoting Independent Living and Recreation in Life through AAL Technology**, In Ambient Assisted Living, (Re Visions: Critical Studies in the History & Theory of Art), Taylor and Francis / CRC Press, ISBN: 978-1439869840.

Abstract: The increase of life expectancy with a decrease in birth rates is contributing to the aging of the European population. This phenomenon, coupled with greater awareness to the quality of life, the need to have cost-efficient elder assistive care, the intention of people to age independently at their homes, and the technology developments in recent decades, have contributed to the emergence of the concept of Ambient Assisted Living (AAL). AAL solutions aim to provide healthy and safe aging to users through promoting independence in performing daily activities and interacting with technology, taking into consideration the deterioration of the users' capabilities and the reduced costs of the solutions. In this paper, AAL developments of monitoring activities of daily living (ADL) and participation in a virtual community with the selected stakeholders are introduced, their roadmap with the expected technological developments described, and the expected impact of these solutions on the end users of the developed solutions are discussed. This enables a real user guidance structure that represents the different needs and limitations of each user, presenting a highly structured project based on personas and possible solutions for them. The AAL4ALL project is considered here as a case study to analyze and illustrate the ALL concepts discussed in this paper.

– Paulo Novais, Davide Carneiro, Ângelo Costa, Ricardo Costa. 2012. **A Framework for Monitoring and Assisting Seniors with Memory Disabilities**. in Ambient Assisted Living (Re Visions: Critical Studies in the History & Theory of Art), Taylor and Francis / CRC Press, ISBN: 978-1439869840.

Abstract: Population aging brings increased social problems. Solutions for this new reality must be devised. The providing of care services at home may benefit patients, health services providers, social security systems and needs to be seen as a possible solution for those social

problems. Maintaining the patient at home, in its own environment, care services costs can be diminished and, at the same time, the comfort and wellbeing of the person in need is, significantly, increased. To pursue this goal, we explore the advantages that Ambient Assisted Living can bring to people in a home environment, narrowing down to the problematic of the health care services at home. Specifically, in this chapter we present a framework focused on the monitoring and assistance of elderly living alone, focusing on elderly with memory disabilities. We believe that this approach will allow tackling the challenges that the current trend of population ageing poses.

— Ângelo Costa, Paulo Novais. 2011. **An Intelligent Multi-Agent Memory Assistant**,

Handbook of Digital Homecare - Successes and Failures, Bos, L.; Goldschmidt, L.;

Verhenneman, G.; Yogesan, K. (Eds.), Communications in Medical and Care Compunetics, 3:

197-221, ISBN: 978-3-642-19646-1, DOI:10.1007/8754_2011_18.

Abstract: World population is ageing and increasingly scarce resources are required to cover the needs of everyone adequately. Medical conditions, especially memory problems, restrict the daily life of a broad slice of the elderly population, affect their independence. To prevent this, providing the right care and assistance while having in mind the costs implicated is essential. One possible path is to work with resources that we already have today and create innovative solutions to achieve the required level of support. There are not many solution either technological or not to prevent memory loss. In this work we present a possible solution aimed at restoring or maintaining the independence of elderly people, through the use of so-called Memory Assistants. We thus present an Intelligent Multi-Agent Memory Assistant designed to help people with memory problems remember their events and activities. The implementation of an event manager, free time manger, medication remainder and a sensory system, to manage and monitor the user, we aim to improve their quality of life and increase their independence.

7.2.3 Conference Proceedings

— Ângelo Costa, José Carlos Castillo Montotya, Paulo Novais, Antonio Fernández-Caballero, and María Teresa López Bonal. 2012. **Sensor-Driven Intelligent Ambient Agenda**, In Ambient Intelligence - Software and Applications, ed. Paulo Novais, Kasper Hallenborg, Dante I. Tapia, and Juan M. Corchado Rodríguez, 153:19-26. Springer Berlin / Heidelberg. DOI:10.1007/978-3-642-28783-1_3.

Abstract: The rapid increasing of elderly persons living alone presents a need for continuous monitoring to detect hazardous situations. Besides, in some cases, the forgetfulness of these people leads to disorientations or accidents. For these reasons, this paper introduces a system that brings together visual monitoring capabilities to track people and to perform activity detection, such as falls, with scheduling abilities to intelligently schedule urgent and non-urgent events.

— Tiago Oliveira, João Neves, Ângelo Costa, Paulo Novais, and José Neves. 2012. **An Interpretable Guideline Model to Handle Incomplete Information**, In Distributed Computing and Artificial Intelligence, ed. Sigeru Omatu, Juan F. De Paz Santana, Sara Rodríguez González, Jose M. Molina, Ana M. Bernardos, and Juan M. Corchado Rodríguez, 151:437-444. Berlin, Heidelberg: Springer Berlin Heidelberg. DOI:10.1007/978-3-642-28765-7_52.

