Universidade do Minho
Escola de Engenharia

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Collaborative Networks in Ambient Assisted Living

Julho de 2009

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A thesis submitted at University of Minho for the degree of Informatics Doctor (PhD)

Under the supervision of
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ABSTRACT

Collaborative Work plays an important role in today's organizations, especially in areas where decisions must be made. However, any decision that involves a collective or group of decision makers is, by itself, complex, but is becoming recurrent in recent years. 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 last year's there has been a substantially increase on the number of people needed of intensive care, especially among the elderly, a phenomenon that is related to population ageing. However, this is becoming not exclusive of the elderly, as diseases like obesity, diabetes and blood pressure have been increasing among young adults. This is a new reality that needs to be dealt by the health sector, particularly by the public one. Given this scenario, the importance of finding new and cost effective ways for health care delivery are of particular importance, especially when it is believed that they should not be removed from their natural "habitat". Following this line of thinking, the *VirtualECare* project will be presented, like similar ones that preceded it. On the other hand, this is a growing interest in combining the advances in information society - computing, telecommunications and presentation – in order to create Group Decision Support Systems (GDSSs). Indeed, the new economy, along with increased competition in today's complex business environments, takes the companies to seek complementarities in order to increase competitiveness and reduce risks. Under these settings, planning takes a major role in a company life. However, effective planning depends on the generation and analysis of ideas (innovative or not) and, as a result, the idea generation and management processes are crucial. In particular if is believed that the use of GDSS in the healthcare arena will allow professionals to achieve better results in the analysis of one's Electronically Clinical Profile (ECP). This achievement is vital, regarding the explosion of knowledge and skills, together with the need to use limited resources and get the expected outcomes.

RESUMO

Hoje em dia, o Trabalho Colaborativo desempenha um papel deveras importante na maioria das organizações, especialmente em áreas em que decisões têm de ser tomadas. No entanto, e muito embora comece a ser recorrente, qualquer decisão que envolva um grupo colectivo de decisores é, por si só, complexa. Nesta tese apresenta-se o projecto *VirtualECare*, um sistema inteligente multi-agente capaz de monitorar, interagir e servir os seus utilizadores, com necessidades de cuidados de saúde. Nos últimos anos têm-se verificado um aumento substancial no número de pessoas necessitadas de cuidados intensivos, especialmente entre a população mais envelhecida, um fenómeno directamente relacionado com o envelhecimento gradual da população. No entanto, esta é uma problemática que começa a deixar de estar exclusivamente associada aos idosos, uma vez que, doenças como a obesidade, diabetes e a pressão arterial têm vindo a aumentar junto dos, assim chamados, jovens adultos. Esta é uma nova realidade com a qual o sector da saúde necessita de lidar, especialmente o sector público. Apresentados estes cenários, a importância de encontrar novas formas, mais eficazes ao nível dos custos, de providenciar cuidados de saúde, a quem deles necessita, torna-se ainda mais premente, especialmente quando acreditamos que estes não devem ser deslocalizados do seu “habitat” natural. Seguindo esta linha de raciocínio, vamos apresentar o projecto VirtualECare, bem como similares que o precederam. Recentemente tem-se vindo a assistir a um interesse crescente em combinar os avanços na, assim chamada, sociedade da informação – computação, telecomunicações e apresentação – de forma a se criarem Sistemas de Apoio à Decisão em Grupo (GDSS). Na realidade, a nova economia, associada ao elevado crescimento da competitividade do, já de si, complexo mundo empresarial, provoca a procura, por parte das empresas e/ou instituições, de outras que as possam complementar para assim se poderem tornar mais competitivas e reduzir os riscos assumidos. Neste cenário, o planeamento assume um papel da maior importância na vida de uma empresa. No entanto, um planeamento eficaz depende da geração e posterior análise de ideias (inovativas ou não) e, como resultado, o processo de geração e análise de ideias também se torna crucial. O nosso

objectivo é aplicar os já apresentados GDSS a uma nova área. É de esperar que o uso de GDSS na área da prestação de cuidados de saúde irá permitir que os seus profissionais obtenham melhores e mais imediatos resultados na análise de um qualquer Processo Clínico Electrónico (ECP), sendo este um factor crucial, tendo em conta a explosão de conhecimento e técnicas conjugadas com a necessidade de melhor se utilizar os recursos existentes.

*Para a **Marisa** - pelo seu enorme apoio e compreensão …*

*Para o **André** - pelo tempo passado sem mim …*

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GLOSSARY

1.	**AAL**	Ambient Assisted Living
2.	**AC**	Agent Container
3.	**ACL**	Agent Communication Language
4.	**AI**	Artificial Intelligence
5.	**AM**	Agenda Manager
6.	**AmI**	Ambient Intelligence
7.	**API**	Application Program Interface
8.	**CAC**	Context Aware Computing
9.	**CHI**	Consumer Health Informatics
10.	**CM**	Conflict Manager
11.	**CN**	Collaborative Networks
12.	**CNO**	Closed-World Assumption
13.	**CWA**	Collaborative Network Organizations
14.	**DB**	Database System
15.	**DSS**	Decision Support System
16.	**EC**	European Community
17.	**ECP**	Electronic Clinical Profile
18.	**EHR**	Electronic Health Record
19.	**ELP**	Extended Logic Programming
20.	**EMR**	Electronic Medical Record
21.	**FIPA**	Foundation for Intelligent Physical Agents
22.	**FIPA ACL**	FIPA Agent Communication Language
23.	**FTM**	Free Time Manager
24.	**GDSS**	Group Decision Support System
25.	**GPS**	Global Positioning System

26.	**GSM**	Global System for Mobile Communications
27.	**GSS**	Group Support System
28.	**GUI**	Graphical User Interface
29.	**HL7**	Health Level 7 Protocol
30.	**HVAC**	Heating Ventilation and Air Conditioning
31.	**IBIS**	Issue Based Information System
32.	**ICT**	Information and Communication Technologies
33.	**ICS**	Internet Calendar Data
34.	**ISTAG**	Informational Society Technology Advisory Group
35.	**JGa**	Jade Gateway Agent
36.	**LAN**	Local Area Network
37.	**MAN**	Metropolitan Area Network
38.	**MAS**	Multi-Agent System
39.	**MIT**	Massachusetts Institute of Technology
40.	**MS**	Monitoring System
41.	**OSGi**	Open Services Gateway initiative
42.	**PDA**	Personal Digital Assistant
43.	**QI**	Quality of Information
44.	**RFID**	Radio Frequency Identification
45.	**RS**	Recommendation System
46.	**ST**	Scheduling Techniques
47.	**SUP**	Supported User Premise
48.	**UMTS**	Universal Mobile Telecommunications System
49.	**UN**	United Nations
50.	**UPnP**	Universal Plug and Play
51.	**VC**	Virtual Communities
52.	**VO**	Virtual Organizations

53.	**WAN**	Wide Area Network
54.	**WS**	Web Services

Chapter 1

Introduction

As the human population is unprecedented ageing and expected to continue its rapid evolution thru the twenty-first century, it is a matter of fact that elderly in need of special attention is also, and will keep, growing. Old age brings new problems (e.g., health, loneliness) [1, 2], aggravated with the lack of specialized human resources to assist their needs. However, this is not exclusive of the elderly, as diseases like obesity, diabetes, and blood pressure have been increasing among young adults [3]. As a new reality, it has to be dealt by the health sector and its care systems, especially by the public ones. The same health sector care systems that are already unable to respond to today’s needs [4]. In this, negative, scenario the importance of finding new and cost effective ways for health care delivery are of particular importance, and the design of new health care provision systems, technologically based, is crucial.

1.1. Motivation

The human population is ageing is an irrefutable true, sustained by the current change in demographics, and today's society does not seem to know how to deal with this problem. This global phenomenon, simple labelled as population ageing, is occurring in both developed and on developing countries, thought in different stages of the process. Countries that started the, ageing, process later will have more time to adapt, but countries (more developed one) where the, ageing, process is already in its climax should, already, be adapted [5]. Worldwide, improvements in sanitation, housing, nutrition, and medical innovations, including new vaccines and the discovery of antibiotics, are contributing to the fast increase in the number of people reaching older ages, raising the average life expectancy (Figure 1). On the other hand, fertility rates have been fallen (Figure 2), mainly due to the development of effective contraceptive methods and improvements in women’s education, as well as more

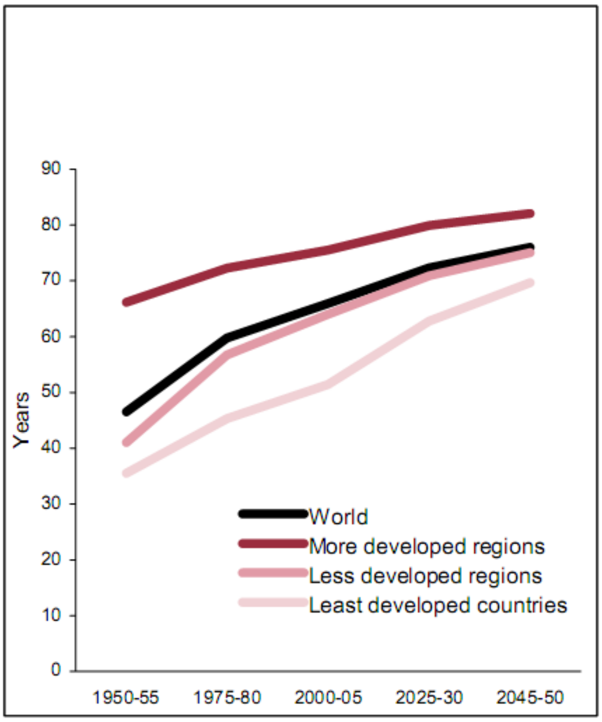

Figure 1 - Life expectancy at birth: word and development regions, 1950-2050 [6].

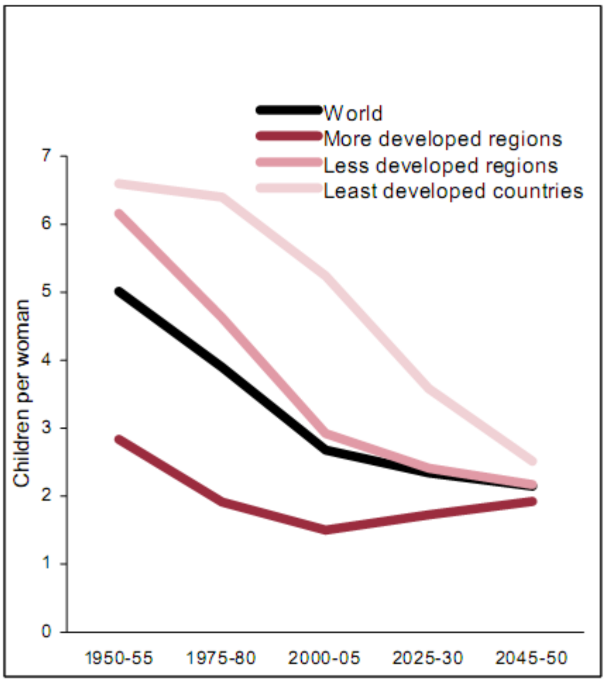

Figure 2 - Total fertility rate: world and development regions, 1950-2050 [6].

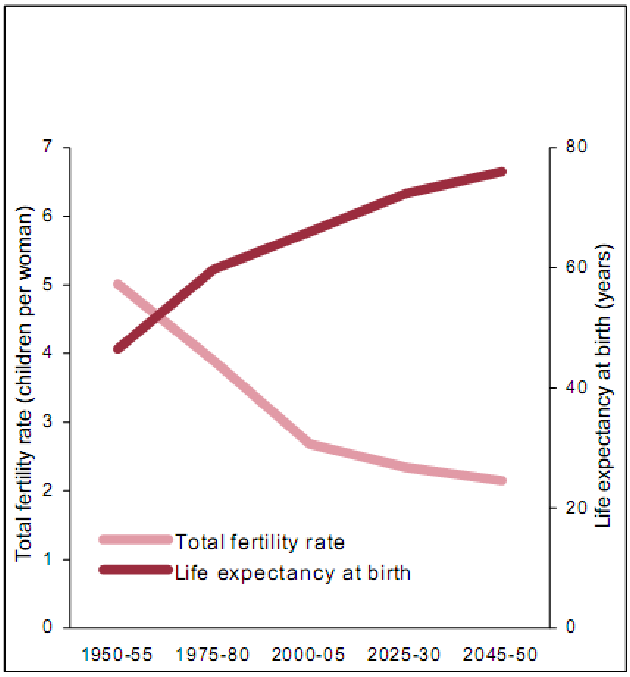

Figure 3 - Total fertility rate and life expectancy at birth: world, 1950-2050 [6].

women incorporate into the formal labour market [6, 7]. These factors, thought positive ones and considerer as a success story for humanity, are causing a fast growing in the proportion of the population above 60 years old (Figure 3, Figure 4 and Figure 5), starting to raise concerns about whether or not a decreasing labor force will be able to support that part of the population who are dependent on others (i.e. children and elder). Although, the dependency ratio, a commonly used measure of potential social support needs based on the simple assumption that everyone under 15 and over 65 years olds are likely to be, in some sense, dependent on the population between 15 and 64 years old, is projected to remain at almost the same level in 2050, comparatively with 2000 (Figure 6), the old age dependency ratio will increase substantial (Figure 7). This fact, more than economical costs, will bring high social costs. Old age people frequently has special needs and require a close and personalized daily monitoring (caregivers), mainly due to health related issues. Traditionally, elderly main caregiver, were their families and woman. However, families size diminution and, the already mentioned, woman employment outside the home, adds some more complexity to the, already not very simple, equation. One left possibility is moving the elderly to elderly centres.

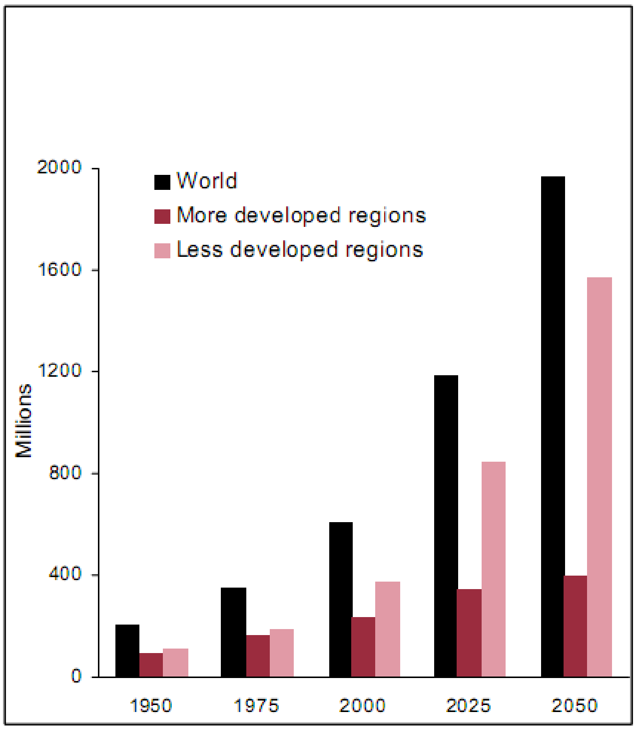

Figure 4 - Population aged 60 or over: world and development regions, 1950-2050 [6].

However, this possibility carries high economical costs, which not every family are able to support. Moreover, normally, it is does not represent a good option for the elder in question since they usually show high reluctance when moved outside their normal habitat, where they have their life, their friends and their routine. We believe it is mandatory that older people can age maintaining their quality of life, while able to deal with all the diseases and limitations that will arise from that fact. A concept has risen in last year's which address this subject: Active Ageing. According to the World Health Organization, active ageing is the process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age [8]. It is desirable that older people participate on the society as they always had, the way they can, while ageing. This does not mean that older people should continue to work, but that they may still play an important role on their community, being in social, cultural, civic or spiritual affairs. Older people need, therefore, to feel independent and integrated on their communities, living as they always had, nevertheless having access to the security and health facilities they need.

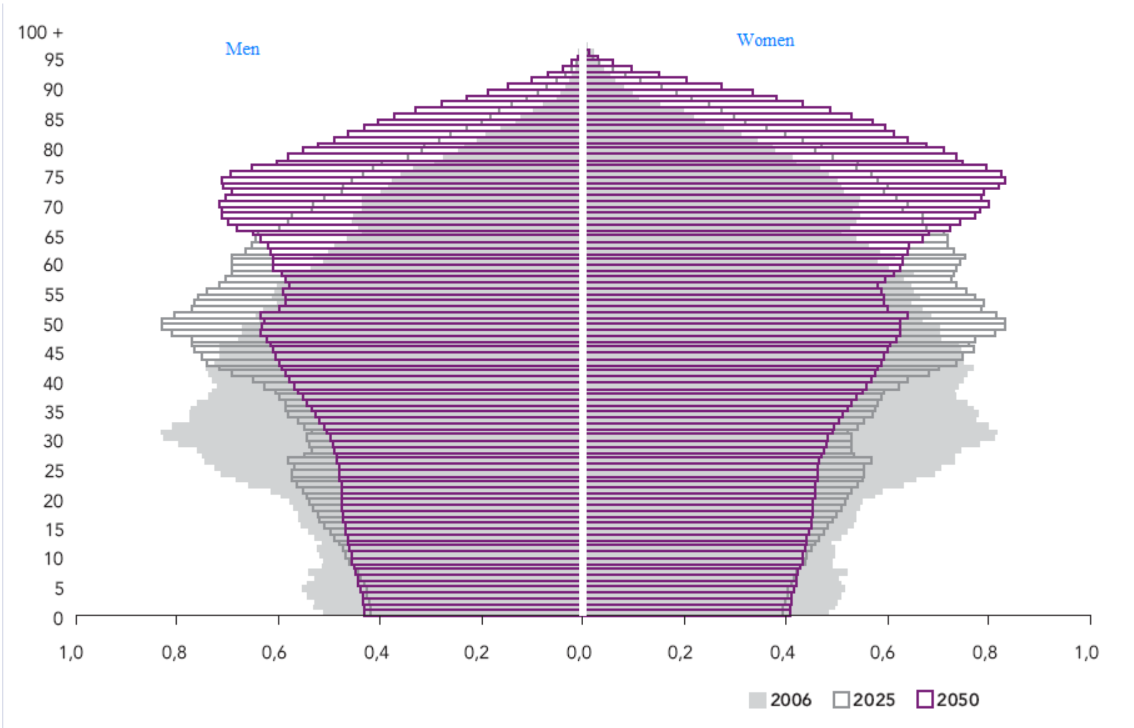

Figure 5 - Population pyramid for Portugal: 2006 and projections for 2025 and 2050 [9].

All the above presented problematic represent a real challenge for the social and security policies in years to come. These policies have always been surrounding of intense public debate since their initial implementation, but now, the debate seems to be growing in intensity as decisions makes around the world demonstrates to be particularly worried about the apparent fatalism of governments effectiveness to tackle this new reality. Indeed, normally, the only solution presented, was to tax, even more, the working population in order to support the costs associated with the population ageing [7]. Recently, some societies started to highlight the importance and necessity of finding new, cost effective ways, of delivering care and support to the ones in need (elderly or not), who generally wish to continue living independently in their natural habitat (Home), thus ensuring social and economic sustainability in an ageing world. Follow this idea, in the last years we have assisted to the evolution of a new promising approach to the health care system: the supply of health care services to the ones in need in a remote way.