Abstract: Healthcare institutions are both natural and emotional stressful environments; indeed, the healthcare professionals may fall into practices that may lead to medical errors, undesirable variations in clinical doing and defensive medicine. On the other hand, Clinical Guidelines may offer an effective response to these irregularities in clinical practice, if the issues concerning their availability during the clinical process are solved. Hence, in this work it is proposed a model intended to provide a formal representation of Computer-Interpretable Guidelines, in terms of the extensions of the predicates that make their universe of discourse, as well as a Decision Support System framework to handle Incomplete Information. It will be used an extension to the language of Logic Programming, where an assessment of the Quality-of-Information of the extensions of the predicates referred to above is paramount.

— João Ramos, Ricardo Anacleto, Ângelo Costa, Paulo Novais, Lino Figueiredo, and Ana Almeida. 2012. **Orientation System for People with Cognitive Disabilities**, In Ambient Intelligence - Software and Applications, ed. Paulo Novais, Kasper Hallenborg, Dante I. Tapia, and Juan M. Corchado Rodríguez, 153:43-50. Springer Berlin / Heidelberg. DOI:10.1007/978-3-642-28783-1_6.

Abstract: In health care there has been a growing interest and investment in various forms of constant individuals monitoring. The increasing of average life expectation and, consequently, the costs in health care due to elderly population are the motivation for this investment. However, health monitoring is not only important to elderly people, it can be also applied to people with cognitive disabilities. Health monitoring can be developed based on Ambient Intelligence applications which are physically versatile and user friendly, i.e., the system can perform their tasks without causing panic to the user, providing comfort and pleasure to use.

— Vitor Marques, Angelo Costa, Paulo Novais. 2011. **A dynamic user profiling technique in a AmI environment**, In Information and Communication Technologies (WICT), 2011 World Congress on, 1247-1252, ISBN: 978-1-4673-0127-5, DOI: 10.1109/WICT.2011.6141427

Abstract: Currently there are many services that can assist the human being in his decision making. Many of these services provide aid as consistent as possible attending the characteristics and preferences of a user, which compiled results in a person's profile. Without profiles, systems could not provide a coherent aid to a user. In addition we can consider the profiles as the basis of recommendation systems. Paramount with cognitive helping systems, that provide decisions and recommendations these actions can more accurate and user driven. However, the profiles need to be updated over time, as a human being changes of preferences

or beliefs, the profiles also need to adapt to dynamic environments. It is introduced a project that applies the Bayesian Networks and Case Based Reasoning techniques to create and modulate user profiles in a coherent and dynamic way, using stochastic models and high-level event relations and characteristics to devise an accurate suggestion of activities the user can perform, being integrated in an Ambient Assisted Living Project.

— Tiago Oliveira, Ângelo Costa, João Neves, Paulo Novais. 2011. **Digital Clinical Guidelines Modelling**, In Modelling and Simulation 2011, 392-398, (ESM'2011 – The 2011 European Simulation and Modelling Conference), EUROSIS, ISBN: 978-9077381-66-3.

Abstract: Healthcare environments are very demanding, because practitioners are required to consult many patients in a short period of time, increasing the levels of stress which usually harms the outcome of healthcare processes. The short time practitioners have with their patients does not facilitate informed decision making and checking all possibilities. A possible solution is the use of guideline-based applications, because they have the potential of being an effective means of both changing the process of healthcare and improving its outcomes. However, current Clinical Guidelines are available in text format as long documents, which render them difficult to consult and to integrate in clinical Decision Support Systems. With this paper we present a new model for guideline interpretation, in order to facilitate de development of guideline-based Decision Support Systems and to increase the availability of Clinical Guidelines at the moment of the clinical process. This model will also provide mechanisms to comply with cases where incomplete and uncertain information is present.

— Ângelo Costa, Guilherme Barbosa, Tiago Melo, Paulo Novais. 2011. **Using Mobile Systems to Monitor an Ambulatory Patient**, In International Symposium on Distributed Computing and Artificial Intelligence, Advances in Intelligent and Soft Computing, 91: 337-344, DOI:10.1007/978-3-642-19934-9_43.

ISI Indexed.

Abstract: Medical diagnostics and vital signs monitoring demands more technological solutions to cope with new methods of treatment. Continuous monitoring and information processing tools are vital to a physician with several patients under his care. In this work, a system that relies on agents and mobile and wireless devices is presented. Its use with small scale sensors allows to collect and analyse vital data in real-time, triggering appropriate reactions in case of eminent danger. This includes real-time notifications to practitioners. In cases in which the physician is unable to divide his attention among all his patients, the system is able to drive his attention to one patient only and, when it is necessary, to another one, according to their medical state. This concept represents a breakthrough in terms of the physician's time and task management, being possible to apply it two major scenarios: patient recovery in a hospital environment or elderly living alone in a domestic environment. In that sense, we present a brief contextualization of the problem as well as the architecture and technologies used to implement the proposed work.

— Ângelo Costa, Juan Laredo, Paulo Novais, Juan M. Corchado, José Neves. 2010. **iGenda: An Event Scheduler for Common Users and Centralised Systems**, in Soft Computing Models in Industrial and Environmental Applications, 73:55-62, 5th International Workshop (SOCO 2010), Springer - Series Advances in Intelligent and Soft Computing, ISBN 978-3-642-13160-8.

ISI Indexed.

Abstract: The world is walking towards an aged society as a consequence of the increasing rate of longevity in modern cultures. With age comes the fact that memory decreases its efficiency and memory loss starts to surge. Within this context, iGenda is a Personal Memory Assistant (PMA) designed to run on a personal computer or mobile device that tries to help final-users in keeping track of their daily activities. In addition, iGenda has included a Centralised Management System (CMS) on the side of an hospital-like institution, the CMS stands a level above the PMA and the goal is to manage the medical staff (e.g. physicians and nurses) daily work schedule taking into account the patients and resources, communicating directly with the PMA of the patient. This paper presents the platform concept, the overall architecture of the system and the key features on the different agents and components.

— Ângelo Costa, Paulo Novais, Ricardo Costa, Juan M. Corchado, José Neves. 2010. **Multi-Agent Personal Memory Assistant**, in Trends in Practical Applications of Agents and Multiagent Systems, in Advances in Intelligent and Soft Computing, 71: 97-104, Springer-Verlag, ISBN 978-3-642-12432-7.

ISI Indexed.

Abstract: Memory is one of our most precious goods has it gives us the ability to store, retain and recall information thus giving a meaning to our past and help us to envision our future, dreams and expectations. However, ageing decreases the capacity of remembering and the capacity to store new memories, thus affecting our life quality. These presented problems configure a social and human dilemma. With the presented work we intend to address some of these problems, thru the use of the Personal Memory Assistant (PMA) concept in order to help its user to remember things and occurrences in a proactive manner. We will also address socialization and relaxation events that should be part of the user's life. With the use of a Multi-Agent System to implement the PMA, the objectives can be achieved in a ubiquitous and highly configurable manner. It is presented here the platform concept, scheme and the agent characteristics and their contribution to each and every agent.

— Paulo Novais, Ângelo Costa, Ricardo Costa, Luís Lima. 2010. **Collaborative Group Support in e-Health**, in Proceedings of the ICIS 2010 - 9th IEEE/ACIS International Conference on Computer and Information Science, 177-182, Yamagata, Japan, IEEE Computer Society, ISBN: 978-0-7695-4147-1.

Abstract: In critical areas such as decision making, the Collaborative Work has an uttermost importance. Being a complex problem, the collective decision taking is currently a popular form of taking decisions. In this work we present the VirtualECare project: an intelligent multi-agent system able to monitor, interact and serve its customers (in need of care services). In developed countries, recent census data report a sudden increase in the elderly community together with a decrease of child birth. This is a new reality that needs to be dealt by the health sector, particularly by the public one. In an early stage, this new situation appears mostly as a financial problem. The costs involved in the health care are considerable. Thus, alternative technological solutions that lead to straightforward solutions should be adopted. Recently, a growing interest in combining the advances in information society - computing, telecommunications and presentation - to create Group Decision Support Systems (GDSS), has been observed. It is our view that the use of the GDSS in the health care area will pursue the achievement of better results in terms of patients Electronically Clinical Profile (ECP). Additionally, we believe that the best way of managing health appointments is through the use of calendars - one application that can manage both the physicians and patients calendars and consequently their day schedule. Within this area, the approaches used in the VirtualECare and iGenda projects are presented.

— Pedro Gomes, Alberto Marques, Ângelo Costa, Paulo Novais, José Neves. 2010. **Patient Monitoring under Ambient Intelligence Setting**, in Ambient Intelligence, Future Trends - International Symposium on Ambient Intelligence (ISAmI 2010), Augusto JC., Corchado JM, Paulo Novais, Analide C. (Eds.), Springer - Series Advances in Intelligent and Soft Computing, 72: 185-188, ISBN 978-3-642-13267-4.

ISI Indexed.

Abstract: In recent years there has been a growing interest in developing Ambient Intelligence based systems in order to create smart environments for user and environmental monitoring. In fact, higher-level monitoring systems with vital information about the user and the environment around him/her represents an improvement of the quality of care provided. In this paper, we propose an architecture that implements a multi-agent user-profile based system for patient monitoring aimed to improve the assistance and health care provided. This system mixes logical based reasoning mechanisms with context-aware technologies. It is also presented a case based on a scenario developed at a major Portuguese healthcare institution.

— Ângelo Costa, Paulo Novais, Ricardo Costa, José Neves. 2009. **Memory Assistant in Everyday Living**, in proceedings of the ESM 2009 - The 23rd annual European Simulation and Modelling Conference, United Kingdom, pp 269-276, ISBN: 978-90-77381-52-6.

Abstract: Memory is one's mental ability to store, to retain, and recall information, representing past and future, our dreams and/or expectations. However, as the human been ages, the capacity of remembering decreases as well the ability to pile up new memories, therefore affecting our quality-of-living and lowering our self- esteem. This configures a social and human dilemma. With the present work we intend to address some of these problems, in terms of a Personal Memory Assistant (PMA), in order to help the user to remember things and

occurrences, making it in a proactive mode. It will also cater for some form of relaxation on the part of the user.