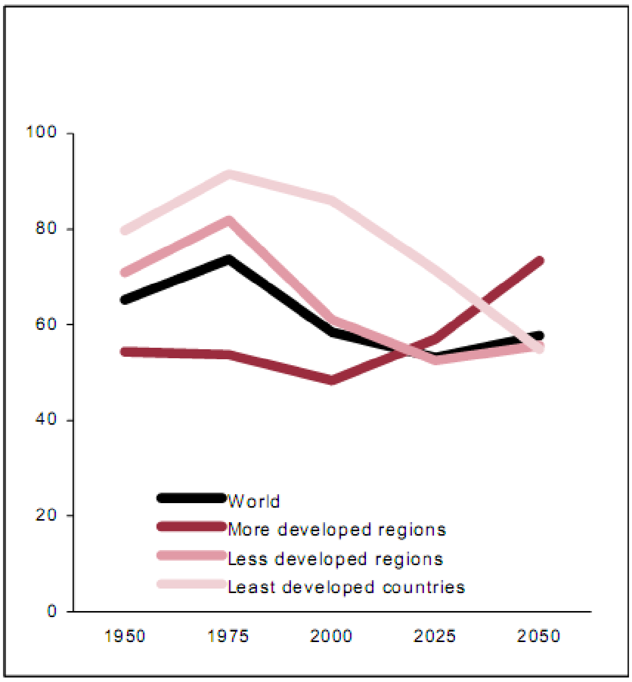

Figure 6 - Total dependency ratio: world and development regions, 1950-2050 [6].

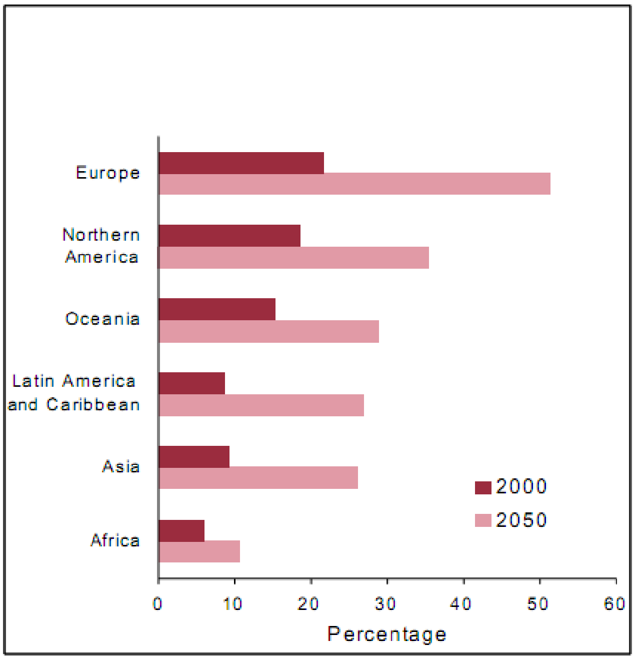

Figure 7 - Old-age dependency ratio: major areas, 2000 and 2050 [6].

1.2. Scope of the Thesis

The health care systems problematic, derivate from population ageing, presented in the previous section raises challenges countries must face, especially developed ones. The need to find new solutions able to ensure that the, growing, number of older people will have the necessary, quality, care is a reality. We believe that the use of new, already available and low cost, technologies to support the provision of care is one of those possible solutions. However, the use of technology in such possibility raises one fundamental question:

- How can technology help in the provision of health care to the ones in need?

In order to give some possible answer to this question, the work presented in this thesis proposes the use of a integrated healthcare provision system as a collaborative networked organization, where the different institutions that support care provision (e.g., hospitals, day/care centres, social security institutions, nursing homes, etc.) may operate as a long-term virtual organization, and the various actors involved (e.g., the elderly and their caregivers, such as relatives, friends, neighbours, nurses, physicians, practitioners, etc.) could become part of a virtual care community platform able, not only to monitor its users (people in need of care provision) and its natural habitat (home environment), based on the concept of Ambient Intelligence (AmI), more specifically Ambient Assisted Living (AAL) and reactively act in concordance but also to be proactive thru the constant interconnection with decision centres, equipped with qualified staff and equipment.

Although technology may not be the solutions to all the existent ageing associated health problems, it may play a fundamental role in the creation of new concepts and approximations, which will allow elderly quality of life improvement.

1.3. Objectives

The main objective pursued in this work is concerned with the design of a support architecture which would allow the development of intelligent systems, properly integrated in normal, day-to-day, environments, based on the Ambient Intelligence paradigm. However, this architecture should be different of the preceding ones, providing the expected functionalities (e.g. being reactive, proactive, autonomous) for this kind of systems, being dynamic, distributed and easy to interact with. It must also be empowered with the findings already know and successful applied in other areas of knowledge, namely technologies and methodologies for problem solving.

In pursue of such an objective, the VirtualECare project has arise, presenting a multi-agent architecture with a service oriented philosophy built on top of multiple technologies, some of them without any kind of integration history (e.g. JADE and OSGi), which allowed the natural flow of information among the several components of the system, making it able, not only to react, but also to anticipate eventual activities and/or problematic situations.

To achieve all of the presented goals it is show and endorsed the hypothesis of the possibility to model a Collaborative Network of multiple Virtual Organizations, combined in order to form an Ambient Assisted Living environment.

To achieve this purpose several studies and analysis have been conducted, starting from the state of the art in different areas of interest, namely on e-Health, Collaborative Networks, Group Decision, Ambient Intelligent and Ambient Assisted Living, and them moving to service oriented architecture models, passing by compatible or possible of interconnecting technologies that could be of use.

In other words, we are proposing to create a system that can provide some basic care and well being for persons in their natural environment, with the aim of fighting the social problems depicted above, allow a better quality of life, privacy and well being with less economical costs and immediate intervention in case of necessity, thus contributing for their active ageing. In order for this work to be accomplished, the following more specific findings were set:

- Design and develop Ambient Assisted Living multi-agent architecture and corresponding framework, which will allow for the construction and deployment of an Ambient Intelligent environment;
- Design and present a Collaborative Network for acting as a support for the Ambient Assisted Living environment being propose;
- Allow the control and quality measure of all the information that flows in the Collaborative Network; and
- Define the Group Decision Support System which will be responsible for all the decisions make in the Ambient Assisted Living environment.

1.4. Investigation Methodology

To accomplish the objectives previously enumerated we intend to follow the Action-Research methodology. This methodology starts by identifying the problem so that a hypothesis can be formulated on which the development will be based. Subsequently, the information is recompiled, organized and analyzed, continuously building a proposal for solving the identified problem. Finally, one can make its conclusions based on the results obtained during the investigation. For this research model to be followed, 6 (six) complementary stages have been defined, which will allow us to achieve the planned objectives. These points are described below, in the form:

- Specification of the problem and its characteristics;
- Constant and incremental update and review of the state of the art;

- Idealization and gradual and interactive development of the proposal model;
- Experimentation and implementation of the solution throughout the development of a prototype;
- Result analysis and formulation of conclusions; and
- Constant diffusion of knowledge, results obtained and experiences with the scientific community.

1.5. Organization of the Thesis

This document is organized as follows: Chapter 2 contains a detailed description of e-Health, starting by making an historic contextualization and ending with the several types of e-Health systems.

In Chapter 3 the concepts of Collaborative Networks and Group Decision are introduced, to better understand the subsequently developments.

Chapter 4 contains a detailed description of Ambient Intelligence, starting by emphasizing its main characteristics. It continues by detailing some important components of an Intelligent Environment like sensors or actuators, and the advantages of having such environments working for us, Humans. It them introduces the concept of Ambient Assisted Living in terms of the main paradigms behind it and its relation with e-Health. To conclude a related work of both areas is presented.

In Chapter 5 the VirtualECare project is presented, as well as its main architecture, framework and modules in conjunction with a detailed description of each of one of them.

In Chapter 6 we present our Case Studies and respective results, as The Simulation Platform, The Monitoring Platform and the iGenda sub module.

The document ends with Chapter 7, where a synthesis of the work done is presented, as well as some important contributions. It finishes with the conclusions obtained and our expected evolution in the future work.

Chapter 2

e-Health

2.1. Introduction

E-health (or eHealth) is the commonly accepted used abbreviation for electronic health in which the use of ICT as a support for the provision of health care services is presupposed. However, until recent years, this was practically the same as Electronic Health Records (EHR), as this was the only real life application of that term, in all its amplitude. Today's, there is a wide range of services that use IT in the practice of medical acts: Electronic Health Records (EHR) or Electronic Medical Records (EMR) [10-12], Consumer Health Informatics (CHI) [13-15], Telemedicine [16-18], m-Health [19-21], Telecare and Remote Care [22-25], and, most recently, Group Decision Support Systems (GDSS) [26-28], just to name a few.

The chapter is organized as follows: Section 2.2 brings up a brief assessment of technologies and systems dealing with the provision of care to the elderly, emphasizing the telecare systems and some implications about them; Section 2.3 presents a briefly the telemedicine paradigm and how it differs from the telecare one and Section 2.3 presents a set of requirements that shall be needed for elderly care, and also a first approach to a scenario containing the main actors to carry out the necessary activities.

2.2. Home Telecare Technologies and Systems

The search of new cost effective ways in the provision of care services, mainly for the elderly, but which may be applied to anyone in need, while maintaining, as far as possible, their autonomy, privacy and quality of life [29], has accelerated the evolution of care provision thru the use of ICT which fall broadly into three generations [23, 30-33].

First-generation Systems

First-generation systems where designed to reduce anxiety among elderly and high-risk patients and reduce their use of primary healthcare services and facilities. Typical technologies include personal alarm systems and emergency response telephones that make a voice connection between the patient and the response centre whenever a pendant alarm button is pressed (panic buttons - Figure 8).

Figure 8 - Panic button example.

Second-generation Systems

Second-generation systems can generate alarms without the intervention of the patient, on the suspicion that something may be wrong. These systems can, and should, continuously monitor a large number of variables sensitive to changes in functional health status (Figure 9), and generate an alarm in accordance with the changes observed. These second-generation systems should be unobtrusive and should not require direct patient intervention or participation. In order to achieve this “invisibility” they should be integrated with evolving "smart home" technology in order to achieve home automation, security and total in doors environmental control. New recent developments include the use of several sensors, worn by the patient (wearable computing - Figure 10 and Figure 11) [34-37], capable of measuring factors such as temperature, respiration, electrocardiogram and skin blood flow. The, collected, data can then be transmitted to a portable computational system (e.g. PDA, Smart Phone) or to a local (in home) specialised controller via low cost telemetry before transmission to a central computational system (in the health Institution, for example). Here, an intelligent decision-support system using robust algorithms can be used to detect emergencies, false alarms and long-term.

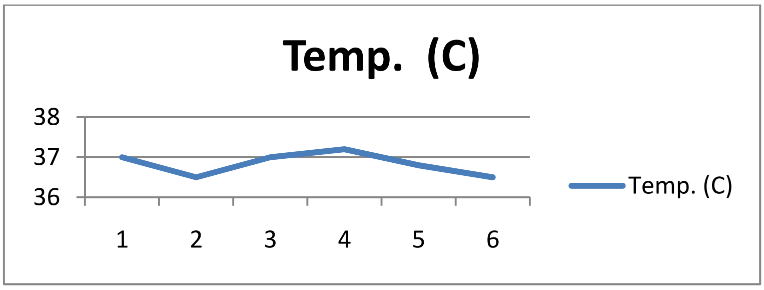

Figure 9 - Body temperature sensor graphic

Figure 10 - Wearable computing example 1[1]

Figure 11 - Wearable computing example 2[2]

[1] URL: http://biodevices.pt or http://www.vitaljacket.com/
[2] URL: http://www.angel-med.com/

Third-generation Systems

Third-generation systems are the most advanced ones and represent the effort of integrating new technologies, concepts and methodologies in order to achieve a higher level of telecare systems. They, not only add additional detection capabilities to the already present in the previous systems (Figure 12), specially Second-generation ones, but arise to deal with issues of loneliness contributing to a better quality of life of patients, achieved thru the creation of virtual communities: clients, carers, healthcare providers, family, friends and other community services (e.g. banking, shopping, interactive exercise support), connected via ICT (e.g. telephone, interactive television, Internet). With all this technology, third-generation systems, may be able, in some case, to enable remote health diagnosis, virtual physicians visits, promote personal health in conjunction with wellness activities. These third-generations systems, in conjunction with user centric methodologies [38-40], extend the traditionally concept of remote care in the pursuit of well being and active ageing.

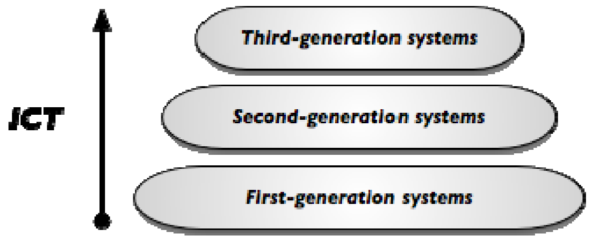

Figure 12 - The three generations of telecare systems

Another advantages of these third-generation systems, is that with the growing accessibility of the Internet, the intensive use of ICT and with the most recent computing developments, in specially the new wide available collaborative technologies, allow them to support care services independently of where the individual (patient) is physically (e.g. home, walking around, visiting neighbours or friends, daily activities centres, etc.). This major advantage allows patients to maintain their day-to-day habits and preferences, autonomy and independence promoting, even more, the state of well being.

2.3. Telemedicine

Telecare, as mentioned in the previous section, deals with the provision of care services remotely. It is, however, essential to make a distinction between Telecare and Telemedicine systems. Telemedicine concepts, traditionally, have been used in combination with the areas of tele-robotics and tele-operation and may mean something as simple as a telephone call or as complex as robotic surgery [17, 41-43]. Telemedicine, normally, also requires the presence of all intervenient parties at the same time and some kind of communication technologies between them in order to allow a real-time interaction to take place, being the video-conference equipment between the most common used technologies (Figure 13). Several other peripherals devices, like tele-otoscope (see inside the patient's ear) or tele-stethoscope (hear the patient's heartbeat), may also be used in order to allow the remote physician to do a more accurate diagnose. Nowadays, especially in remote locations, there tend to be several medical specialties recurring to the use of Telemedicine, including psychiatry, family practice, internal medicine, rehabilitation, cardiology, paediatrics, obstetrics, gynaecology, neurology, speech-language pathology and pharmacy.

Figure 13 - Telemedicine example.

Another area normally associated with Telemedicine is the acquiring of medical data (e.g. medical images, bio-signals, radiology, etc) and the posterior transmitting of this data to a doctor, a medical specialist or a team of specialists at a convenient time for offline assessment, also now as store-and-forward Telemedicine [43, 44]. One major advantage is that it does not require the presence of both parties at the same time, since the medical data may be collected by a technician and not by a medical doctor or specialist. Dermatology (tele-dermatology), radiology (tele-radiology), and pathology are the most common specialties that use this variant of Telemedicine.

As a conclusion we may say that Telemedicine is most beneficial in two situations:

- Populations living in isolated communities and remote regions (applied in virtually all medical domains);
- As a communication tool between a general practitioner and a specialist available at a remote location.

Specialties that use telemedicine often use a "tele-" prefix; for example, telemedicine as applied by radiologists is called Tele-radiology. Similarly telemedicine as applied by cardiologists is termed as tele-cardiology, etc.

2.4. Requirements for a Telecare System

Traditionally the care provision to the ones in need, especially elderly, was supported by relatives or care centers. However, these two solutions are becoming insufficient do to several reasons:

- Relatives active life, especially women which wore the most traditional caregivers, and their need to work in order to secure steady monthly incomes;
- Inexistence of enough public care centres, and often far away of their homes;

- Many patients, although in need of constant monitoring, still have enough robustness to live their normal life and do their normal day-to-day activities.

Recurring to the use of recent development in the, so called, Information Society and recurring to a combination of new, but already available, technologies, the achievement of a solution which will allow the adequate provision of care services in a remote matter to the ones in need, which autonomy is still sufficient to allow them to remain at home, is a reality. However, and in this new context, all the technological solutions must have in consideration all the several actors and/or entities involved in such a support system [45]:

- **Elderly** usually has the need for some special attention, being because of some special medication it needs to take or because their health is very susceptible to sudden changes. They are required to be under constant surveillance and to have facilitated access to advice/help systems strategically located (easy access). They should be, however, encouraged to maintain their normal day-to-day tasks and activities, including social ones, in order to better obtain the necessary well-being and relegate the problems associated with anxiety and loneliness;

- **Home** or **Environment**, since the definition of home is not necessarily house, is the physical place where the patient lives. It must include the necessary options in order to guarantee the security and well-being of its, health reduced, inhabitants according to their needs;

- **Care Centres** must actualize themselves in order to deal with this new reality. They must have all the necessary equipment to offer social care in a remote way, thus becoming a valuable intervenient by monitoring patient activities as well as reminding them of their tasks;

- **Health Centres** should be responsible for providing the required special health surveillance for the patients, thru the real time monitoring of their physical and emotional conditions, medication and day-to-day schedule. It should be able to allow caregivers to remotely access to patient data and make decisions about detected problems;

- **Relatives** need, or at least be given the possibility, to be informed about their love ones actual conditions. In this line of thinking they should be given access of some kind of remote monitoring/vigilance facility, not to intrusive, in order to be able obtain, real time, information, increase contacts and act in case or emergency;

- **Leisure Centres** are extremely important in regard of providing, not necessary for free, activities to occupied patients free time. These activities could be as diversified as books, videos, meals and social ones according to each patient limitations;

- **Sales** and **Services** are responsible to provide to the patient specialized electronic commerce in order to allow them the acquisition of goods and services in a easy way;

- **Safety, privacy** and **security** concerns should always be present and considered critical aspects. Data confidentiality must be guaranteed and an adequate balance between safety and privacy should be obtained, according to the health condition of the patient but always preserving privacy minimal bounds. Systems should also have in consideration malfunctions and failures (e.g. communications failures) in order to accomplish patient safety in these situations. Systems that do not correctly address this issues will not be attractive to its possibly users as a trust relationship cannot be obtained [46]

In order to achieve a high geographically distribution, available not only in urban areas but also in rural one, these kinds of systems should use the Internet as their communication backbone (Figure 14) due to its low cost and widespread availability. However, a high level of autonomy of each component of the system is needed, once the Internet, has as downside, its stability and communication failures are, more or less, frequent.

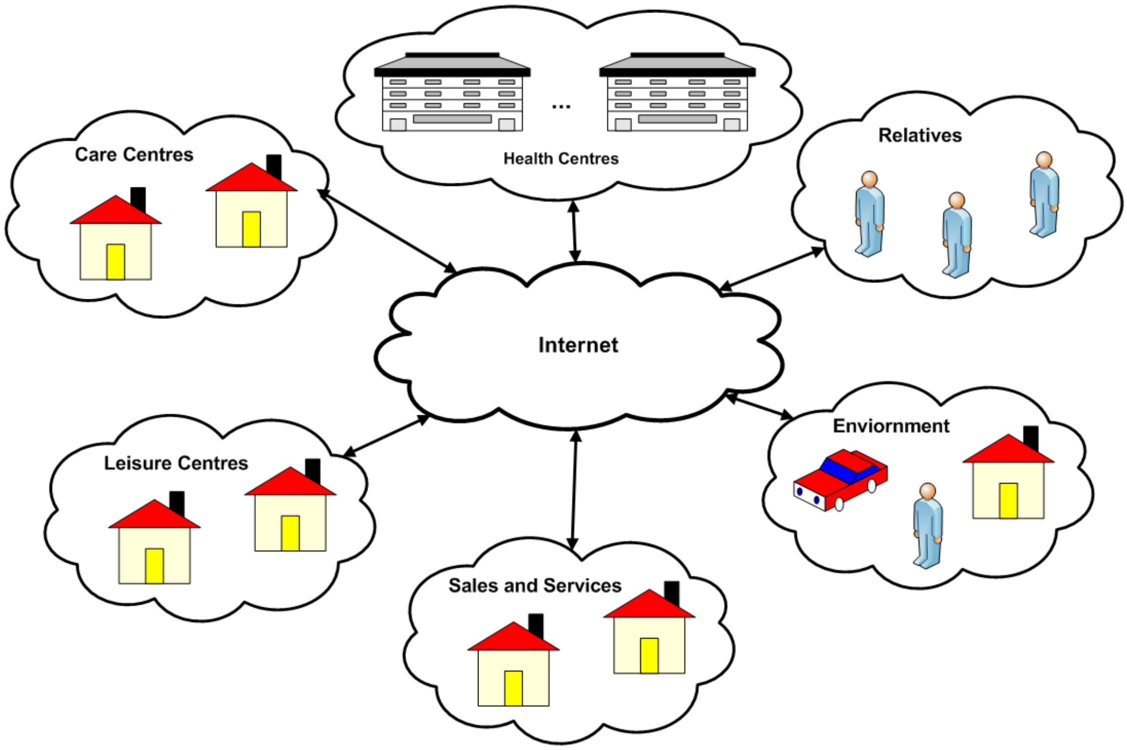

Figure 14 - Generic telecare system scenario.