— Ângelo Costa, Paulo Novais, Ricardo Costa, José Machado, José Neves. 2009. **A Memory Assistant For The Elderly**, in Intelligent Distributed Computing III, George Papadopoulos and Costin Badica (eds), Springer-Verlag, Series: Studies in Computational Intelligence, pp 209-214, ISBN 978-3-642-03213-4.

ISI Indexed.

Abstract: In the present-day the ageing population is not receiving the proper attention and care they need, because there aren't enough healthcare providers to everyone. As the elderly relatives have less time to take care of them the healthcare centers are without any doubt insufficient for all, for these reasons there is an extra pressure or demand on the healthcare sector. Focusing on the elderly care, as the human capacity of memorizing events decreases over time, it is intended to promote an active ageing lifestyle for the elderly, where memory assistance tools are vital component. In this paper, it is presented an scheduler which takes charge of the day-to-day tasks and the user agenda.

— Ricardo Costa, Paulo Novais, Ângelo Costa, José Neves. 2009. **Memory Assist in Ambient Assisted Living**, in Levering Knowledge for Innovation in Collaborative Networks, Luís Camarinha-Matos, Iraklis Paraskakis and Hamideh Afsarmanesh (eds), Springer-Verlag, Series: IFIP International Federation for Information Processing, pp 745-752, ISBN 978-3-642-04567-7.

Best paper award. ISI Indexed.

Abstract: Human collective set of experiences makes us who we are and help us delineate a path for our ongoing life. Ageing, however, progressively limits our ability to save, in our internal memory, these same experiences, or, at least, limits our capability to remember them. The capability to remember, intrinsic to our memory, is a very important one to us, as a human been, being this what deferents us from several other species. In this paper we present a memory assistant sub module of a bigger project, the VirtualECare, which ability will be to remember us, not our past experiences, but our routine day-to-day tasks and activities, in a somehow proactive manner, thus, allowing us to have some relaxation about them, and focus the remaining of our ability in most important facts.

7.3 Future Work

Throughout this work, some issues have arisen. In fact, they complement the iGenda core development in some way. For that reason, as future work to be developed we consider:

— The development of a fall detection system based on sensors available in a common mobile device. This work will complement the work already done in the sense of providing a low-cost system for monitoring falls inside and outside the home;

— The development of a communication system capable of supporting the HL7 standard and the IEEE 11073. The implementation of communication skills with medical devices enables the project to be implemented in nursing homes and day centers;

— The development of modules under standard OGSi. These modules will be able to communicate with the middleware developed for home care medical devices;

— The development of a web platform for remote communication with iGenda. It serves to users and health care providers for remaining aware of events;

— The development of hybrid user profiles. These systems will have the ability to adapt in real time and can create relationships between events, times and locations as well as display them immediately;

— The development of interfaces for data summaries. This data is the result of the knowledge extraction from all the gathered sensory information. In that way, the user is provided with a general report of his/her health status, allowing to discovering some latent health problems.

Final Remarks

With this research work we have tried to do our part in an area where few efforts have been made so far. Interesting conclusions have been achieved and different future research lines have been defined to go a step further and get closer to a truly Cognitive Assistants environment.

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9 Annexes

The document structure as well as its leading thread led to a simpler explanation about the work performed. Nevertheless, these annexes will present the architectures of each component of the iGenda core in more detail. They serve as an implementation guide and as a manual for future iterations that may be added to the iGenda platform.

In the following subsections, each core component appearing throughout this document will be presented in the form of class diagrams in UML format.

9.1.1 Agenda Manager

The class Server_Jade leads to boot the whole server platform. As expected, each user has a unique interaction as a thread. This class provides the necessary means to establish a new agent platform in Jade, and to initialize the remaining agents.

The class checkCred verifies the user credentials and those users who send a message to the system. Serving as a security barrier and mediator, it initially balances the importance of an event received by processing the data in a JSON file.
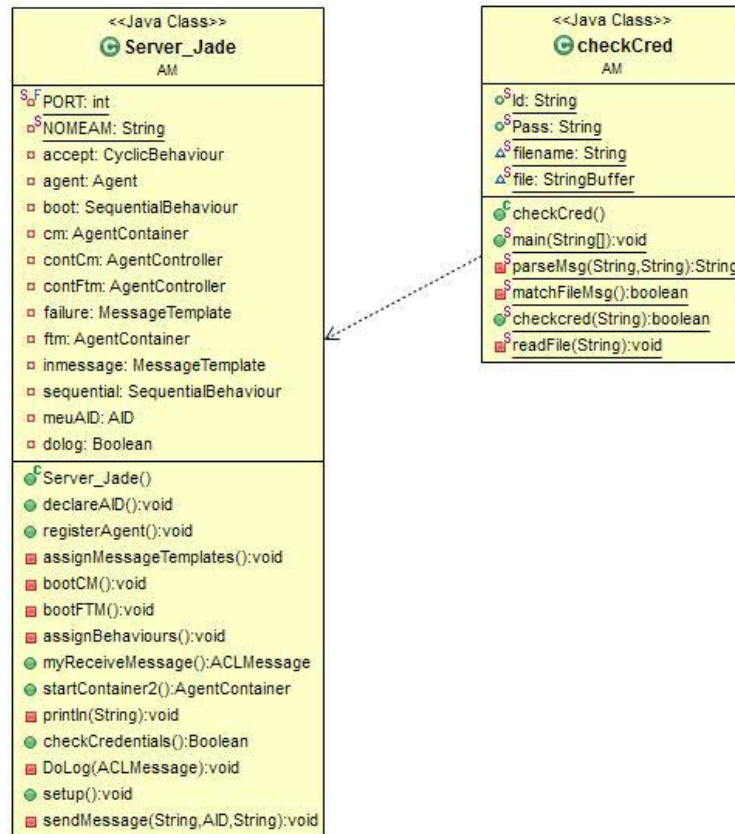

Figure 68: AM classes and their associations

9.1.2 Conflicts Manager

Figure 69 and Figure 70 represent the whole Conflicts Manager module. The CM aims to provide the agent structure and it serves as an event data filter. The prolog_cm, as its name suggests, connects to the Prolog application, establishing a bridge between the logic decision engine and the Java application.
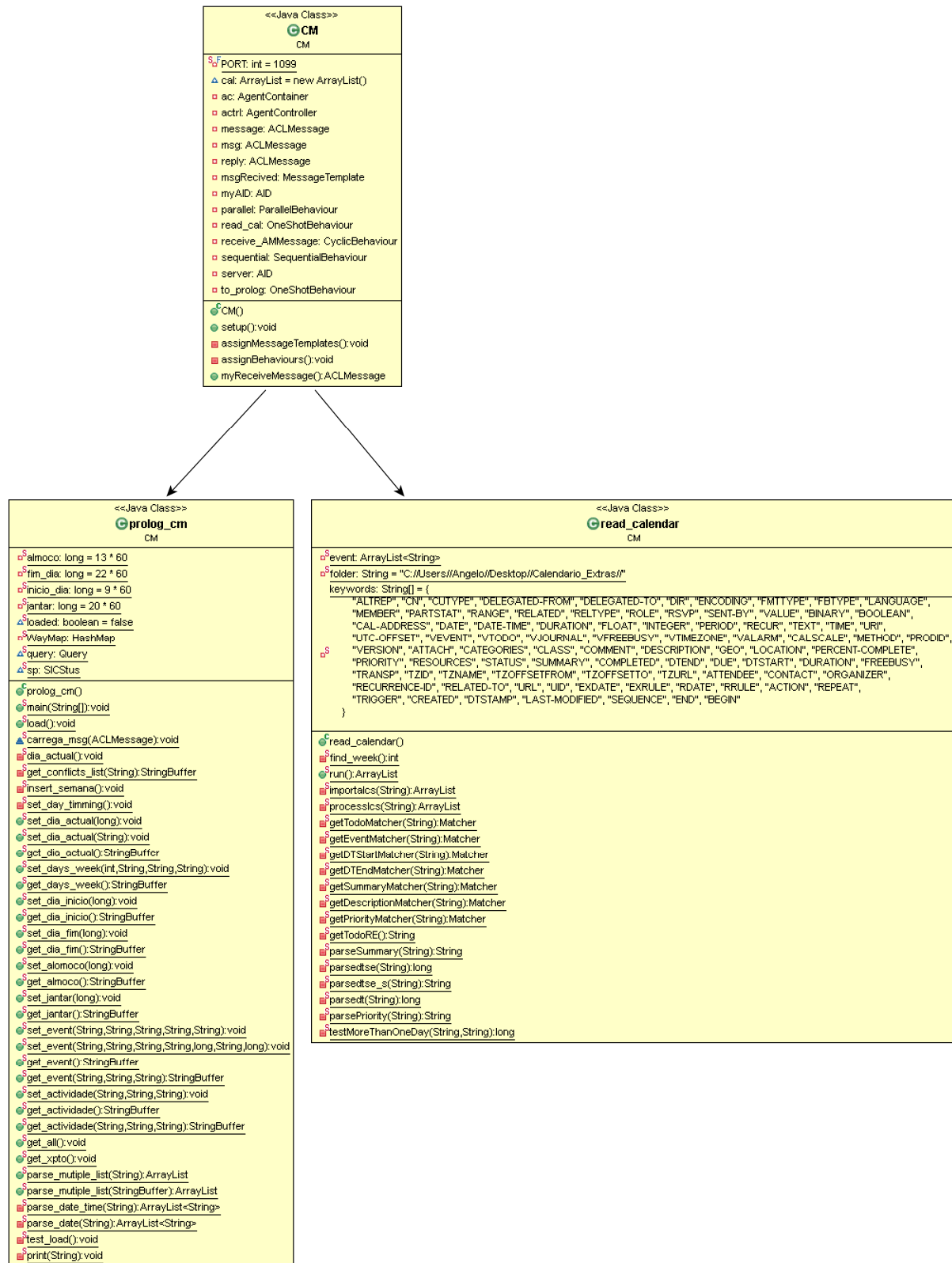
CM