2.5. Conclusion

The use of new technological means in the healthcare sector is not new. However, initially, and thru the use of Telemedicine, the objective was to minimize the insufficient of medical staff, especially in rural, far away, places. Today, although the insufficient of medical staff and all type of caregivers still remains, the objectives are rapidly changing. We have demonstrated, in a generic way, how new, advanced, ICT system may be built, recurring to already existent technologies and devices (e.g. sensors, computers, communication systems, etc.) in order to promote ageing-in-place (patient natural environment) and well-being. These system can them be upgraded to most advanced ones thru the use of Collaborative Networks (CN) and Group Decision Support Systems (GDSS) which we will discuss in the next chapter.

Chapter 3

Collaborative Networks

and

Group Support

3.1. Introduction

The challenges faced by both business and academy in recruit years, in association with the advances in information and communication technology, lead to the creation of a large variety of Networks, namely Collaborative Networks (CN). Basically, CN let professionals and organizations to seek complementary and joint activities, allowing them to participate in new and more competitive businesses opportunities, reaching new markets and/or allowing the achievement of scientific excellence, either in forms of services or products. This can be done, namely, through highly integrated supply chains, virtual enterprises/organizations, professional virtual communities, value constellations and/or virtual laboratories [47]. There is all kind of networks in the world. Each one of us is connected, thru relationships or linkages, to a network - friends, relatives, colleagues, classmates, and so on – which is normally called a social network, where we are its nodes in network terminology. Besides social networks, there also exist organizations networks, where each node is an organization and where the relationships or linkages tend are based on cooperation and collaboration. However, while social networks arise from everyday interaction between individuals, organizations networks tend to arise for a specific purpose: respond to an occurring problem or in anticipation to it [48].

The chapter is organized as follows: Section 3.1 introduces the concepts of collaborative networks, virtual organizations and virtual communities; Section 3.2 introduces the concepts of group support and Section 3.3 introduces the concepts of quality of information and knowledge representation.

3.2. Collaborative Networks

Virtual Organizations

As previously presented, in order to have organizations based CN, we first need to have several nodes (organizations) collaborating, which according to Russ Linden: “Collaboration is about co-labor, about joint effort and ownership. The end result is not mine or yours, is ours” [49], and cooperating with each other in the form of Virtual Organizations (VO), sharing skill and resources through the use of information and communication technologies. Much has been published about VO, but there isn’t a consensus in the scientific community about a sole definition of what it is [48, 50-58]. Instead of proposing and/or using one or several, non consensual, definitions we are going to present several VO key concepts [55]:

- A VO is a flexible network of independent entities linked by information and communications technologies in order to share skills, knowledge and expertise in a non traditional form;
- A VO is a form of cooperation involving companies, institutions and/or individuals delivering a product or service on the basis of a common business understanding.
- A VO does not need to have all of the intervenient, or even any of them, in the same place in order to deliver their services. The organization exists, virtually but you cannot see it. It is a network, not an office.

A VO should also obey to some key attributes, which include:

- A dispersed network of skills and capabilities – the structure of a VO is distributed among multiple locations resulting in the capacity of bringing in a wider pool of skills and capabilities;

- The use of telecommunications and computing technologies – these technologies serve as the enabler that makes a VO exist. One could argue that VOs have always existed (e.g., travelling sales staff, outsourced staff and staff working at home), however new technologies have made it much easier to support distributed work teams, overcoming the barriers of distance and time.
- Flexible, dynamic, restless – organizations no longer are constrained by traditional barriers of place and time. VOs support dynamic changes to the organization including employee work environments and processing structures. Restlessness refers to the attitude to willingly change products and services, geographic dispersion, communication patterns which has the potential of leading toward higher levels of innovation and creativity.
- Integration – when different individuals, groups and organizations get together in a VO, they need to interact collectively to achieve success. This implies greater levels of collaboration, cooperation and trust. Integration leverages the synergy of individuals.

Situations that are driving many organizations to examine and implement VOs include:

- A need for process innovation – this is often motivated by competitive pressures, stakeholder demands and other factors to achieve increased productivity and quality;
- Sharing of core competencies – VOs help address the voids in an organization resulting from starting up, turnover and retirements;
- Globalization – many organizations are finally realizing there is a vast pool of untapped skills, knowledge and abilities throughout the world;
- Mobile workers – VO concepts can help the numerous companies employing mobile workers such as auditors, consultants, salespersons and service technicians;

- Cost reduction – improving efficiency often means reducing overhead, such as physical assets used to support traditional work environments or redistributing costs over several physical locations.
- Changes in employee values and attitudes toward work – quality of life is a major factor particularly in attracting and retaining quality employees. Employers have realized that a balance of work and personal life, family requirements, personal fulfilment and flexibility are important considerations among employees.
- Costs and problems of travelling – VOs address transportation issues, such as unproductive commute time, traffic hassles, the cost of fuel and environmental impact of commuting vehicles.

Virtual Communities

All humans have a natural tendency to communications and to form communities and, as so, participation in a community is an important aspect of life for us all. Virtual Communities (VC) exists since the early day of the USENET and, basically, allowed humans to communicate using information and communications technologies, but, in very basic forms those days. With the rapid evolution of those same information and communications technologies, the creation of new VC was largely stimulated specially thought the use of the Internet. Once again, as with VO, the lack of a formal definition also exists in VC, however some generically key components are accepted [25, 59-62]:

- VC are groups of people that interact via information and communication technologies through the Internet;
- VC are social relationships in the cyberspace, with a common point of interest that can occur only once or in a series of interactions;

- VC where the transposing of the, already existent community concept, to the Internet with the associated growth explosion;
- VC are distributed on-line services connecting groups of peoples, focused on a common interest;
- VC is, nothing more, than people that interact together on a technical platform.

However all VC, to be considered so, should have *a sufficient human feeling* [63] or a *sense of community* [64], which is characterized as personal investment, intimacy, commitment and some discussion of all the community members. For instance, an email distribution list may have hundreds of members, but the communication which takes place may be merely informational, with members remaining complete strangers to each other. If this is the case, and according Howard Rheingold [63] and David McMillan [64], it should not be considered a VC.

3.3. Group Support

3.3.1. Group Support Systems

By definition, any CN or Collaborative Network Organizations (CNO) has to support collaborative work, that presupposes the existence of a group of people that has as mission the completion of a specific task [65]. The number of elements involved in such group may be variable, as well as the persistency of the group. The group members may inclusive be at different places, may meet in an asynchronous way or may belong to different organizations. Collaborative work has not only inherent advantages (e.g., greater pool of knowledge, different world perspectives, increased acceptance), but also assertive goals (e.g., social pressure, domination, goal displacement, group thinking) [66].

3.3.2. Meeting phases

Group Support Systems (GSS) intend, as we shall see, to support collaborative work. In this work we will call “meeting” to all the processes necessary to the completion of a specific collaborative task. A meeting is a consequence or an objective of the interaction between two or more persons [67]. Physically, a meeting can be realized in one of the four scenarios: same time / same place, same time / different places, different times / same place and different times / different places. Each one of these scenarios will require from the GSS a different kind of support.

Until now we discussed collaborative work and present group members as the only persons involved in the process. However, it is very common to see a third element taking part in the course of action, the facilitator. The meeting facilitator is a person welcomed by all the members of the group, neutral and without authority to make decisions, which intervenes in the process in order to support the group in the identification of a problem and in the finding of a solution, in order to increase group efficiency [68].

According to Dubs and Hayne [69] a meeting has three distinct phases, as it is depicted in Figure 15.

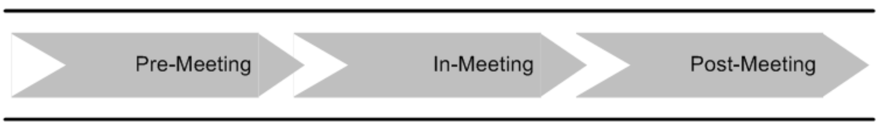

Figure 15 - Meeting Phases.

In the Pre-Meeting phase the facilitator prepares the meeting, i.e., establishes the meeting goals, proceeds with the group formation (making sure that all the participants have the necessary background), selects the best supporting tools, informs the meeting members about the goals and distributes among them the meeting materials.

In the In-Meeting phase the participants will be working in order to accomplish the meeting goals, and the facilitator has the task of monitoring the meeting interactions (e.g., to observe the relationship between the group members) and to intervene if necessary.

In the Post-Meeting phase, it is important to evaluate the results achieved by the group, as well as by how much each group member is acquit with the achieved results (satisfied/unsatisfied). Still, in this phase it is very important to identify and store information that can be useful in future meetings (e.g., how to actualize the participant's profile for future selection).

3.3.3. Group Decision Support Systems

In the last years, we have assisted to a growing interest in combining the advances in information society - computing, telecommunications and presentation – in order to create Group Decision Support Systems (GDSS). Indeed, the new economy, along with increased competition in today's complex business environments, takes the companies to seek complementarities in order to increase their competitiveness and reduce risks. In this scenario, planning takes a major role in a company life. However, effective planning depends on the generation and analysis of ideas (innovative or not) and, for this reason, the idea generation and management processes become a crucial tool in present days.

Decision Support Systems (DSS) are interactive computer-based systems aimed to help decision makers use communication technologies, information (structured or unstructured), knowledge and/or models to solve problems and make decisions. It is a general definition for any computer application that augments a person or group capabilities to make decisions.

It is expected that knowledge-driven DSS will be more comprehensive, cover broader domains and give better advice [70]. Also, DSS and particularly Group Decision Support Systems (GDSS) will benefit from progress in more basic research on behavioural topics in the areas of organizational decision making, behavioural decision theory and organizational behaviour [71, 72].

Our objective is to apply the above-presented GDSS to a new sector. We believe the use of GDSS in the Healthcare sector will allow professionals to achieve better results in the analysis of one's Electronically Clinical Profile (ECP). This achievement is vital, regarding the explosion of knowledge and skills, together with the growing need to use limited resources more efficiently.

3.4. Quality of Information

Introduction

Imperfect information is ubiquitous; we take most of our decisions, if not all, of our day to day life based on incomplete, not precise and even uncertain information. Most information systems just ignore this characteristic of the information about the real world and build upon models were some idealisation expunges the inherent uncertainty [73]. The consequence is that one ends up with an elegant model which never gives completely correct answers, because it is not able to model exactly what is going on. Instead, one should deal with the uncertainty in the model itself, even at the cost of less simplicity and elegance. Therefore, to implement useful information systems, in particular knowledge based ones, it is necessary to represent and reason with imperfect information.

Examples of such systems are Group Decision Support Systems (GDSS) based on agent perception that are such in vogue in today's complex business environments and that we try to associate with the healthcare practice and respective information systems (e-Health systems), in which lack of verification of the quality of information is a key omission [74]. e-Health is a relatively recent term for healthcare practice supported by electronic processes and communication. *"e-health is an emerging field in the intersection of medical informatics, public health and business, referring to* *health services and information delivered or enhanced through the Internet and related technologies."* [75].

One of the components of VirtualECare is a knowledge-based GDSS. As any system dealing with information and knowledge, it must encompass uncertainty. In section 0 we define a method to evaluate the quality of knowledge involved in the VirtualECare GDSS, despite it can be used in any GDSS, and present the foundations of a theory that permits to represent and reason with uncertain knowledge.

A brief note about the word "uncertain" used in the text: although sometimes used interchangeably with "incomplete" and "imperfect" as a generic term for imperfection in data, it will be used to characterise a particular form of imperfect knowledge of whether or not a statement is true.

Knowledge Representation

VirtualECare GDSS deals with information and knowledge in an environment of uncertainty. The information available must always be considered incomplete and imperfect.

How can a decision maker be confident about the reliability of the information at hand? In group decisions each person that participates in the final decision must be confident on: the reliability of the computer support system; the other decision makers; the information rolling in and out of the system and the information exchanged between participants. The Group Decision of the VirtualECare system operates in such environment. We leave the first issue to others and concentrate in the last two, proposing a model for computing the quality of information.

A suitable representation of incomplete information and uncertainty is needed, one that supports non-monotonic reasoning. In a classical logical theory, the proof of a theorem results in a *true* or *false* truth value, or is made in terms of representing something, with respect to one may not be conclusive. In opposition, in a logic program, the answer to a question is only of two types: *true* or *false*. This is a consequence of the limitations of the knowledge representation in a logic program, because it is not allowed explicit representation of negative information. Additionally, the operational semantics applies the Closed-World Assumption (CWA) [76, 77] to all the predicates. The generality of logic programs represents implicitly negative information, assuming the application of reasoning according to the CWA.

An extended logic program, on the other hand, is a finite collection of rules of the form [78, 79]:

$q \leftarrow p_1 \wedge \ldots \wedge p_m \wedge not\ p_{m+1} \wedge \ldots \wedge not\ p_{m+n}$	(1)
$?\, p_1 \wedge \ldots \wedge p_m \wedge not\ p_{m+1} \wedge \ldots \wedge not\ p_{m+n}$	(2)

where ? is a domain atom denoting falsity, the pi, qj, and p are classical ground literals, i.e. either positive atoms or atoms preceded by the classical negation sign ¬. Every program is associated with a set of abducibles. Abducibles can be seen as hypotheses that provide possible solutions or explanations of given queries, being given here in the form of exceptions to the extensions of the predicates that make the program.

The objective is to provide expressive power for representing explicitly negative information, as well as directly describe the CWA for some predicates, also known as *predicate circumscription* [80]. Three types of answers to a given question are then possible: *true*, *false* and *unknown* [77]. The representation of null values will be scoped by the ELP. In this work, we will consider two types of null values: the first will allow for the representation of unknown values, not necessarily from a given set of values, and the second will represent unknown values from a given set of possible values. We will show now how null values can be used to represent unknown information. In the following, we consider the extensions of the predicates that represent some of the properties of the participants, as a measure of their skills for the decision making process:

```
area_of_expertise: Entities x StrValue
role: Entities x StrValue
credible: Entities x Value
reputed: Entities x Value
```

The first argument denotes the participant and the second represents the value of the property (e.g., `credible(luis, 100)` means that the credibility of the participant `luis` has the value `100`).

```
credible(luis,100)
¬credible(E,V)←
          not credible(E,V)
```

Program 1 - Extension of the predicate that states the credibility of a participant.

In Program 1, the symbol ¬ represents the strong negation, denoting what should be interpreted as false, and the term *not* designates negation-by-failure.

Let us now admit that the credibility of another possible participant *ricardo* has not, yet, been established. This will be denoted by a null value, of the type unknown, and represents the situation in Program 2: the participant is credible but it is not possible to be certain (affirmative) about its value. In the second clause of Program 2, the symbol ⊥ represents a null value of an undefined type. It is a representation that assumes any value as a viable solution, but without being given a clue to conclude about which value one is speaking about. It is not possible to compute, from the positive information, the value of the credibility of the participant *ricardo*. The fourth clause of Program 2 (the closure of predicate credibility) discards the possibility of being assumed as false any question on the specific value of credibility for participant *ricardo*.

```
credible(luis,100)
credible(ricardo,⊥)
¬credible(E,V)←
          not credible(E,V),
          not exception(credible(E,V))
exception(credible(E,V))←
          credible(E,⊥)
```

Program 2 - Credibility about participant ricardo, with an unknown value.

Let's now consider the case in which the value of the credibility of a participant is foreseen to be 60, with a margin of mistake of 15. It is not possible to be positive, concerning the credibility value. However, it is false that the participant has a credibility value of 80 or 100. This example suggests that the lack of knowledge may only be associated to a enumerated set of possible known values. As a different case, let's consider the credibility of the participant *paulo*, that is unknown, but one knows that it is specifically 30 or 50.

```
credible(luis,100)
credible(ricardo,⊥)
¬credible(E,V)←
          not credible(E,V),
          not exception(credible(E,V))
exception(credible(E,V))← credible(E,⊥)
exception(credible(carlos,V))← V ≥ 45 ∧ V ≤ 75
exception(credible(paulo,30))
exception(credible(paulo,50))
```

Program 3 - Representation of the credibility of the participants carlos and paulo.

Using Extended Logic Programming, as the logic programming language, a procedure given in terms of the extension of a predicate called *demo* is presented here. This predicate allows one to reason about the body of knowledge presented in a particular domain, set on the formalism previously referred to. Given a question, it returns a solution based on a set of assumptions. This Meta predicate is defined as:
`Demo: Question x Answer`

Where Question indicates a theorem to be proved and Answer denotes a truth value (see Program 4): true (T), false (F) or unknown (U).

```
demo(Q,T)← Q
demo(Q,F)← ¬Q
demo(Q,U)← not Q ∧ not ¬Q
```

Program 4 - Extension of meta-predicate demo.

Let i ($i \in 1,\dots, m$) represent the predicates whose extensions make an extended logic program that models the universe of discourse and j ($j \in 1,\dots, n$) the attributes of those predicates. Let $x_j \in [min_j, max_j]$ be a value for attribute j. To each predicate is also associated a scoring function $V_{ij}[min_j, max_j] \rightarrow 0 \dots 1$, that gives the score predicate i assigns to a value of attribute j in the range of its acceptable values, i.e., its domain (for simplicity, scores are kept in the interval $[0 \dots 1]$), here given in the form: `all(attribute_exception_list, sub_expression, invariants)`

This denotes that *sub_expression* should hold for each combination of the exceptions of the extensions of the predicates that represent the attributes in the *attribute_exception_list* and the *invariants*.

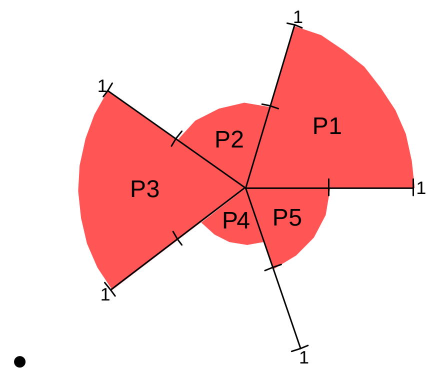

Figure 16 - A measure of the quality of information for a logic program or theory P.

This is further translated by introducing three new predicates. The first predicate creates a list of all possible exception combinations (pairs, triples, ..., n-tuples) as a list of sets determined by the domain size (and the invariants). The second predicate recourses through this list and makes a call to the third predicate for each exception combination. The third predicate denotes sub_expression, giving for each predicate, as a result, the respective score function. The Quality of Information (QI) with respect to a generic predicate P is therefore given by

QI_P = 1/Card, where Card denotes the cardinality of the exception set for P, if the exception set is not disjoint. If the exception set is disjoint, the quality of information is given by:

$QI_P = \frac{1}{C_1^{Card} + \cdots + C_{Card}^{Card}}$	(3)

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

The next element of the model to be considered is the relative importance that a predicate assigns to each of its attributes under observation: w_{ij} stands for the relevance of attribute *j* for predicate *i* (it is also assumed that the weights of all predicates are normalized, i.e.:

$\forall i \sum_{j=1}^{n} w_{ij} = 1$	(4)

It is now possible to define a predicate's scoring function, i.e., for a value $x = (x_1, ..., n)$ in the multi dimensional space defined by the attributes domains, which is given in the form:

$V_i(x) = \sum_{j=1}^{n} w_{ij} * V_{ij}(x_j)$	(5)

It is now possible to measure the QI that occurs as a result of a logic program, by posting the $V_i(x)$ values into a multi-dimensional space and projecting it onto a two dimensional one.