<<Java Class>>
CM
CM

- PORT: int = 1099
- cal: ArrayList = new ArrayList()
- ac: AgentContainer
- actrl: AgentController
- message: ACLMessage
- msg: ACLMessage
- reply: ACLMessage
- msgRecived: MessageTemplate
- myAID: AID
- parallel: ParallelBehaviour
- read_cal: OneShotBehaviour
- receive_AMMessage: CyclicBehaviour
- sequential: SequentialBehaviour
- server: AID
- to_prolog: OneShotBehaviour

- CM()
- setup():void
- assignMessageTemplates():void
- assignBehaviours():void
- myReceiveMessage():ACLMessage

<<Java Class>>
prolog_cm
CM

- almoco: long = 13 * 60
- fim_dia: long = 22 * 60
- inicio_dia: long = 9 * 60
- jantar: long = 20 * 60
- loaded: boolean = false
- WayMap: HashMap
- query: Query
- sp: SICStus

- prolog_cm()
- main(String[]):void
- load():void
- carrega_msg(ACLMessage):void
- dia_actual():void
- get_conflicts_list(String):StringBuffer
- insert_semana():void
- set_day_timming():void
- set_dia_actual(long):void
- set_dia_actual(String):void
- get_dia_actual():StringBuffer
- set_days_week(int,String,String,String):void
- get_days_week():StringBuffer
- set_dia_inicio(long):void
- get_dia_inicio():StringBuffer
- set_dia_fim(long):void
- get_dia_fim():StringBuffer
- set_alomoco(long):void
- get_almoco():StringBuffer
- set_jantar(long):void
- get_jantar():StringBuffer
- set_event(String,String,String,String,String):void
- set_event(String,String,String,String,long,String,long):void
- get_event():StringBuffer
- get_event(String,String,String):StringBuffer
- set_actividade(String,String,String):void
- get_actividade():StringBuffer
- get_actividade(String,String,String):StringBuffer
- get_all():void
- get_xpto():void
- parse_mutiple_list(String):ArrayList
- parse_mutiple_list(StringBuffer):ArrayList
- parse_date_time(String):ArrayList<String>
- parse_date(String):ArrayList<String>
- test_load():void
- print(String):void

<<Java Class>>
read_calendar
CM

- event: ArrayList<String>
- folder: String = "C://Users//Angelo//Desktop//Calendario_Extras//"
- keywords: String[] = {
  "ALTREP", "CN", "CUTYPE", "DELEGATED-FROM", "DELEGATED-TO", "DIR", "ENCODING", "FMTTYPE", "FBTYPE", "LANGUAGE",
  "MEMBER", "PARTSTAT", "RANGE", "RELATED", "RELTYPE", "ROLE", "RSVP", "SENT-BY", "VALUE", "BINARY", "BOOLEAN",
  "CAL-ADDRESS", "DATE", "DATE-TIME", "DURATION", "FLOAT", "INTEGER", "PERIOD", "RECUR", "TEXT", "TIME", "URI",
  "UTC-OFFSET", "VEVENT", "VTODO", "VJOURNAL", "VFREEBUSY", "VTIMEZONE", "VALARM", "CALSCALE", "METHOD", "PRODID",
  "VERSION", "ATTACH", "CATEGORIES", "CLASS", "COMMENT", "DESCRIPTION", "GEO", "LOCATION", "PERCENT-COMPLETE",
  "PRIORITY", "RESOURCES", "STATUS", "SUMMARY", "COMPLETED", "DTEND", "DUE", "DTSTART", "DURATION", "FREEBUSY",
  "TRANSP", "TZID", "TZNAME", "TZOFFSETFROM", "TZOFFSETTO", "TZURL", "ATTENDEE", "CONTACT", "ORGANIZER",
  "RECURRENCE-ID", "RELATED-TO", "URL", "UID", "EXDATE", "EXRULE", "RDATE", "RRULE", "ACTION", "REPEAT",
  "TRIGGER", "CREATED", "DTSTAMP", "LAST-MODIFIED", "SEQUENCE", "END", "BEGIN"
  }

- read_calendar()
- find_week():int
- run():ArrayList
- importalcs(String):ArrayList
- processIcs(String):ArrayList
- getTodoMatcher(String):Matcher
- getEventMatcher(String):Matcher
- getDTStartMatcher(String):Matcher
- getDTEndMatcher(String):Matcher
- getSummaryMatcher(String):Matcher
- getDescriptionMatcher(String):Matcher
- getPriorityMatcher(String):Matcher
- getTodoRE():String
- parseSummary(String):String
- parsedtse(String):long
- parsedtse_s(String):String
- parsedt(String):long
- parsePriority(String):String
- testMoreThanOneDay(String,String):long