Using this procedure, it is defined a circle, as the one given in Figure 3. Here, the dashed n-slices of the circle (in this example built on the extensions of five predicates, named as $p_1 \dots p_5$) denote de QI that is associated with each of the predicate extensions that make the logic program. It is now possible to return to our case above and evaluate the global credibility of the system. Let us consider the logic program (Program 5).

```
¬credible(E,V) ←
        not credible(E,V),
        not exception(credible(E,V))
exception(credible(E,V)) ← credible(E,⊥)
credible(luis,100)
credible(ricardo,⊥)
exception(credible(carlos,V)) ← V ≥ 45 ∧ V ≤ 75
exception(credible(paulo,30))
exception(credible(paulo,50))
role(luis,⊥)
role(ricardo,doctor)
exception(role(carlos,doctor))
exception(reputed(luis,80))
exception(reputed(luis,50))
exception(reputed(ricardo,40))
exception(reputed(ricardo,60))
reputed(carlos,100)
```

Program 5 - Example of universe of discourse

As an example we represent the QI associated with participants *luis* and *ricardo*, depicted in Figures 4 and 5.

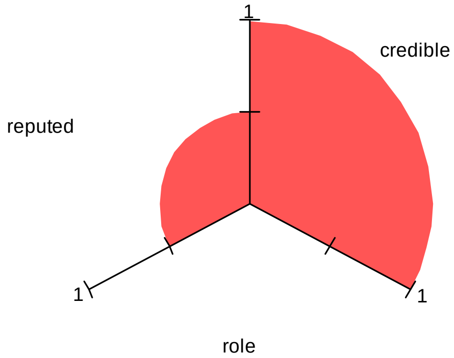

Figure 17 - A measure of quality of information about participant luis.

In order to find the relationships among the extensions of these predicates, we evaluate the relevance of the QI, given in the form $V_{credible}$(luis) = 1; $V_{reputed}$(luis) = 0.785; V_{role}(luis) = 0. It is now possible to measure the QI associated to a logic program referred to above: the shaded n-slices (here n is equal to three) of the circle denote the QI for predicates *credible*, *reputed* and *role*. However, in order to accomplish the main goal of this work, we need to further extend the purpose of Figures 4 and 5, i.e., we may define a new predicate, *trustworthiness*; whose extension may be given in the form of the example (Program 6).

```
¬trustworthiness (X,Y)←
        not trustworthiness (X,Y),
        not exception(trustworthiness (X,Y))
trustworthiness(luis,((credible,1),(reputed,0.785)(rol
e,0)))
trustworthiness(ricardo,((credible,0),(reputed,0.785),
(role,1)))
```

Program 6 - Measuring the global quality.

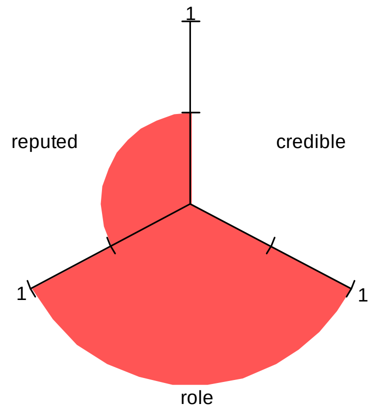

Figure 18 - A measure of quality of information about participant ricardo.

Besides being able to evaluate the quality of individual actors and individual pieces of information that flows in a group decision system, we aim to have an overall mechanism that allows one to measure the global quality of the system itself and, consequently, the outcomes from it. There is too much in stake when we deal with healthcare, and one must raise the confidence on decisions, especially in an environment of uncertainty, incomplete and imperfect information. The same mechanism used to evaluate individual parts of the system is consistently used to evaluate all the system, through an extension process.

3.5. Conclusion

The need for seek new alternatives for the substantially increase in the number of people needed of intensive care is real. The use of collaborative network environments, combined with some other, to be presented, different technologies may be a solution to the problem, allowing not only a successful ageing-in-place, but also an active ageing. These new CN to provide comprehensive care to the needed ones may be obtained thru the formation of several VO encompassing the various institutions involved in care provision (e.g., care centres, emergency services, playful services, and so on) and the respective creation of VC comprising the people who will participate in the care network (e.g., the persons in need, caregivers, family, and so on) with the additional advantage of also being a way to encourage the needed ones to be socially active.

Chapter 4

Ambient Intelligence

and

Ambient Assisted Living

4.1. Introduction

Computers, and especially human-computer interaction, have come a long way since the early days with their rude interfaces [81]. Actually, since they first appeared, they have always been seen as a work tool, and, therefore, our interaction with them has always been very computer centred, as it is with any other tool. Normally, when we want, or need, to use a computational system, we have to delocalize ourselves to it and interact with it by its, very basic, means. This way of interacting with computational systems is, however, changing very rapidly, thanks to new emerging methodologies and technologies, with a very high impulse from, what is nowadays known as, Ambient Intelligence (Ami) [82].

AmI is a relatively new paradigm of Artificial Intelligence (AI). In this new paradigm, computers are seen as proactive tools that assist us in our day-to-day, making our lives more comfortable. The interaction with those computers is also rapidly changing, as we no longer need to do it in ways not natural for us, since a main concern of this paradigm consists in make possible to interact with computational systems using friendly interfaces, allowing input thru our natural language or gestures. This inclusion of technology in our day-to-day object and environments tend also to be as invisible as possible, as computational power and communication technologies are nowadays, already, present in almost every device we use. The objective is, therefore, the interaction with one or more computational systems without, probably, noticing it. The only awareness we should have is the result of AmI: a more safety, comfort and well being, inflicted in a natural way, in our day-to-day [82, 83].

Although recent, AmI has already several trends, being one of them, in association with e-health, the creation of Ambient Assisted Living (AAL) environments. These AAL environments will have the objective of modeling themselves to the special and particular needs of its users, according to their state of health [83, 84].

The chapter is organized as follows: Section 4.2 presents and explains the AmI paradigm, from its Vision to its Technologies, passing by its Concept and its Services; Section 4.3 presents and explains the Ambient Assisted Living paradigm; and Section 4.4 presents some relevant AmI and AAL related works consulted during this work.

4.2. Ambient Intelligence

4.2.1. The Vision

AmI is a relatively new concept and depends on new technologies and methodologies. According to the Informational Society Technology Advisory Group (ISTAG) of the European Community (EC) [85-87], AmI is the Information Society future where the emphasis is on user friendliness, efficient and distributed services support, user-empowerment, and support for human interactions (in a natural way, as if we where interacting with another human). People are surrounded by intelligent intuitive interfaces that are embedded in all kinds of objects and an environment that is capable of recognizing and responding to the presence of different individuals, with different preferences and different needs, in a seamless, unobtrusive and often invisible way [88].

This vision however, assumes a shift from our actual, most common, computation systems (desktops) to a multiplicity of computational mobile devices present in our everyday lives, where the user is the centre of future developments and where the technology should be designed for him rather than make him adapt to the technology [88, 89].

4.2.2. The Concept

AmI concept was introduced on 2001 by the ISTAG of the EC [85-87], based on three relatively new key technologies: Ubiquitous Computing [90, 91], Ubiquitous Communication [90, 91] and Intelligent User Interfaces [83] which combined with some others like: Embedded Systems [92], Pervasive Computing [93, 94] and Context Awareness [83] are changing the way we "see" computers.

We may describe AmI as a new world where computing devices are available everywhere, including day-to-day objects, allowing the human being to interact with them, in a physical world environment aware of the needs of people with the ability of customize requirements and forecast behaviours, in an intelligence and unobtrusive way [95].

Computers, in AmI environments, are no longer mere tools: they are learning our preferences and our habits (what we like to do and when do we like to do it) so they can simplify our lives [83, 96, 97]. Moreover, they are shrinking and hiding in very common devices, so we already do not notice them [98].

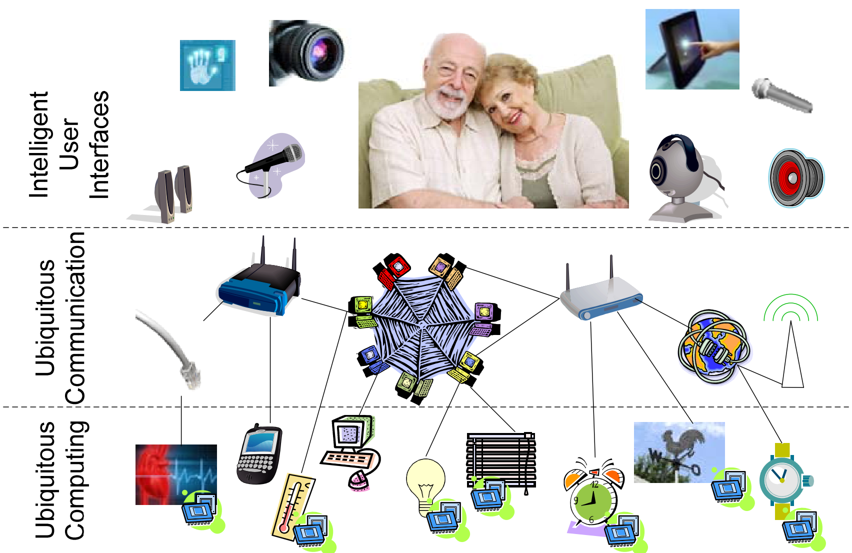

Figure 19 - The three main layers of AmI.

Physically, an AmI environment is composed by the ambient itself (e.g. a house, a room, a car, a school, an office, etc.) and the devices present on it. These devices are common ones like: mobile phone, air conditioning systems, computers (laptops or desktops), media servers, micro-waves, PDA's, etc., all of them so common these days. The novelty is that they are all inter-connected throughout a control network, allowing them to be controlled from any point of the network. However this characteristic, by itself, is no more than what we, nowadays, call Domotics[3]. In Domotics, devices are inter-connected in order to allow us to control them from distance. AmI may take advantage of Domotics to achieve its objectives, as it takes advantage of Ubiquitous Computing in order to maintain all its components as hidden as possible. The ideal AmI environment should appear a perfectly normal environment, embedding its components in common devices, noticeable only by its actions. This is why Ubiquitous Computing and AmI are so deeply related, since. Both of them try to integrate computational power into small devices, so that they can pass unnoticed but, nevertheless, do their job.

AmI main objective is to ensure people's safety and well being. To achieve this objective, it must know the needs and the preferences of each person, which can be set manually, when configuring AmI environment or, it can learn them from person day-to-day activities and habits [99, 100]. This is a very important intrinsic and distinctive characteristic of AmI, it *learns* by just interact with people (user), without them even notice. The system must be able to study their behaviour and learn with it, learn what he does and when e does it. With this characteristic, learning, another important aspect arises. If the system is able to learn the habits of the people it interacts with, then every environment will be unique, depending on the persons it interacts with. This leaves us with another important characteristic of AmI, it is *personalized* [101]. We can also, already, say that it is *adaptive* since, even after learning our habits, if we change them, the system will automatically adapt and learn our the new habits, i.e., it will always adapt to us and to our lifestyle [100]. After learning and adapting to the user, the system can then demonstrate even more intelligence, as it can start to predict what the user will do and take measures that will assist him in that action. For instance, if the user drinks a cup of coffee every day

[3] Domotics or Home Automation is the automation of private homes with the objective of providing security and comfort to its inhabitants.

when he wakes up, the system learns it and will turn on the coffee machine when the wake up alarm is triggered. This way AmI also becomes *proactive* [92] (Figure 20). This shift from interactive to proactive computing will allow a higher level of automation to the user, thus been able to stay less confined to the same spaces.

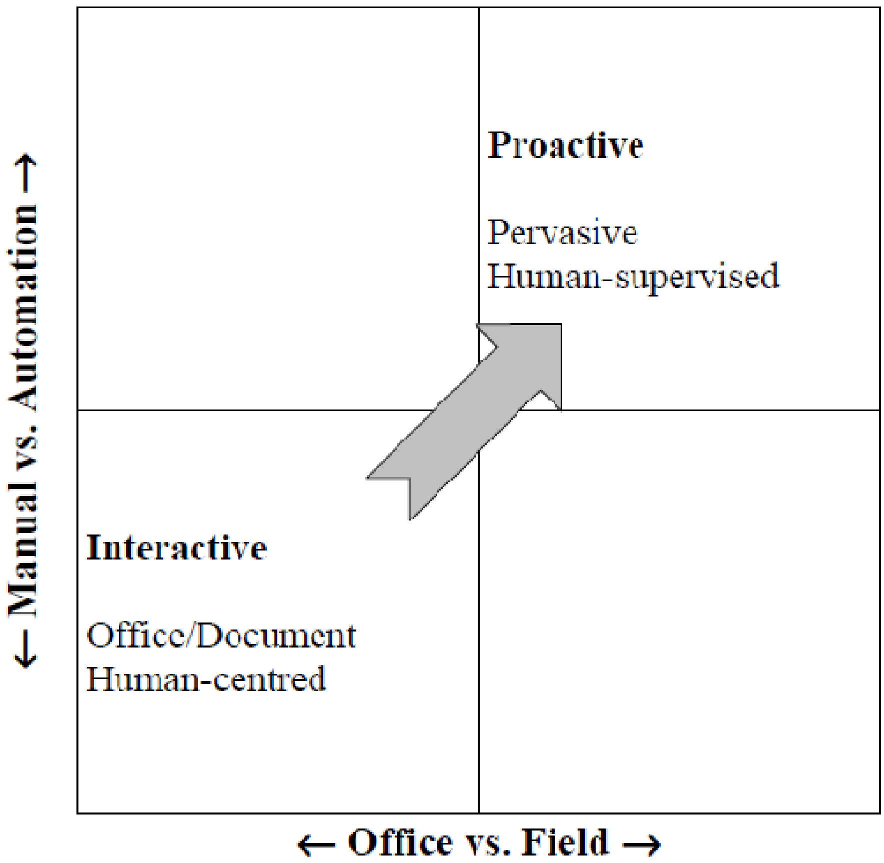

Figure 20 - The shift from interactive to proactive computing [92].

However, in order to be able to put in practice all the above characteristics, the system must first be able to recognize people and their situational context: current activity and/or task, location, time, emotional and physical conditions, surrounding weather, etc; making it also context-aware [88].

4.2.3. The Service

AmI can be seen as a continuous providing of services[4] to its users [102]. Let's assume the following example: a teacher, when entering a classroom, might have to services like: the control of the lights, the control of the air conditioning, a digital assistant or an interactive whiteboard. A student, when entering that same room, might or might not have access to all or part of the same services. Having this distinction between users in consideration, we can identify some important premises for an AmI environment. First of all, any AmI system must be able to properly distinct the users present in the environment, what is their role, and based on, every user, available information (e.g. access rights, preferences, limitations, etc.) decide what service they should have access to or should be provided to. Having all this information about its users, the system will then be able to "decide" which services to provide, when to provide, how to provide and who to provide them. The system must also be able to know the availability of the devices, eventually, needed for providing every service, as it should not announce a service if it cannot provide it. The system must also know some other important characteristics about the services it is providing, as the geographic location, the cost, the probable effects, etc., so that when it suggests a specific service to a specific user, it is actually suggesting what it thinks is the service most adequate to that specific situation [83, 88, 92].

Another important issue we must discuss is the adaptation of the services to meet the specific needs of elderly users [103, 104]. This important and growing group of people usually have physical impairments (e.g. mobility limitations, partial or total blindness, deafness, etc.) that prevent them to use the appliances or devices in the normal way. As previously mentioned, AmI services must adapt to meet the needs of its users, especially if they have specific limitations. This is, by itself, a very interesting field of investigation and where much work can, and must, be done. If AmI services are able to correctly adapt to elder or impaired specific limitations, there will be a

[4] A service, in the ambit of this document, is defined as something (physical or not) that is available in the context of the user, that performs some useful task (with or without user intervention) and that can be used by him, when needed.

growing portion or the human population that will have much to profit and will see AmI as a very positive technology [105-108].

Sensing

We have already described some of AmI main features. We have said it is able to learn from our behaviours, to adapt to them and to us, to “hide” itself in common devices, to be context- aware and to predict our actions. It is now time to describe is behind AmI, what are the devices upon which this behaviour can be achieved.

One group of devices essential for any AmI system are sensors. A sensorial network is indispensable for obtaining the correct information of the environment and its users. For safety, we can use nowadays common smoke detectors, flood detectors, gas detectors or intrusion alarms systems, among others. But those are not enough to build an AmI environment with the previously mentioned characteristics. We must also use other, starting to become also common, sensors in order to obtain, for instance, environmental parameters like luminosity, temperature or humidity. These one will makes possible to obtain the needed environmental data so it can be monitored and adjusted to maintain the needs, preferences and the safety of its users. We must also know the users location inside the environment. This a much more complex subject and must be resolved through the use of several types of several sensors and technologies, since there is not one that, by itself, can resolve it. To determine in which division the user is, AmI can use motion detectors or RFID (Radio Frequency Identification) [109], but to determine where exactly the user is inside a division, it is necessary to recur to complementary sensors like weight sensors on furniture (e.g. sofas, beds, etc.) or by proximity thru the detection of activity in some devices (e.g. if the user has just turned on the coffee machine, this means he is close to it). According to the importance of knowing the exact location, more complex location systems can be used, like triangulations in RFID technology [109].

Another important type of sensors that can be used in AmI, and especially in Ambient Assisted Living environments which we will discuss further ahead, are the ones that allow the monitoring of the users vital signs. Recently, several types of these sensors have arisen, from normal temperature sensors, passing by wristwatches until the more complex clothes. This last type of sensors is called wearable computing: using clothes with computational power. In this specific case, the users can wear clothes that have sensing capabilities [110, 111]. These clothes are then able to share the obtained information, from the sensors integrated in them, with the system using wireless communications protocols, mostly Bluetooth.

There are much more types of sensors that can be used to enrich the information that an AmI system can acquire. A final example can be an outside weather station, which when connected to the system provides information about the exterior environment. This may be important, not only to inform the user about the weather outside, but also to make adjustments in the inside environment (e.g. if the luminosity is a specific room is low, and we still have external day light, the system can open the blinds).

Acting

Any AmI environment, in order to achieve its objective, must be able to act. These actions, despite being mainly observed on the environment itself, may also be directed to its users or even to other external entities. Generally, there can be two triggers to enable a specific action: an action to respond to a specific event or an action to prevent or cause another specific event. To these two, possible, triggers we call reactive and proactive behaviours, respectively.

In reactive behaviour mode, the system detects a predetermined event and reacts according to it in a predetermined way. For instance, the lights being turned on when the user enters his house or the air conditioning being turned to minimum when the client is sleeping. In proactive behaviour mode, the system, by its initiative, takes an action. For instance, the system turning on the coffee machine at the usual hour its users wake up or turning on the air conditioning before the usual hour its users arrive.

Actions can, additionally, be classified according to its purpose. The system can take actions concerning the safety of the user, his well being or simply for his assistance. For instance, as analogy, we can think of the fire-fighters being called automatically after a fire alarm going on, the air condition being switched off or on according to the environment temperature and the coffee machine being switched on.

The most important actions are, obviously, the ones that concern the user safety. In this area, an AmI environment can constantly monitor its actual state and rapidly react in case of detected danger, even if the user is not aware of it or is not in the house at that time. For instance, if fire, water, or gas is detected inside the house, the AmI environment has enough autonomy to automatically react and call for help in order to prevent the situation develop and get worst, without the need to interact with any user. If the user vital signs are being monitored, it is even possible to detect a heart attack before it actually occurs, and start taking immediate measures in order to medical assistance for the user, thus gaining precious time in his favour.

The actions concerning the user comfort are, probably, the ones most widely used in an AmI environment. They are, mainly, intended to interact with all the house components in order to regulate the environmental parameters. This group of components can be composed by air conditioning systems, heaters, dehumidifiers, windows, doors, blinds, etc. The objective is to enable the system to change the environmental parameters, thru the use of these components, in order to approximate it as closely as possible to the user preferences. Another possible configuration may be in order to save as much energy as possible, for instance if the user need luminosity in his current location inside the house and if that location as windows with blinds and the outside weather station is given the information that there still is day light, the system may opt by open the blinds instead of turn the lights on. As a result, it possible to increase or maintain the comfort of the environment inhabitants while at the same time diminishing the energy bill [112].

At last, the actions that have has objective to assist the user. These actions can be helpful for us in many different types of environments. Imagine that your workplace is enriched with an AmI environment. It is constantly examining your work and identifying what you are doing so that it can proactively help you. The way it helps depends on the nature of the work but it may be by taking care of your daily schedule, by showing you a schematic of the electric device you are currently putting together or by automatically fetching components needed for finishing assembling a car on the assembly line. In the specific scope of this work, these actions can be even more profitable for elder or impaired users. Imagine a user that cannot reach a device on its house because it is on a wheelchair or it simply is too far to walk to it. An AmI environment would respond to a voice command or even automatically turn on that device, this way assisting the user.

Communicating

Obviously, all the component of an AmI environment must be interconnected in order to communicate with each other. This fact makes the need to communicate essential in any AmI environment. The wired network is very important in connecting devices with low mobility and is very common nowadays, working also as a backbone for other networks. We have the example of the widely used Ethernet protocol, which uses a dedicated line for data transmission, or the less common Power line, which uses the electric signal of the power line as a carrier of data, while, at the same time, providing power to the devices. It is common to have wireless networks supported by these wired networks, so that portable devices can also integrate the network. Moreover there should also be a gateway through which devices and users inside the environment access the outside network. Regarding the sensorial network, there are several protocols for connecting sensors which are oriented for low power consumption and low bandwidth, since sensors don't need to transmit much data. The result of all these different protocols working together is a very dynamic network which allows very different types of devices to be connected.

Because of the existence of so much different devices communicating, there must be a common language to be spoken between all of them: we don't need just the air so that our voice can go from the speaker to the listener, we also need to share the same language so that we can communicate. The same happens here. Different devices use different infrastructures and different protocols for communicating and there must be a way for making the bridge between the different protocols. There are some possible solutions for fulfilling this goal. One of the most promising ones are the so called Service Oriented Architecture. In this paradigm, what is visible is not the device itself but rather what the device can do, what the device has to offer. It does not matter how the device works or what it is, it only matters what it does. Services are announced in a common language that every device knows and these same services can be used by every device in the architecture. This may be a solution for integrating the heterogeneity that is happening nowadays with the emerging of networking devices. This solution is detailed in the next chapters.

Using

Another important component of an intelligent environment is the interface with the person. Interfaces until now have not usually been very user friendly. For years, one had to interact with computers first through a keyboard, later also with a mouse pointer. However, that is not the most intuitive way, especially for people that are not used to it or have poor contact with computers. Interfaces in AmI tend to be much more user friendly so that everyone can use then, despite their experience with computers. This fact is even more important when it comes to impaired persons, which can have a big difficulty or even be unable to use the common interfaces.

This way, interfaces can be built upon very different devices, depending on the type of AmI and the target population. In a classroom for example, the interface could be an interactive board, while in a house could be a standard desktop computer or a handheld device. The trend is that interfaces get as natural for us humans as possible. Therefore, it is expected that in the future our hands and our body will no longer be stuck to the computer but our interaction will be with our voice, in our natural language and with gestures. This way, we can be doing other things and, nevertheless, interact with the computer.

Another important, although sometimes ignored, characteristic about interfaces is that they are the visible face of any, human interact, system. We can achieve an amazing AmI environment, but if its interface does not correctly explains to its users what it does, if it is not friendly and easy to use, if they feel that they do not have control, then its acceptance will, surely, be poor. The interface should be appealing and dynamic, able to adapt to its user and his specific characteristics. For instance, if the user is an elderly it would be better to keep the interface as simple as possible, giving the minimum necessary information and in a more explicit way, although, if the user is a teenager, which normally have a better understanding about computer systems, the interface should be more elaborate and can provide more information, inclusively in a more rapid way.

Enjoying

Now that we have presented the concepts behind AmI as well as its main components, let us present what this new paradigm can do for us and how we can profit from its use. As already said before, an AmI environment is an extension of a conventional environment, enforcing to appear as traditional as possible, but assisting its users in their day-to-day activities, making their life more comfortable. Taking this aspect in consideration, AmI can be classified in three major types, according to the way it behaves towards its users: decision-support, control-support and assistive, each one of them with its own specific advantages [113].

A decision-support environment objective is to help its users to take a decision within the existing possibilities, or to generate itself some new possibilities or decision scenarios given the user actual context, providing the pros and cons for each one. A simple decision-support example would be the AmI environment generating one or more recipes, based on the goods available on the refrigerator and present them, for instance, in the refrigerator door. A more complex one, as we will discuss further ahead, can be a decision-support environment helping an elder decide what to do on the next weekend, based on factors like the weather, his health status and if there are relatives visiting him or not [114].

A control-support AmI is more oriented to help the user with the control of the environment itself. Already common, yet simple, examples of control-support AmI found in homes or offices are systems that control the presence of people in the rooms for energy saving and personal preferences satisfaction (by turning off the lights in unoccupied rooms, by maintaining a temperature according to the user preferences, etc). One of the major uses for control-support AmI already widely used is the control of HVAC in big buildings like skyscrapers, shopping malls or big factories. HVAC is the acronym that stands for heating ventilation and air condition and it refers to the modern systems we, nowadays, have that control every environmental parameter inside buildings. In standard buildings the objective is to ensure the comfort of the persons living or working there. More specific buildings require more specific parameters. A building like a library or that hosts a server farm would be interested in maintaining the humidity as low as possible while in hospitals, these systems spare are also interested in maintaining a constant temperature and constantly renewing the air. No need to say that this control is made in a completely autonomous way. Least, the assistive AmI aims to assist the user in whatever he is doing. A good example would be an impaired or sick person, who has difficulties in going outside. An assistive system would check the refrigerator and order on-line the goods needed. Another example would be to provide the best route for a person in wheelchair, avoiding stairs or other obstacles. In AmI at home and, more particularly in healthcare, the most helpful will be Assistive and Control-Support AmI.

The main advantage of this paradigm towards the user is that the user is the centre of AmI. For the first time, a computer system is built thinking of the user, with the objective of ensuring his well-being. The advantages are obvious. Computers always were powerful tools but when they become more than tools and start to “live” for us, the possibilities are boundless. The innovation in AmI is that the user doesn’t need do go to the computer when he needs some service from it. In AmI, the computer is all around the user although disguised, and, in the ideal AmI, the user won't even have to ask what he needs. What the user gets from AmI is a better and simplified life. At home, in the office, in the hospital, in the mall, at the theatre, AmI can ensure the comfort and the safety of the people. At work, AmI provides tools, on-time information, support, at the moment the user needs it. The user gets an environment which shapes to his needs, constantly adapting, constantly searching for new ways to help him. More than that, the environment can be extended to the outside world, accompanying him to wherever he goes, providing services on the move using handheld devices. These are advantages that users may already take profit of nowadays.

4.2.4. The Technologies

Domotics

Domotics is a field dedicated to building automation, reason why it is also known as home automation. Its aim is to automate buildings, mainly in the more repetitive tasks that do not need our interaction. Domotics can be found in a wide range of domains: automatic watering and climate control in green houses, lights or climate control in big buildings (e.g. factories, malls, etc), grass watering in a big city or in our homes. This is in fact the main use of this technology nowadays: to automate our homes.

The objective, normally, when automating the home is, first of all, to achieve security, then comfort and at the end energy saving. In the security field we can enumerate a wide number of applications: access control, surveillance, intrusion, gas, fire or flood alarms, among others. In the comfort and energy saving fields, the main task of the technology are to interact with HVAC systems, lights or windows blinds in order to promote comfort to the user and, if possible, to do it in an energy efficient way. Common tasks in this area are to maintain a specific level of temperature or luminosity inside determinate rooms according to the user preferences. Using domotics, we can set specific configurations or preferences and the system automatically takes care of interacting with the appliances in order to achieve that. More than that, the system tries to achieve the desired configuration in the most effective way, something that we humans do not always try to do.

Domotics, by itself, are not enough to build an AmI environment since there must always be human interaction in order to issue the orders to the system. The only change needed to put Domotics to work with an AmI environment is replacing the user issued orders by an automatic intelligent system that acts on behalf him and issues the orders to the Domotics system.

As for the technologies in Domotics there are many standards being used depending on the type of environment pretended. In the field of home automation, the technology which is more used in Europe is X10. It uses the power line to issue commands to appliances and the possible commands are very oriented to the home environment. The fact of using a network available in every house (the power line network) makes it easy to benefit of Domotics and makes it easy to add new elements passive of being used by the system since it is only needed to plug then in the power line.

Ubiquitous Computing

Ubiquitous Computing is a concept introduced in the early 90’s by Mark Weiser, which defended that those days common devices, would, someday, be so ubiquitous that no one would even notice their presence [90, 115-117].

The general vision of Ubiquitous Computing is small, inexpensive, robust networked processing devices, distributed at all scales throughout everyday life and generally turned to distinctly common-place ends, in a way that the interaction with them is simple, transparent and not intrusive but without losing mobility and being proactive (Figure 21 and Figure 22). It can inclusive be saw as an evolution of common distributed systems [116-119].

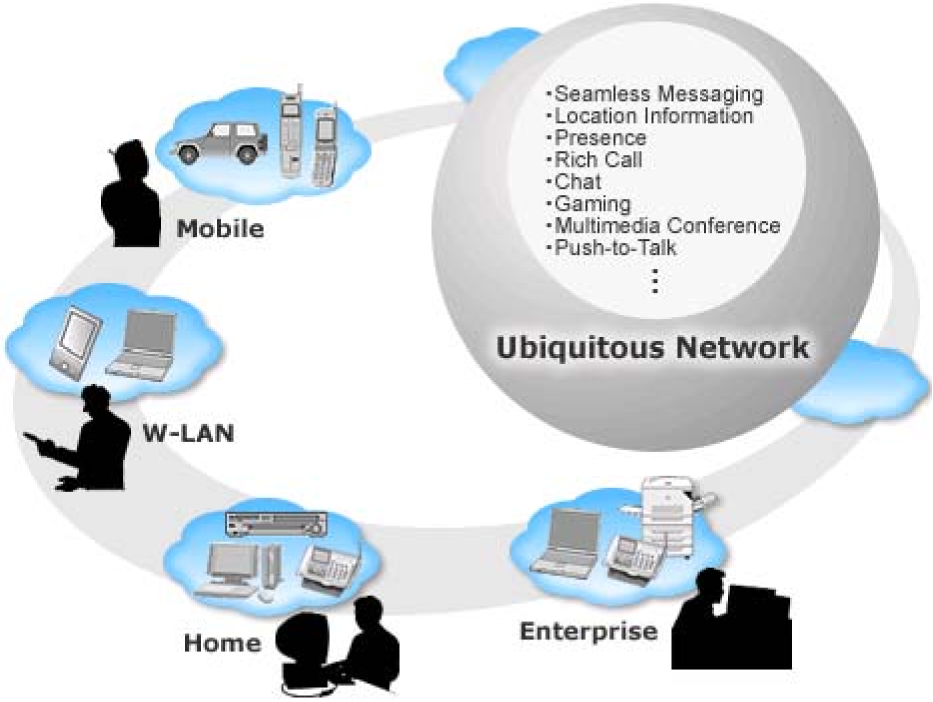

Figure 21- Ubiquitous network sample.

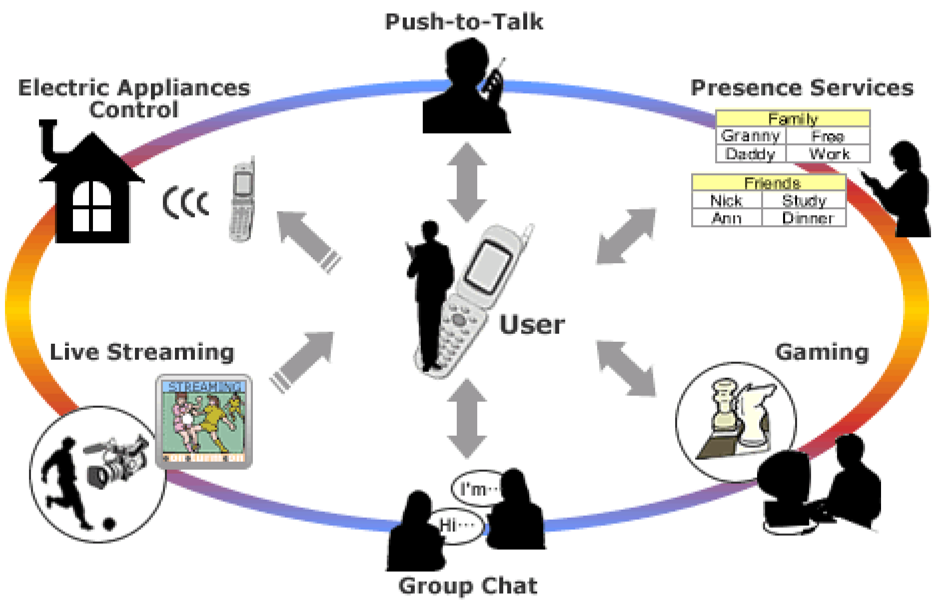

Figure 22 - Ubiquitous computing scenario.

Pervasive Computing

Pervasive Computing, although many times considered a sub-area of it [115], is, nowadays, more than Ubiquitous Computing and refers to a recent trend in which computers are shrinking and hiding so much that in a near future it is expected that we interact with them without even seeing them or even without knowing it [118]. The objective is to create environments that join in an integrated way humans and computers minimizing, as much as possible, the awareness of our interaction with them. Traditionally, computers have always been a tool which had its own environment, its own reality and humans had to transfer themselves to that reality and interact with them according to it. With this new paradigm, the computer and human environment are to be seen as one [119, 120].

The evolution started when computers began to be interconnected through networks, being the Internet the most visible example. At this point computers started to be ubiquitous but were not, however, pervasive. When the mobile technologies developed, mainly on the areas of wireless communication and with the advances on miniaturization, Ubiquitous Computing became pervasive.

When talking about Pervasive Computing we must also talk about Mobile Computing and all the necessary support for interoperability and scalability, as well as about miniaturization and some embedded intelligence. We can therefore say that Pervasive Computing is made of four main areas which are: devices, network, middleware and applications [119, 120].

Devices tend to be the common devices that we have nowadays, however with enhanced computational power, smaller and with more functionalities. Each day environments have more and more devices, and these same devices are becoming computational system with wireless communication capabilities. These devices are also gaining embedded intelligence, for instance, the navigation assistant (or GPS) showing us the ideal path based in economic concerns or the refrigerator issuing an alarm when its door is open for more than a minute. These are all small things, which sometimes pass unnoticed, that are becoming common, but are also the base in which we start to build intelligent environments, missing only their interconnection.

Networks are, nowadays, very common and widely available and are needed for acting as a backbone for all these devices to be interconnected. However, as devices are growing in number and functionalities, networks must also grow. More than just grow, networks must also provide tools for achieving the interoperability that is necessary between these devices. This is even more important when we are nowadays talking of devices that can be so different on its functionalities or communication protocols.

Normally, when we talk about Pervasive Computing, we tend to forgot the middleware layer, which is, however, of great importance since it allows developers to build more powerful and faster applications. The objective of the middleware layer is to hide all the heterogeneity beneath, hiding the many different devices, and show, instead, a single "programmable environment". We do not see the devices one by one, but rather see the services that these devices can provide and work with them. These applications are what give life to the network of interconnected devices and allow their functionalities to be fully exploited [119, 120].

In the future some major challenges are expected in this area (Figure 23), being one of the most important: how to deal with so many different devices and functionalities. Will our "networks" be enough? Other important evolution that is needed is in the miniaturization of batteries. In almost every mobile device, batteries are by far the biggest component which decreases significantly the possibilities of hiding these devices on the environment. We can for example think of wireless sensors which battery is far bigger than all the rest together, including the networking module. Another important challenge to address is how to deal with so much different architectures and types of devices, each one having its own protocols or interaction mechanisms. One cannot create high level APIs for interconnecting each new device with existing ones. In this field, as always, the solution will have to pass by the adoption of standards, as long as there are only the needed standards.

One of the main contributions of Pervasive Computing is the creation of enhanced environments that look just like any normal environments. This is very important, mainly when we are talking of environments that are directed to older people which, sometimes, are even technophobic, i.e., are very reluctant to accept new technologies and to use them. These pervasive environments can even be the only way of an elder person having such a computer system “controlling” its life [119, 120].

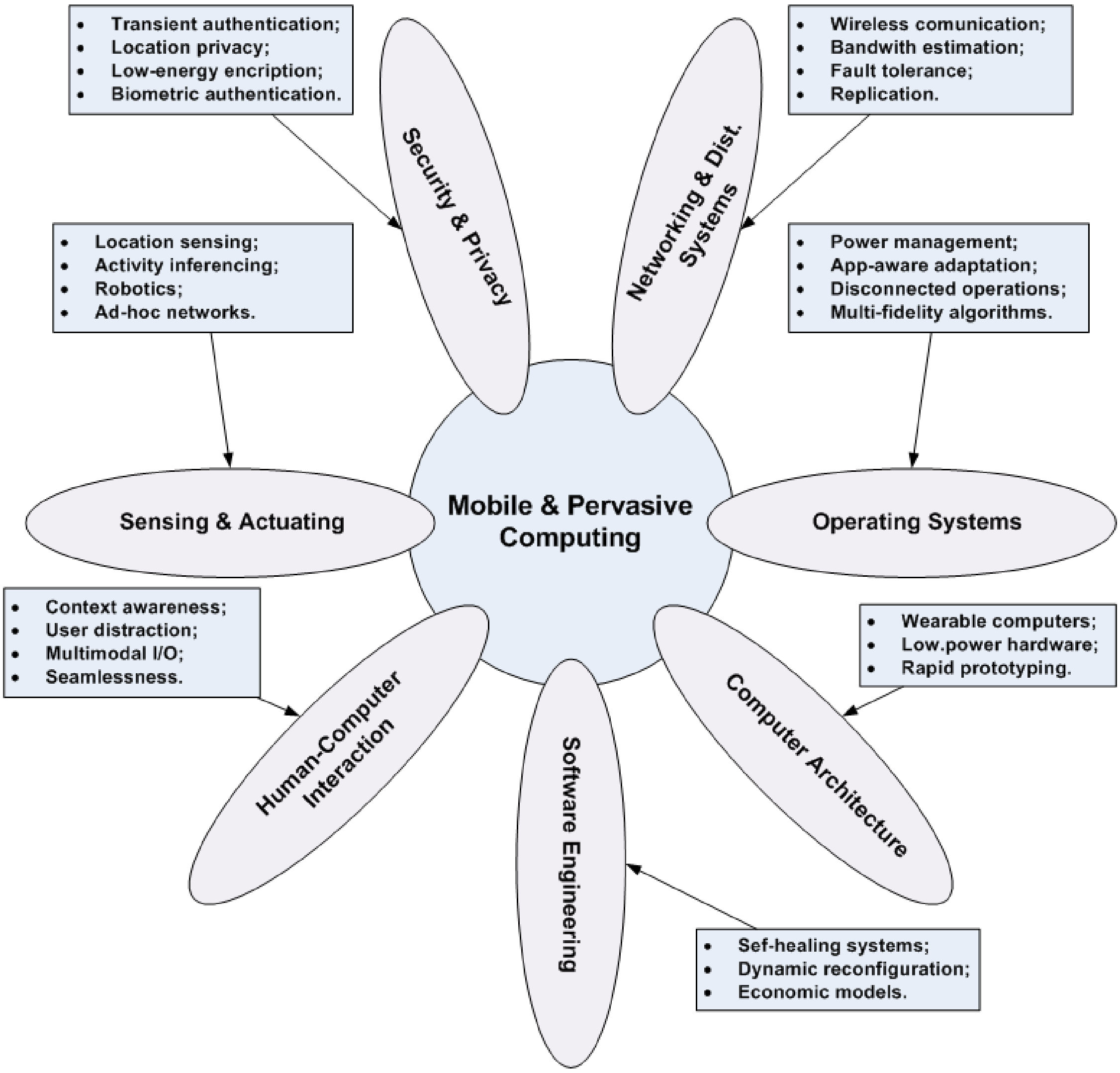

Figure 23 - Mobile & Pervasive Computing research challenges.