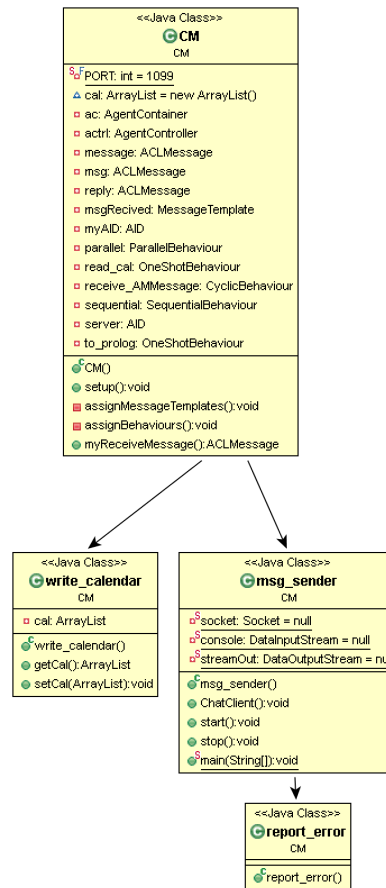Figure 69: CM classes and their associations (partial)

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Figure 70: CM classes and their associations (partial)

The class read_calendar processes the ICS files. Currently, due to the small specificities of calendars viewers, it is necessary to filter and adapt some proprietary data fields to normalize the input data.

On the other hand, the class write_calendar produces an ICS file under the standard RFC 5545, which is supported by the majority of calendars viewers.

Finally, the class msg_sender supports the functionality to send messages to all agents, even the sending user. This class is supported by the class report_error, which interprets the errors coming from the logic engine and checks for logical decisions that should send the error and message content.
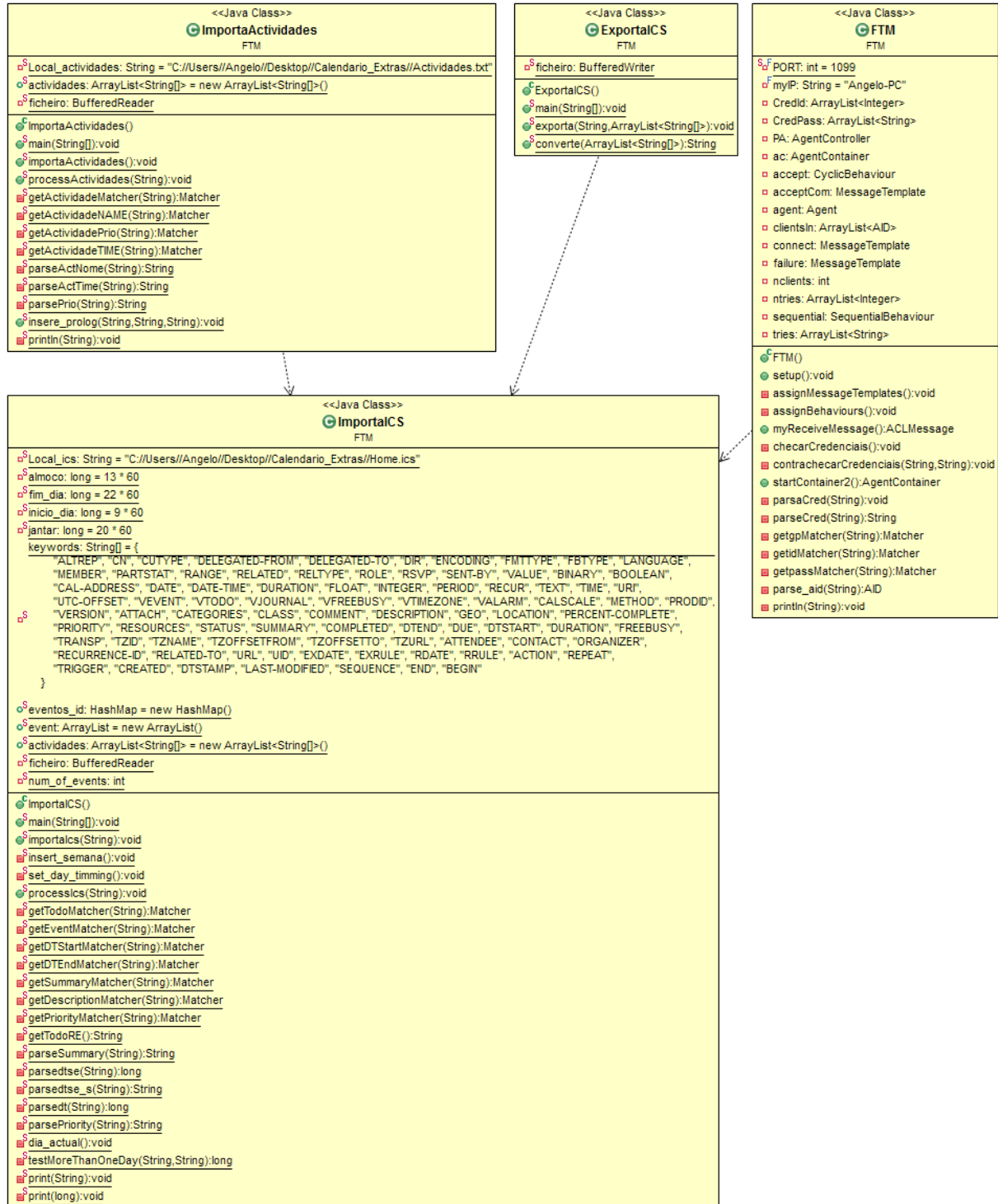
9.1.3 Free Time Manager