Context Aware Computing

In Context Aware Computing (CAC), computers, as the name says, are aware of some context, i.e., they are able of reading and interpreting some context [119, 121, 122]. So, before continuing, it is important to define what is context. Context can be defined from several points of view, but, ultimately, it is accessory information that can be used to describe some object. In computing, context can be described by uptime, bandwidth, network connectivity, available resources, etc. If we think of ourselves, our context can be described by our location, the action we are doing, the people we are interacting with or even our social status. In our homes, the context can be described by factors like environmental parameters, appliances being used or noise level. The historic context is another example that is not much used by existing applications, but that may be of high importance: an object may be described by the changes that occurred on its context along the time and that information could even be used to predict the occurrence of events that tend to repeat with time [119, 121, 122].

This information about context can then be used to develop what is called context-aware applications. These applications use the information about context to operate. They can either, accordingly, react to changes in the context or they can provide the information to other applications that require it. How the information is used depends on the type and objective of the applications. If the application is dealing with an impaired person then the information can be used to provide adapted services having in mind the impairment of the person. There are also applications that automatically adapt their interfaces according to the information about the social context of the user, like his age. If the context is the working environment of the user, then the information can be used to assist the user on its job, according to what he is doing at each specific moment.

However, to acquire such information about context it is necessary to establish a bridge between implicit information that is out of the computer reality and transform it into information that can be understood and used by the computer.

This bridge depends, once again, on the type of context, however an important component is usually present: the sensor. When we are dealing with a home context or even with the person context, sensors are of great importance. They can provide, as disperse information, as temperature, humidity and luminosity, among others, of the environment or heartbeat, body temperature, blood pressure, among others of the user health state. Additionally, information about the user's social context can be retrieved from user profiles, which can store important data and even his preferences. In the work environment, information about context can be retrieved, for example, from a glove which interprets the movements that the worker is doing and forwards that information to the system, which then decides what to do with it. Information about context can even be retrieved from the user agenda or by scanning nearby Bluetooth devices for determining with whom the user is interacting or which persons are around in order that specific services can be provided.

It is not difficult, therefore, to see that context is a very important concept in AmI. Thru the use of the information about context, services can adapt to the person the environment is dealing with. More important than that, using information about the context of the user and its surrounding environment, the system has enough knowledge about his state of health, his security status and can react accordingly or provide that information to other applications so that they can take appropriate measures.

Mobile Computing

The term Mobile Computing describes computing devices that can be used on the move. This, evidently, opposes to what happened until now when computing devices resumed to computers standing still in our houses. This started to change in the 1990's, probably with the appearing of the first mobile phones and later the smart phones, PDA, etc [115, 116, 123].

This field started with the need to move devices to better locations, i.e., with better resources for example. This movement can be either physical or logical: one can move a computer to a better location or change an instance of a user or an application to a better location. The difference is that a physical system can move anywhere while a logical one can only move to a different computer system. That computer system can however, be a mobile one. This of course raises lots of new challenges to address. Entities must be identifiable while changing geographical location or while changing networks. For instance, how do we deliver a message to an entity that is constantly moving? When an entity is not in a network did it finish its execution or it just changed its logical location? These are the main subjects of investigation in this area (Figure 23) [115, 116, 123].

However, the trend that is more nowadays visible is that one can take computational power with us everywhere we go so that we can use it when needed, as we do in our homes or in our workplace. The most common examples are smartphones, PDAs, netbooks and notebooks, in which we have a considerable computational power and portability. One can be in the train or in the car, travelling, and use these devices in a normal way, even connecting to a wireless network and having access to the Internet. The most recent advances in this field are in the area of Wearable Computers which intends to merge computers with our clothing so that they have embedded computational power. That is at the time, the most natural way of transporting computational power since it releases our hands from any device and enables us to perform our common tasks.

However, all the mobile devices on a limited power supply. The batteries were the technology which enabled Mobile Computing and are nowadays the ones that are limiting its evolution. In fact, as mentioned in the previous section, batteries did not follow the pace of evolution of other technologies and nowadays, although still big in size, do not provide the need and desired capacity. This significantly diminishes the potentiality of some mobile devices. Another important technology for the evolution of Mobile Computing was the communication technology. It evolved to a point where we can have connection to a network almost everywhere. It is common to find public buildings with wireless networks which the devices can connect to and they are also common in our houses and workplaces. In the last case, one can connect to a GSM or UMTS network [119].

But what is the importance of Mobile Computing in the field of AmI? The most important contribution is probably the wireless sensor. It would be impossible to constantly monitor the vital signs of a person if one did not have wireless sensors. With this technology, a person can be doing its day to day freely, while their vital signs are being monitored. Devices with this objective have even been already embedded in clothing so that all one has to do to monitor the vital signs is to wear an apparently normal jacket. Another important development in this field is the GPS sensor. One can have nowadays a GPS sensor embedded in a PDA which has also wireless networking capabilities and this way implement a wide range of services. These services are not merely monitoring the position of the person but also location oriented services. These are services that change and adapt themselves to the location of the person or services that become available or unavailable according to the same parameter. As an example, one can think of a city guide installed on a PDA and using the GPS signal to point you to the closest interesting location, according to your preferences.

The evolution on this field will generate smaller devices with enhanced capabilities and portability which will enrich our experience with computer systems. Devices will get so smaller that we will wear them and even use them inside our body, radically changing the way we user computers.

4.3. Ambient Assisted Living

AmI has, as already presented in this chapter, many uses in a wide domain. However, when we think of the specific case of health care provision, AmI can really make the difference. The proof is the number of projects that keep appearing that try to merge Ambient Intelligence in the health care sector, as we will present later on.

With AmI ability to assist people, we can think on the enormous advantages, mainly for impaired, convalescent, pregnant and elder people. In fact this sector, and mainly the people involved, has much to profit from this paradigm. For instance, with a constant monitoring from an AmI environment it is possible to provide to this, in need, persons a very important feature: safety. The fact of knowing that, despite being physically alone, if something happens to them, help will arise surely brings safety, or at least a safety sensation, for the ones in need and their relatives. Above that, AmI can also provide comfort. When interacting with the environment, these kinds of systems can change it so that it is always in line with the user preferences or needs. Being in an environment that constantly monitors them and responds in case of need, these persons can stay at their homes, with its routine and nevertheless live calmly.

Ambient Assisted Living (AAL) can be considered as a sub field of AmI. It is more specifically dedicated to assist people on its day to day, mainly in the health care area. It builds on recent developments of IT and aims to promote the advantages that these technologies can have, mainly for the elderly. In this chapter, these technologies are detailed. By bringing together all these technologies, the result is a paradigm which has the better of each one working to assist the user. We may say that AAL aims to prolongate the time people can live in a decent way in their own home by increasing their autonomy and self-confidence, the discharge of monotonously everyday activities, to monitor and care for the elderly or ill person, to enhance the security and to save resources [124].

But these new paradigms in the health care sector do not have to be applied just to home care. These new kinds of systems can and have been successfully applied in environments like hospitals, leisure centres or elder houses. In these environments, they are not only enjoyed by the users but also by the persons working there, resulting in a better care being provided. We can think of a hospital environment where the vital signs of the patients are constantly being monitored and alarms raise in case of danger. We can also think of nurses scheduled tasks being dynamically adjusted according to the patient’s state or location. Another example would be to automatically adjust the environment in the room of each patient according to its health status. But maybe, more important than all that is the facts of knowing at each time the context of the user. Having constantly knowledge of its location, the state of the environment around him and its own state may be very important. As we can see, the possibilities are infinite and result in many profits to all the persons involved. These profits should be deeply exploited so that we can make the best use of the technologies we have available nowadays [125-127].

When designing an AAL environment there are some challenges that are raised by the heterogeneity and number of devices and technologies present. These devices must interact and exchange information and compatibility must be ensured between the different technologies. More than that, organization must be achieved so that an AAL environment is not just a bunch of devices interconnected but instead, a group of devices working together and sharing information towards a common goal. In this section we talk about the main technologies that can be used in a AAL environment and how to organize it from the architecture point of view [125, 128-130].

4.4. Related Work

We are now going to present some related projects that were studied and analyzed during this work. Although they vary from AmI to AAL, all of them cover complementary areas with the objective of provide benefits for its users. They are the major evidence that this is an in development area and that many other researchers believe that the solution to the presented problem may pass by the use of new technologies.

Amigo – Ambient Intelligence for the networked home environment[5]

This project was born as a consortium of fifteen European companies who joined efforts to exploit the potential of, nowadays common, home networks in order to improve people's lives. The general idea was to be able take profit of, nowadays also common, network connection that almost all equipment has. However, the complex installation procedures, the lack of interoperability between different manufacturer's equipment and the absence of compelling user services make very difficult their interoperability. By focusing on solving these key issues, the Amigo project aims to overcome the obstacles to widespread acceptance of this new technology. The project objectives passed by develop open, standardized, interoperable middleware and attractive user services, thus improving end-user usability and attractiveness thus showing the end-user usability and attractiveness of such a home system by creating and demonstrating prototype applications improving everyday life, addressing all vital user aspects: home care and safety, home information and entertainment, and extension of the home environment by means of ambience sharing for advanced personal communication [131].

Oxygen[6]

This MIT project has as main objective to make technology available everywhere. In their vision computation will be human-centred. It will be freely available everywhere, like batteries and power sockets, or oxygen in the air we breathe. It will enter the human world, handling our goals and needs and helping us

[5] URL: http://www.hitech-projects.com/euprojects/amigo/
[6] URL: http://www.oxygen.lcs.mit.edu/

to do more while doing less, unlike what was the reality for over the last forty years, which computation has centred about machines, not people.

Oxygen approach is to enables pervasive, human-centred computing through a combination of specific user and system technologies. Oxygen's user technologies directly address human needs. Speech and vision technologies enable us to communicate with Oxygen as if we're interacting with another person, saving much time and effort. Automation, individualized knowledge access, and collaboration technologies help us perform a wide variety of tasks that we want to do in the ways we like to do them.

I.L.S.A. – The Independent Lifestyle Assistant

This initiative from University of Minnesota [132] has as main objective to study the response of elderly to a monitoring computer system inside their houses and determine how such these systems can help them. They do not only determined which are the main problems of elder people living alone, but they also have implemented parts of a monitoring system, recurring to some test houses to watch its behaviour in real conditions. This AmI application was one of the first to have in consideration not only the elder living alone but also their caregivers as a part of the solution.

ReachMedia[7]

This, another, MIT project [133] consists on an RFID equipped wristband (Figure 24) to provide us with on-the-move interaction with everyday objects. Usually, there is a lot of information related to the objects we deal with every day, mainly on Internet but it is normally only accessible through a computer. This project aims to present us that information wherever we are, in real time, without driving our attention from what we are doing. The system is built around a wireless wristband

[7] URL: http://fluid.media.mit.edu/projects.php?action=details&id=14

with an RFID reader and accelerometers. The wristband detects physical objects that the user is interacting with, and retrieves relevant and personalized information via a smart phone. The user can then have its hands and eyes free interaction with the application by using a unique combination of slight gestural input and audio output.

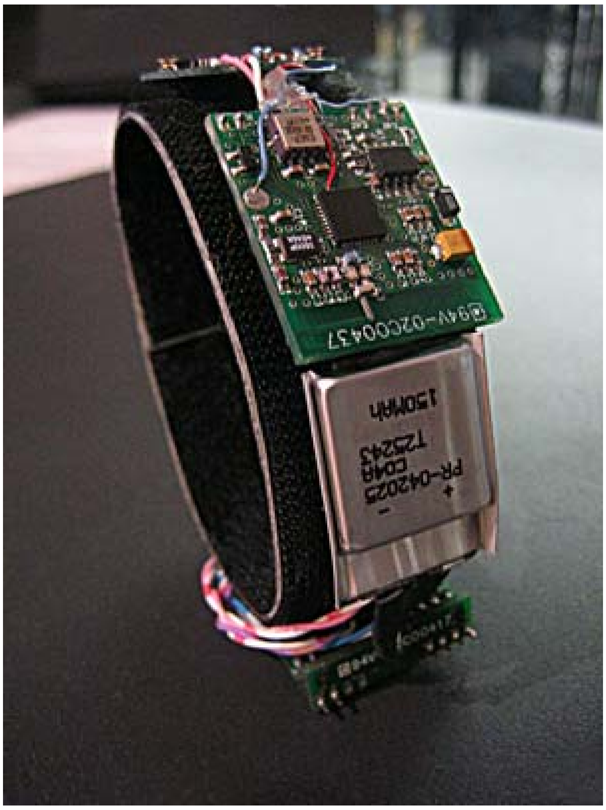

Figure 24 - The ReachMedia wristband.

RoboCare[8]

RoboCare project goals are to build a multi-agent system which generates user services for human assistance. The system is to be implemented on a distributed and heterogeneous platform, consisting of a hardware and software prototype. The use of autonomous robotics and distributed computing technologies constitutes the basis for the implementation of a user service generating system in a closed environment such as a health-care institution or a domestic environment. The fact that robotic

[8] URL: http://robocare.istc.cnr.it/

components, intelligent systems and human beings are to act in a cooperative setting is what makes the study of such a system challenging, for research and also from the technology integration point of view.

FUSION@

FUSION@ (Flexible User and ServIces Oriented multi-ageNt Architecture) [134] proposes an new, SOA based, architecture for the development of AmI systems, based on ubiquitous, simplicity and simplicity and for a new and easier method of building distributed multi-agent systems, where the functionalities of them are not integrated into the structure of the agents; rather they are modelled as distributed services and applications which are invoked by the agents acting as controllers and coordinators. With this approximation they hope, not only to overcome the malfunctions and crashes in multi-agents systems developed with current agent's platforms, where developers tend to integrate all functionalities inside the agent's internal structure, creating agents with high computational requirements but also to optimize usability and performance [134, 135].

Telecare[9]

Telecare [136] project main objective is to develop a configurable framework for assisting elderly, based on the integration of a multi-agent and a federated information management approach. The results are services likely to be offered by the emerging ubiquitous computing and intelligent home appliances, which may be useful for the elderly. With this approach, the project expects to address issues like elderly being delocalized from their homes and the provision of autonomy and independence. To achieve these objectives, this project is based on tele-supervision

[9] URL: http://www.uninova.pt/~telecare/

and tele-assistance technologies. A virtual network is created, which connects the elderly home, the relative's office, the care or leisure centres, a virtual shop among others. The project claims that it is already possible, nowadays to create such a network that can provide remote health care to elderly, namely because of the current development of internet-based infrastructures. The development of such projects is one important step towards countering the problems of ageing population and possible elderly marginalization [25, 137].

4.5. Conclusion

Several authors and/or developers, as presented, see in the new technologies the solution for the ageing phenomena, and for the problem of health care provision associated with it. As you can see, the technological base solutions are already available, but there is still the need to congregate them with a single purpose: the provision of dignified and quality health care for the ones in need, even if remotely, and the achievement of the needed active ageing. In the next two chapters we will present how the VirtualEcare project arises to contribute to this purpose.

Chapter 5

VirtualECare

5.1. Introduction

The VirtualECare project [138] is an intelligent multi-agent system able, not only to monitor, but also to interact with its users (patients and/or relatives). It can, and should, be interconnected with other computing systems running in different health care institutions, care centres, leisure centres, training facilities and/or shops. It is composed by several components/modules, interconnected through a network (e.g., LAN, MAN, WAN), having each one a different role (Figure 25):

- **SupportedUser –** elderly people with special health care needs, whose clinical data is sent to the CallCareCenter and redirected to the Group Decision Support System. This user should be constantly monitored, inside and outside its environment in order for the data to be provided in real time to the interested parts. It is the central component of the architecture and all the other components must work together to ensure its safety and well being;

- **Environment** – the elderly natural environment, provided with sensors, with the clinical data being sent to the Group Decision Support System through the CallCareCenter, with the remaining ones being redirected to the CallServiceCenter. The data provided by this module must also be constantly available and analyzed so a reliable network connection is mandatory. The environment can be the user home, a hospital room, a day centre, just to name a few. The main actions of the other components towards the environment are to maintain the comfort and security parameters;

- **Group Decision –** This module is responsible for the long term planning regarding the health care of the patients. It should be composed of specialized staff like nurses and doctors as well as Recommendation

Systems and tools for time and space distant meetings. In the overall this module should be able of planning all the issues related to visits to doctors, tests, automatically scheduling all this according to the user agenda;

- **CallServiceCenter –** Entity with all the necessary computational and qualified personal resources, capable of receiving and analyze the miscellaneous data and take the necessary actions according to it;

- **CallCareCenter –** Entity in charge of the computational and qualified personal resources (i.e., health care professionals and auxiliary personnel), capable of receiving and analyze the clinical data, and to take the necessary actions;

- **Relatives –** individuals that may have an active role in the supervising task of their love ones, being able to give precious complementary information about them and being able to intervene, in a complementary way, in specific crises (e.g., loneliness). By being an important part of the equation, the relatives should also have access to the health status of the patient so that they are constantly aware of its situation.

In order to the Group Decision module take the necessary decisions it needs the **SupportedUser** digital profile, to better understand his/her special needs. This digital profile should be a combination of the ECP with their own personal experiences and preferences (e.g., musical, gastronomic, environment), thus providing the tools and methodologies for creating an information-on-demand environment that can improve quality-of-living, safety, and quality-of-care.

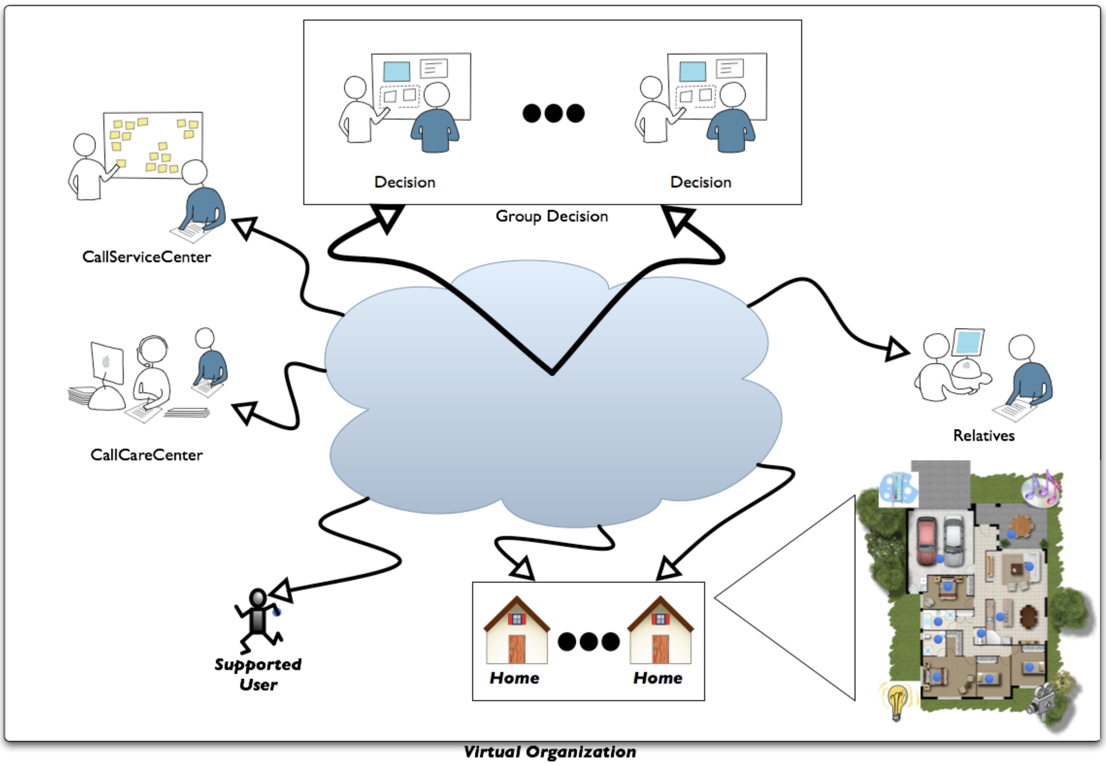

Figure 25 - VirtualECare System Overview.

Use Scenario

The main goal of the VirtualECare system is to improve end user's quality of life allowing them to enjoy the so-called active ageing. To achieve this purpose we will take advantage of the enormous evolution new technologies have assisted in past years. To better understand the amplitude of the VirtualECare system, let's consider the following scenario [113]:

"John has a heart condition and wears a smart watch that takes his blood pressure three times a day. His watch also reminds him to take his medications and the proper dosage for each medicine. If anything is unusual, his watch alerts both him and the GDSS. John also has a PDA that contains an interactive health control table where he can monitor his medications, schedule his exercises, manage his diet and log his vital statistics. The GDSS has access to this table so they can keep up to date on his condition. Currently, John's watch detects that his blood pressure is unusually high.

The GDSS receives a grade B and calls him to check what might be causing his high blood pressure (diagnose). At the same time John receives a checklist of possible causes to review. John compares this list to his own health control table in his PDA to see what might be wrong. Meanwhile, the GDSS decides John should come to an appointment."

The presented scenario requires an infrastructure to support all the several intervening and provide basic interaction mechanisms. On top of this infrastructure an extensive number of services can be deployed and/or be developed.

5.2. The Infrastructure

Considering the above presented ideas and use scenario, we have designed a first approach of a generic, configurable, flexible and scalable infrastructure as presented in Figure 26. It is expectable that on top of it an extensive number of services will progressively arise. These services must, and will be, developed as Web Services, thus allowing the coexistence of several, different, software languages interacting with each other through the use of common messages.

The fundamental components of the proposed infrastructure are:

- **Secure Communications** in order to all the components interact, a secure communication infrastructure is mandatory;
- **Management** responsible for configure and monitor the involved components;
- **Resources** responsible for every component registration and manage the resources catalogue;
- **Authentication** every component must authenticate itself in order to be able to interact with others;

- **Recommendation** responsible to make problem solving recommendations;
- **Monitoring** responsible for interacting with all the sensors and report its results to the GDSS;
- **GDSS** responsible for the Decision Making.

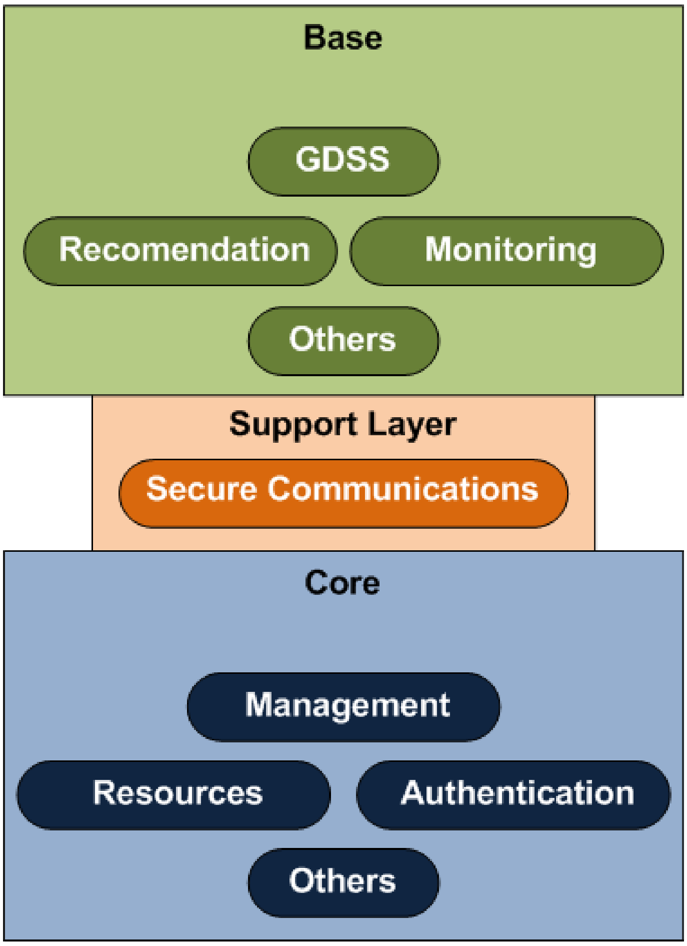

Figure 26 - VirtualECare System Infrastructure.

5.3. The Architecture

On top of the above presented infrastructure we idealized a dynamic distributed architecture composed of a series of different components geographically separated (Figure 27). The dynamism is needed in order to allow components, not only to enter and leave it at any time, but also to adjust or even change the provided services. The architecture main components are: the Supported User and his/her Premise (SUP), the Monitoring System (MS), the Recommendation System (RS), the Group Decision Support System (GDSS) [139], the Database (DB) and the HL7 Translator module [9], among others, which leads us to an ubiquitous computational environment.

Each one of these major components may differ in its implementation, functionality, programming language, etc., but they all have to "talk" the same language (e.g. exchanged messages) making, also, the architecture heterogeneous.

These are the main issues we have and are addressing in our work: how to make our architecture distributed, modular, dynamic, extendable, flexible, scalable and compatible. To achieve these desired capabilities, we are adopting open and widely used technological standards, such as OSGi, R-OSGi, FIPA and Web Services paradigm. The last one is mainly used to ensure communication and compatibility between the different components, as Web Services can be seen, simplistically, as a platform independent way of sharing information over a network, making them ideal for this kind of systems.

The Supported User

The iGenda is one of the base software's in the Home and Relatives modules of the above presented project in conjunction with the monitoring one [129]. Its main objective consists in provide an intelligent organizer and/or scheduler and/or reminder to all the other modules of the VirtualECare project (e.g., GroupDecision, CallCareCenter) in order to allow them to manage the day-to-day diet, medication, activities, tasks and free time of the monitored users [129]. This way, he/she will always know, in real time even if changes are inflicted by one of the several modules, what will be the next "task" to perform.

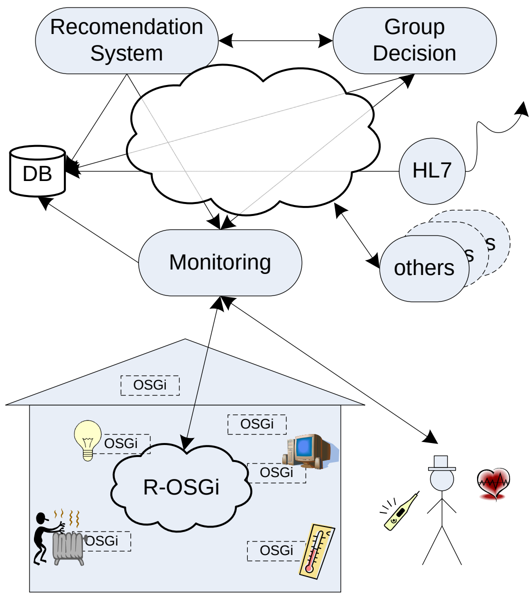

Figure 27 - VirtualECare System Architecture.

The major goal is to create a product that will help its users to remember important information, events or tasks, or, in other words, to provide in-the-fly memory assistant. It can help, specially, people with memory loss (partial or total), by keeping his, all day, events and warn when the time to execute them as arrived, providing an increase in the quality of life and also a greater independence to the user.

This module will also be able to receive information delivered by the remaining VirtualECare platform modules and organize it the most convenient way, given predefined standards. This way the user will not have to be worried about planning or scheduling events and tasks. The iGenda intends to be easy to operate by its users and will play an important role in his day-to-day life, being responsible for planning it (or week, or month). As an example, if the Group Decision module decides that the user must visit a medical centre the iGenda is prepared to receive the respective information and conveniently process it, according to its level of criticism, and reorganize the user schedule in a short period of time.

In order to be fully integrated in the VirtualECare architecture the iGenda archetype has to respects its standards protocols of communication [140]. Moreover, it is expected that the user is always in communication with the system, in order that any event of extreme importance could be, at any time, added in its agenda [126].

This system is organized in a hierarchy of states and events intended to deal with the information received (Figure 28). To fulfil all the work mentioned, four sub-modules will be created: Agenda Manager, Free Time Manager, Conflicts Manager and Interface Manager.

Agenda Manager

The Agenda Manager (AM) is the bridge between the remaining VirtualECare system modules and the scheduling system, using the communication infrastructure to receive and send information. Therefore the AM is the iGenda starting point.

The AM consists in a two stage sub-module application. It manages the incoming, to be scheduled, events and programs the time that triggers the Free Time Manager (FTM). It also supports the receiving of multiple events in the same message in order to increase the overall system performance.

When a new task/event is received, the AM parses in order to be processed by the Conflicts Manager (CM). After being transformed, the data is delivered to the CM to be continuously assimilated and processed.

The FTM is activated by the AM. The AM contains an internal clock that is configured for each user. It is defined a period of execution for the FTM, and when that period is reached the AM orders its execution.

There will also be a set of rules, implemented in Prolog Language, which will be used in the CM, assuring that the new arrived events will be correctly inserted in the user agenda. When a level 1 (high priority) hierarchy conflict is detected, the system will return a message to its sender containing a high priority events overlapping warning, in order to allow the sender to reschedule it to another time.

This module is also capable to communicate in with the remaining modules of VirtualECare platform, in order to report possible detected incoherence's during the processing phase of the received messages.

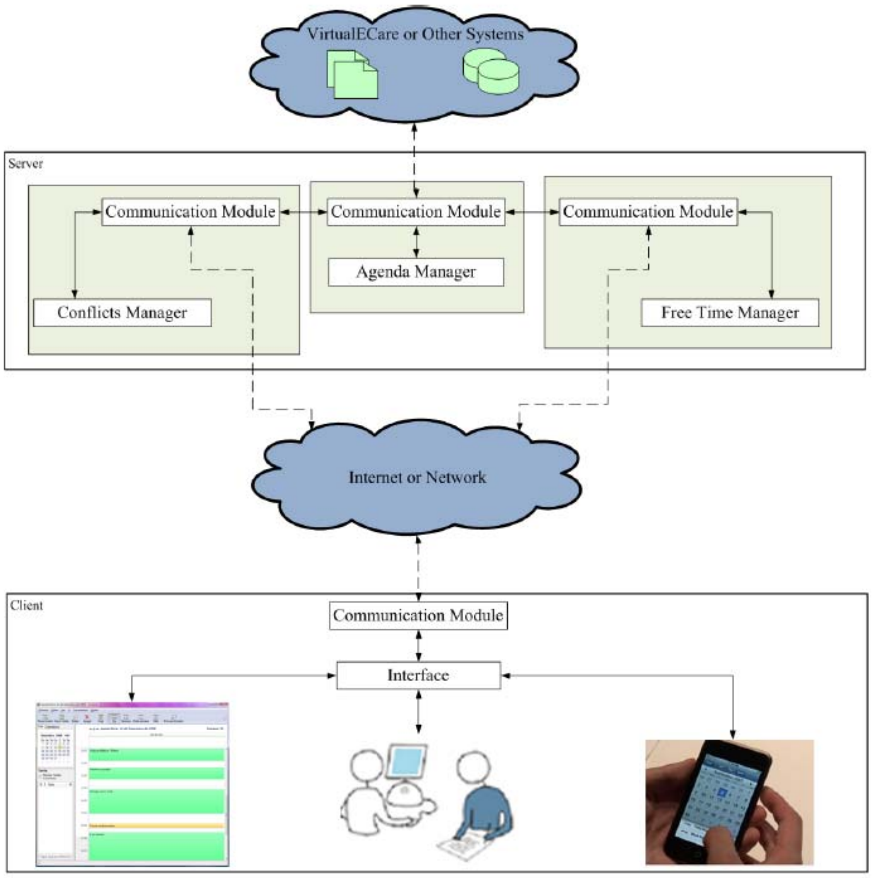

Figure 28 - iGenda Architecture.

Free Time Manager

The Free Time Manager (FTM) will schedule recreational activities, according with the user health condition, in the free spaces of its calendar, in order to keep him occupied, increasing his well-being. These activities may be a very important step in order to allow an active ageing, aiming to create social and cultural dynamism, physical and educational activities, thus obtaining conviviality with others. These recreational activities are meticulously planned for each individual user based in his needs and preferences. To achieve these results, the FTM has a database which contains user's information, as, for instance, the user's favorite activities, previously approved by the Decision Group module, thus, allowing him to have, according to its eventual limitations, the best choice of physical and psychological activities at each time.

Initially we where seduced to use Scheduling Techniques (ST) to obtain the best possible arrangement of all the activities. However, we reached to the conclusion that it was not the best way of engaging the problem. We realized that implementing the user preferences system (presented above), in which the user chooses from a Decision Group module approved list, his favorites activities, it is useless to use any ST because we already have a hierarchy list and once we do not have a equal timed scheduling. We then verified that using a more simple arithmetic solution: pattern matching, was much more efficient. We simply have to match the gaps available with the time consumed by the activities from the hierarchy, pre-defined, list.

Conflicts Manager

The Conflicts Manager (CM) main task is to make sure that there are not any over-lapping activities. This module schedules or reorganizes events that are received from the AM, always verifying they are in accordance with other, already scheduled, events. If there a collision is detected, of different hierarchic events, it can be simple decided by methods of intelligent conflicts management (the most important activities overcomes all the other ones), however, in case of overlapping events with the same priority level, the error must be reported to the GDSS (Group Decision module) in order decide how to resolve that, specific, collision.

Interface Manager

The iGenda sub-module interface must be, above all, intuitive and easy to use. In the implementation phase a technician should introduce the user preferences in the system, which will then be carefully analyzed by a panel of medical specialists (in the Decision Group module) according to the user state of health.

The Interface consists of a main window which contains the weather and time information, and a warning notifier. This warning notifier gives the user important information about schedule updates, like new activities/events and/or important information sent directly to him (e.g., a critical warning from the GroupDecision or the CallCareCenter modules). It has also a calendar window, which is meant to be opened by the, already present in the operating system, default calendar software. The compatibility with this software is guaranteed by the using of the standard iCalendar Calendar Data (ICS) format. Is has also been developed a variable warning system responsibly to, properly, warn the user of a specific event. This warning system can be configured in two different states: always active or selective mode. In the first state, the user will always be notified in the beginning, or in the previously time it has been configured, of a specific event. Otherwise, in the selective mode this warning system has some "Intelligence" associated, been able to, through the real time analysis of the available health sensors, decide if the actual activities, not previously scheduled, is more or less important than the schedule one and act in line. For instance, if the user is actually resting, information obtained from the state of the available sensors, and the time for a activity, let say walking, is coming, the warning systems may decide that resting is more important than walking, at the present time.

The Environment

The user environment, which is much more than solely his house, must include the necessary options in order to guarantee his security and well-being according to his needs. To achieve this ideal environment, we have chosen to use the AmI paradigm and we have idealized an Assisted Living Environment (AAL). The idealized AAL must be able to accept a very heterogeneous group of devices and technologies, which we call components. These components should coexist and work together, and in order to that to occur, the architecture must be able to provide the necessary means, thru communication and information sharing mechanisms. It should also be highly expansible in order to be easily adapted to new component, passive of being used, that may appear in the future. This expansibility, should also be easy put in practise, i.e. it should be easy to add new components to the architecture without having to mess around with the existing ones or with the base architecture itself. With the possibility of adding new devices, the architecture must also be able to ensure the compatibility between all of them, the new ones and the already existing ones. As any distributed architecture, it must also be scalable in order to be able to grow, as needed. Resuming, we believe pretend that our AAL architecture should have the following main characteristics: dynamic, modular, expansible, flexible, scalable and compatible.

The above characteristics where the ones we had in mind when we were searching for the base technologies for our AAL architecture. After a wide search, we have realized that the OSGi[10] technology fitted all of the requisites with the advantage, for us, of being entirely made in the JAVA Programming Language[11] [141].

OSGi (or OSGi Alliance) is an initiative that intends to establish standards in java programming, highly specific, catering for the sharing of java classes, that may be achieved in terms of a services platform paradigm [141, 142]. With OSGi we intend to build applications as an infrastructure to support a generic, platform independent framework. The result is a Service Oriented Architecture.

Adopting OSGi

We are now going to describe the major role that OSGi will play in our AAL architecture. We have a group of components which are part of the environment that must be connected to each other. This fact means that we must have a common base language and a common base communication channel in order to allow all of them to

[10] OSGi – The Dynamic Module System for Java, http://www.osgi.org
[11] URL: http://java.sun.com

cooperate and share information, thus fulfilling their common goals. Our objective is to be able to connect a, growing, group of heterogeneous components, with the most diversified tasks, in an integrated way. The contribution of OSGi will be at this level.

However, the adoption of OSGi was not linear, and faced us up to some challenges. The most obvious challenges where how to make the components based agents, used in our architecture components, OSGi compatible and how to integrate, in the same architecture, components as distinct as: sensors, software based and databases. On top of that, our agents can be very different between themselves, including the signatures of the methods they declare, so we must also have in consideration that every agent should not only be compatible with each other, but also with regular OSGi defined bundles. These issues and the solutions we adopted are addressed in the following sections, where we describe how we have made our architecture OSGi compatible.

Multi-Agent Systems and OSGi

Adopting OSGi on each component of our architecture forced us to find a way to make our agents compatible with OSGi bundles. Our aim was to make agents functionalities (i.e. its methods) accessible as services to other bundles (or agents).The most obvious path to pursue was to simple convert each agent into an OSGi bundle, but this path, not only would have increased the development time, but would also make us throw away the majority of the Multi-Agent Systems (MAS) based methodologies for problem solving advantages. After some internal discussion, our verdict was to create a completely new OSGi bundle which would make the bridge between regular, OSGi compliant, bundles and our, non OSGi compliant, Jade[12] [143] platform agents which we baptized: MAS bundle (Figure 29). Basically, this bundle is able act as an Agent Container (AC) and implement the methods declared in the interface of the agents in that AC as if they where its own services. Additionally, it is able to start and stop agents, which in practice, correspond to the start and stop of

[12] URL: http://jade.tilab.com/

the services provided by them. The MAS bundle, upon the reception of an invocation for an offered service from any other OSGi compliant bundle, acts as a proxy, sending the invocation to the correspondent, non OSGi compliant agent, and delivers the respective result to the original calling bundle. It must be noted that an agent, when trying to satisfy an invocation, may require services provided by other, currently available, OSGi compliant bundles. The MAS bundle also makes this a possibility [144].

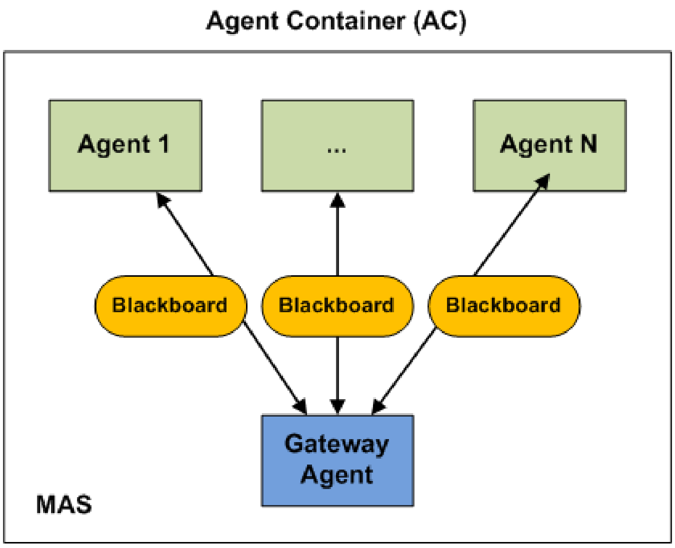

Figure 29 - MAS bundle internal architecture.