Figure 71: FTM classes and their associations (partial)

Figure 71 and Figure 72 represent the totality of Free Time Manager module. This agent is initialized by the class AM. In terms of operation, it is similar to CM. The class ImportaActividades is in charge of

importing data from a collection of information about user preferred events. Classes ImportaICS and ExportaICS are all similar to those in CM.
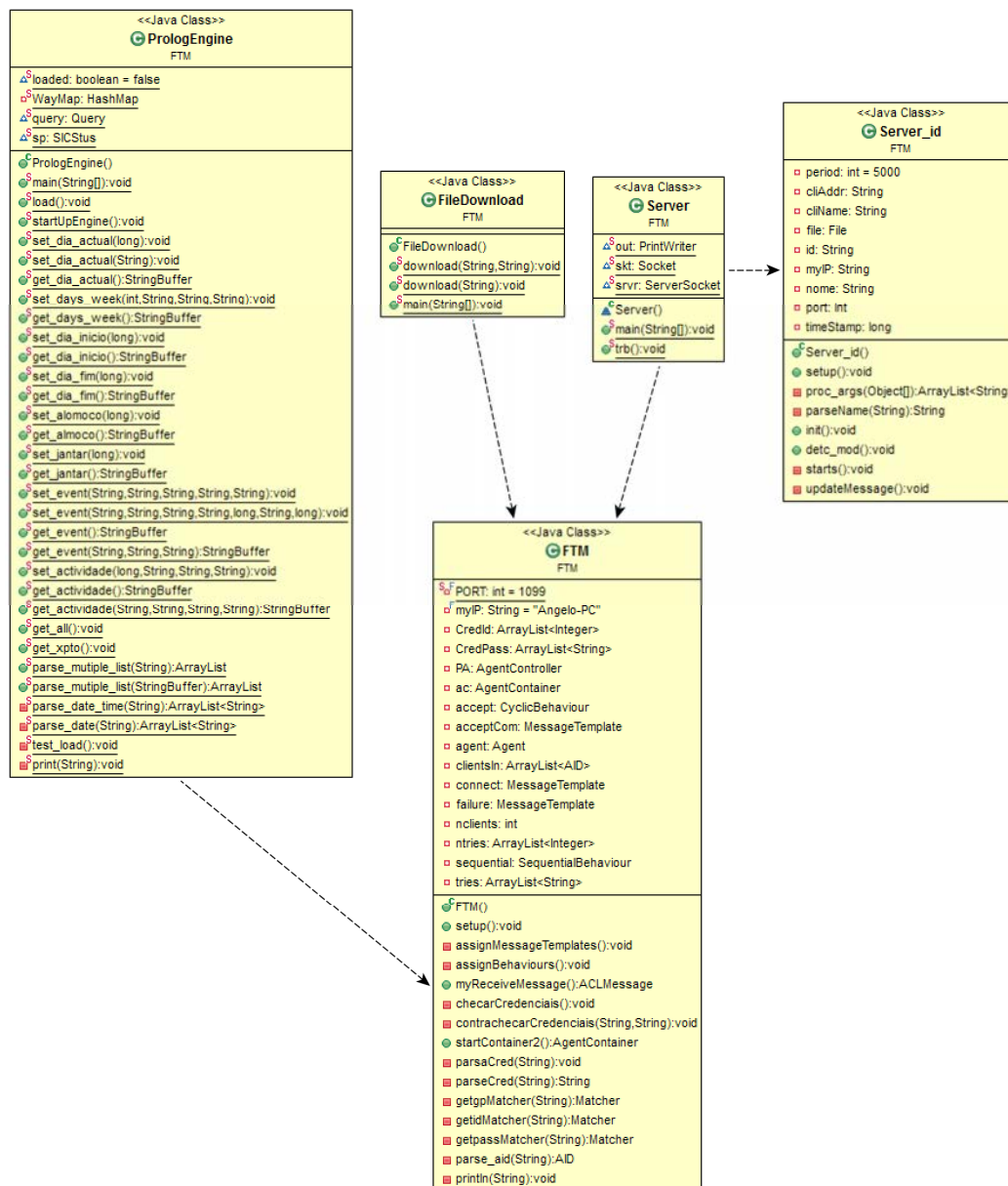

Figure 72: FTM classes and their associations (partial)

The PrologEngine is also similar to the prolog_cm operation. The class FileDownload manages preference files or remote calendars. Classes Server and server_id are modular classes that establish connections between users to share multi-layer calendars.