In a more detailed description, the MAS bundle is able to load the agents declared in his AC and register its services by declaring them on its interface and making them visible to the other bundles as regular OSGi services. The interface between the MAS bundle and the Jade system is made by a JadeGateway agent (JGa). The task of this agent is to act as a bridge between Jade and non-Jade code. This agent is created when the MAS bundle is started, along with the other existent agents. The JGa has the knowledge of which services are provided by each agent running, so whenever a request from a service arrives to the MAS bundle, it knows to which agent that request should be forwarded. When a new request arrives to the MAS bundle, a shared object is created: the blackboard with all the needed information is passed to the JGa, which interacting with one or more agents, gets the answer needed and returns it to the MAS bundle which delivers it to the bundle which requested that specific service, and to which, obviously, all this background tasks where completely transparent (Figure 29). Likewise, if an agent needs to use a service from another bundle, it contacts the MAS bundle, which will be responsible for contacting the correct bundle, invoking the service and forward the result back to the agent.

Another issue of was interaction between agents, inside each platform, which is outside the scope of OSGi, and must be, therefore, addressed. Agent communication is indeed a very important subject, since it implies directly with the performance and behaviour of the whole system. FIPA (Foundation for Intelligent Physical Agents)[13] establishes several agent-related standards, being one of them the Agent Communication Language (FIPA-ACL) [145, 146]. This standard defines how to syntactically and semantically construct a message, based on the concept of speech act, which is the way agents share information. Speech act theory states that through communication we can execute actions much like we do with our hands or tools. As an example, if we ask a friend to close a window and he does so, we have closed the window just using our main communication mechanism: the voice. FIPA-ACL has a group of, what is called, performatives which represent a total of 22 speech acts. Each of these performatives represents a speech act that helps to describe a FIPA-ACL Message. Each FIPA-ACL message is composed by several parameters: sender, content, conversation-ID, among other, being one of them the parameter performative, one of the most important, since it informs the message purpose. Possible performatives are: Inform, Request, Not-Understood, Ask, among others. The communication between the agents of this architecture complies with FIPA-ACL standard. By doing so, some drawbacks are solved and the compatibility of the architecture to foreign agents that follow the same standard is assured. At this point, any agent that complies with FIPA-ACL can run inside a container that is controlled by a MAS bundle.

[13] URL: http://www.fipa.org/

OSGi areas

We have a group of different components, part of our AAL environment, which must be connected to the system:

- **1-Wire[14] sensors**, which are responsible to provide to the system with collected data about temperature, humidity, luminosity, etc;
- **X10 network**, which allow the system to control several electronic equipments like power windows, lights, air conditioning, etc;
- **Software components** like basic decision mechanisms or monitoring modules.

All of these components have to coexist together inside our AAL architecture, but they do not need to be localised inside the same physical location (Figure 30).

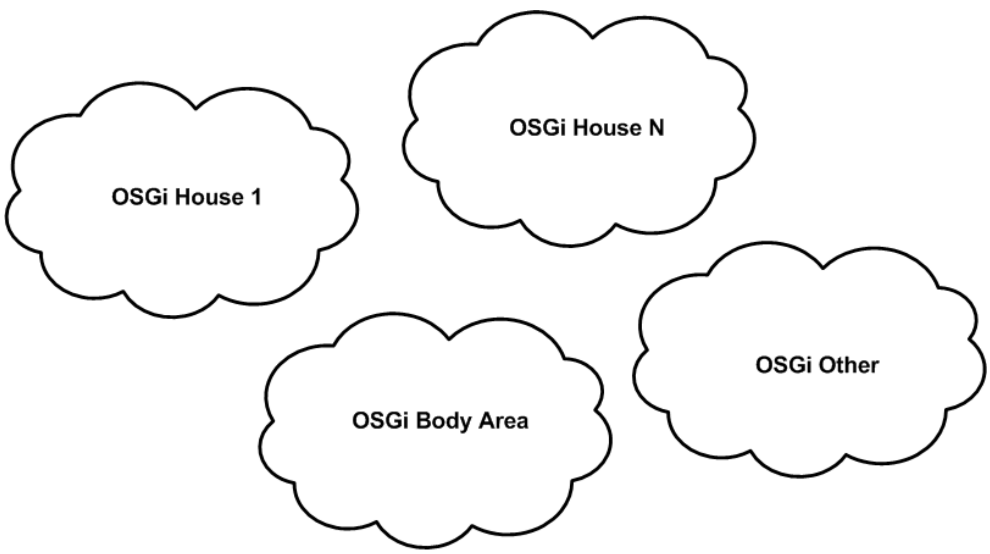

Figure 30 - OSGi cells example.

We have named each OSGi location, an OSGi cell. Each cell will, not only, have its own OSGi compliant "network" (OSGi locally), but may also have to interact with other OSGi areas (OSGi remotely).

[14] URL: http://www.1wire.org/

OSGi locally

Inside an OSGi cell, for instance a house, we will have several OSGi bundles, for instance:

- **OSGi 1-Wire bundle (one or more)**, responsible for constantly, in real time, reading and registering the values from the several 1-wire sensors connected to the area central computer and for provide, as services, these values to the OSGi local cell;

- **OSGi X10 bundle (one or more)**, one bundle for each X10 electrical equipment we wish to control, responsible for providing, as a service, the commands that can be issued to the equipment it represents (e.g. ON, OFF, UP, DOWN, etc);

- **OSGi software bundle (one or more)**,

In order to better understand the possible interaction among them, let's assume that the air conditioning system has enough autonomy to control the temperature based on the client preferences. It would be a hard task, not to say impossible, for an X10 equipment to interact with a 1-Wire sensor, in order to acquire the temperature information from it, without intermediary equipment. Using OSGi, we can give the autonomy to an OSGi software bundle, which can easily ask the environment temperature to the OSGi 1-Wire bundle, and issue an order to the OSGi X10 bundle, which will then issue X10 commands to the equipment based on the order given. Regard that our OSGi software bundle does not need to know how to "talk" with the 1-Wire sensors and not even with the X10 compliant air conditioning system. OSGi gives us the liberty of easily integrated into our system different entities and different technologies working together.

We have encountered, however, another problem: the compatibility of the data interchanged between bundles and the need for all bundles, or at least the ones that need that data, understand it. This problem arises because of our need to have different bundles, aggravated by the fact that we wish to be able to incorporate into the system any OSGi compliant bundle “written” by anyone. To resolve this problem we defined an ontology that all bundles must use. If every bundle import, and only use the data types present in this ontology, the compatibility is assured. If a bundle needs a new data type, only the ontology must be updated and distributed.

Having addressed the presented issues, OSGi can be locally used in the components of our architecture simplifying, by far, its implementation. Moreover, OSGi provides a bundle that, off the shelf, allows for UPnP[15] components to be viewed, by all other bundles, as services extending its possibilities. For instance, if in our home we have a UPnP TV, its control (e.g. ON, OFF, Channel UP, Channel DOWN, etc.) will be provided as a service to the OSGi local cell the moment it is connected. On top of that, the fact of OSGi supporting UPnP devices has yet the advantages associated do the zero-configuration needed for including such new devices, and therefore, for including new services in the OSGi local cell, which is especially useful for the elderly.

OSGi remotely

The fact that OSGi architecture is a centralized one and that our architecture is a distributed one, one additional last challenge is raised and must be overcome. We already presented how everything works inside each standard OSGi cell. These cells, however, need to be interconnected in order to create a, one or more, virtual organization, with a service-sharing basis. We need, therefore, a way of, from one cell, access remote services of another cell. OSGi standard, however, does not address this problem.

R-OSGi[16] , which is an extension to the OSGi standard, allows for a centralized OSGi application to be distributed, using proxy bundles. A proxy bundle is a bundle which provides not only a remote service exactly as if it was a local one, but also allows for local services to be remotely accessed (Figure 31).

[15] URL: http://www.upnp.org/
[16] URL: http://r-osgi.sourceforge.net/

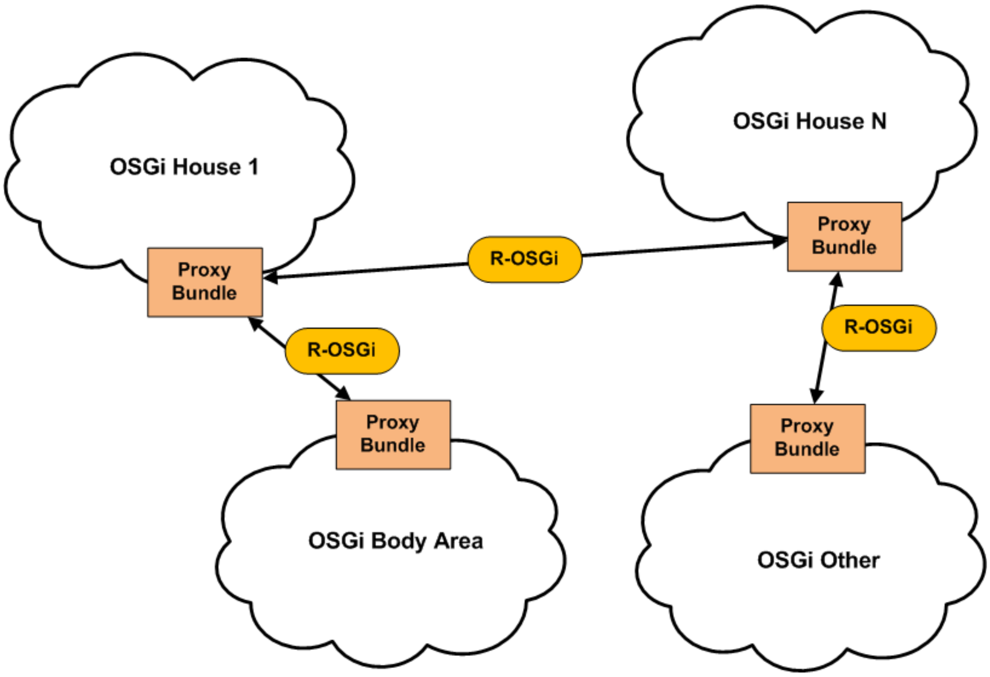

Figure 31 - R-OSGi inter-connection example.

The main idea behind R-OSGi is to allow remote services to be accessed by local bundles as if they were also local, in a completely transparent way. What we need do is to add an additional bundle (proxy bundle) to each cell that provides at last one remote service. This bundle will be responsible, not only for checking the service registry of the OSGi cell it is on, but also to search for services which should be provided remotely, announcing them on an external port. Remote bundles which want to subscribe its services will make a connection to that port and subscribe it. Moreover, each cell should also start a bundle for each service (or bundle of services) it wants to remotely access. This bundle subscribes the remote service as soon as it is needed and registers it on the local OSGi cell, as if it was the bundle providing it. Subsequently, any local bundle can use the service without the need to know if it is accessing a remote or a local one. For instance, suppose that a local bundle in cell A needs a service provided by a bundle in cell B. The local bundle in cell A calls requires the needed service (without the need to know if it is local or remote), that call, once it is a remote service, goes to the proxy bundle as if it was the bundle providing the service. After receiving the call, the proxy bundle identifies the remote cell, B in our case, which is providing the service. It then starts a connection with the proxy bundle of cell B and sends it the call. The proxy bundle in cell B receives it and forwards to the right local bundle (it may also need to connect to other remote bundles), which returns the result of the invocation to the proxy bundle. The proxy bundle in cell B then sends the result to the proxy server in cell A, which forwards it to the original bundle that has make the call. In Figure 32 is an example of a portable device which connects to a remote server to satisfy a request of its user to plan a trip. The user, as well as the interface service on his device, does not need to distinguish if a remote service was used or not to get the results.

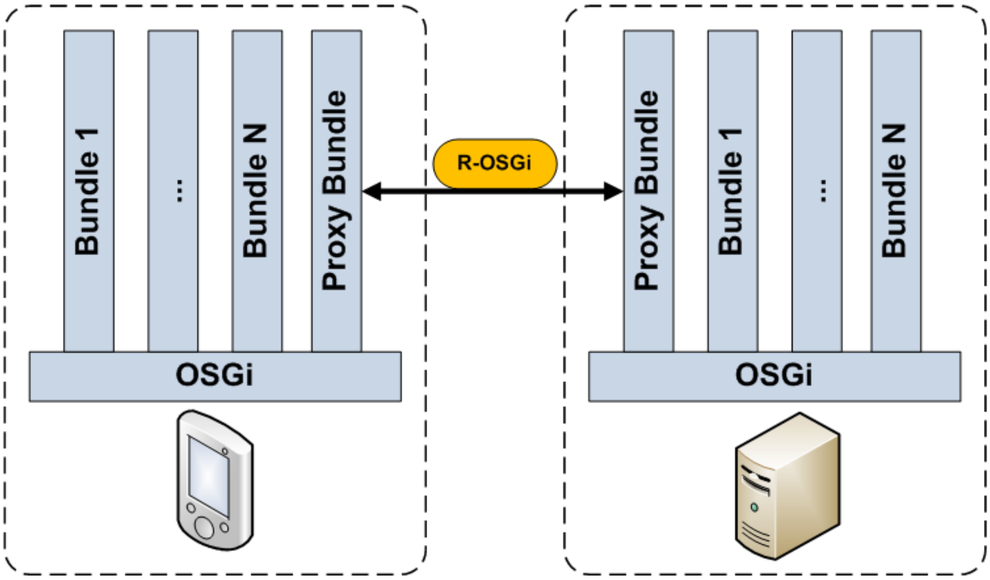

Figure 32 - OSGI accessing a remote service.

In Figure 33 we present an example of the complete architecture from the OSGi point of view. The OSGi network will be made of standard OSGi bundles (i.e., the OSGi cells), that may interact with each other. In this example, we present three autonomous cells, the Group Decision OSGi cell, the Body Area OSGi cell and the House OSGi cell. The proxy bundles provide the local services of their cells as remote services, and the remote service as local services in their OSGi cells. In this implementation, the PDA in the Body Area cell uses the Group Decision bundle services to plan its user weekend, when he requests it. The PDA is also able to use House X10 Bundle to turn the lights on or off, based on the user location as well as using that same location and the 1-Wire Bundle to adjust the environment temperature according to his preferences. Note that a service that is provided by an agent and is to be remotely accessed, is registered locally by the MAS bundle and remotely by the proxy bundle.

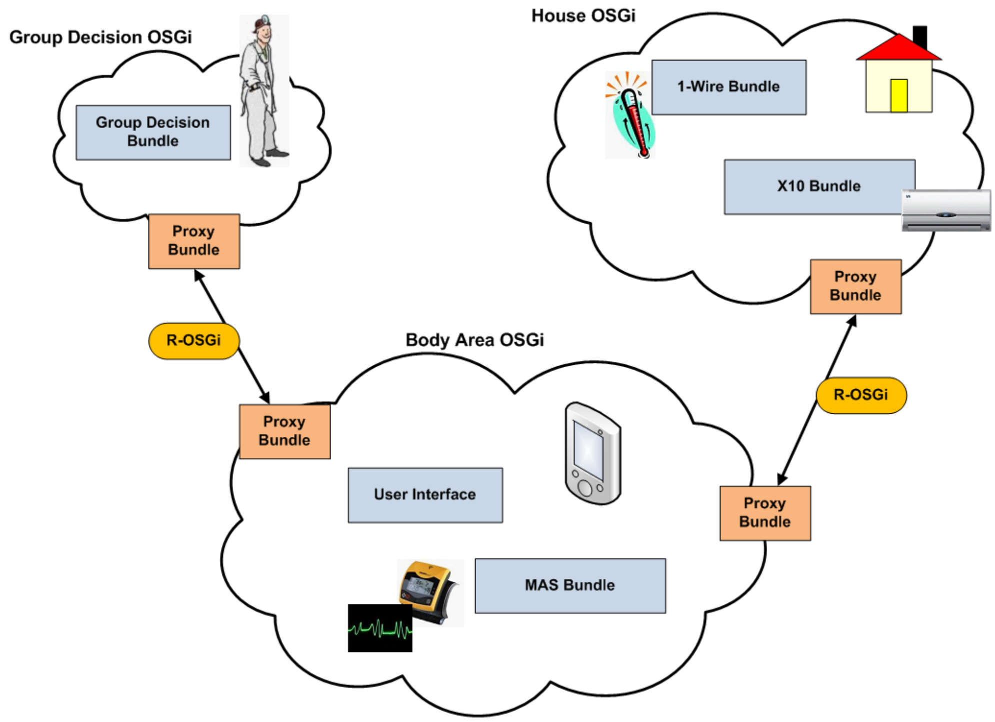

Figure 33 - OSGI complete example architecture.

Integrating Sensors

We have already demonstrated how we use sensors in our AAL architecture in conjunction with OSGi technologies, however, their integration also have the needed an adaptation. The 1-Wire sensor are analogue ones and, as many others, do not directly provide, the value in the format and base we want. Instead, they provide a value that must be converted to the format and base we pretended. On top of that, each sensor, or family of sensors, has its own way of working and we must adapt to it. For instance, in the temperature sensors we must convert the read values to Celsius degrees, in the luminosity sensor to lux, humidity to percentage, etc. This can, evidently, be a major obstacle to development teams, increasing the development time and costs. The solution we achieved was to rely on our Service-Oriented Architecture. We have built several OSGi 1-Wire Bundles, each one with the functionality of interacting with one family of sensors. These bundles provide the services of each sensor they are specialized in, making it easier to interact with them. Using these services, any external application can interact with any kind of sensors without the need to know how the sensor really works, just invoking easy-to-use services.

Communication

As we have said before, we wanted our architecture to be a heterogeneous one. However, we cannot however forget that OSGi and R-OSGi are both java based. In order to allow the introduction of other, non java, technologies we must provide platform independent compatibility mechanisms. To ensure the pretended compatibility between different components of different platforms, we introduced the Web Services (WS) paradigm [147]. WS can be seen, simplistically, as a platform independent way of sharing information over a network, making them ideal for our objective. Each one of our components that is supposed to provide information to a third party must declare a WS that can then be requested by the other components which need to access that information. A component can, however, be at the same time a server and a client. For instance, the Recommendation System (will be present further ahead), will use WS provided by the Home and will provide information, as a service, to the Group Decision.

The communication protocol is, therefore, of major importance. We have then decided that we should make the exchanged messages by all the WS of our architecture standard, and preferably in XML[17] [148, 149] format. As we had already defined FIPA-ACL as our communication protocol between agents, we have also decided to use those same protocol, embedded in XML format, for WS exchanged messages [150, 151] (Figure 34). This FIPA standard allows a description of the main content of the message without actually having to read it by using concepts like ontology, language or speech acts.

[17] URL: http://www.w3.org/XML/

```
<?xml version="1.0"?>
<fipa-message>
 <act>request</act>
 <msg-param>
  <sender><agent-identifier>
    <name>groupdecision</name>
    <addresses><url>
     http://abc.com/groupdecisionwebservice
    </url></addresses>
   </agent-identifier></sender>
 </msg-param>
 <msg-param>
  <receiver><agent-identifier>
    <name>house</name>
    <addresses><url>
     http://def.com/housewebservice
    </url></addresses>
   </agent-identifier></receiver>
 </msg-param>
 <msg-param>
  <content>
   <sensors room='all'>temperature</sensors>
   <sensors room='all'>movement</sensors>
  </content>
 </msg-param>
 <msg-param>
  <conversation-id>188273847728729</conversation-id>
 </msg-param>
</fipa-message>
```

Figure 34 - WS XML exchanged messages example.

In Figure 35 we present an example of a communication sequence of. The all process is triggered by the bundle responsible for monitoring the vital signs of the

Supported User. This bundle detects an irregular heart beat and generates an alarm to the House central OSGi. The MAS, in order to confirm the generated alarm, requests information from the movement sensors and asks, again, information about the cardiac rhythm. Having gathered the needed information, and after confirming the abnormal heart beat, the MAS realizes it cannot do anything to correct the situation and informs the Group Decision sending the collected information. This one, on his turn, contacts the Recommendation System, which reads, again, all the values of the sensors in the House and generates a recommendation which is then sent to the Group Decision. After a discussion (meeting) with the specialized staff (e.g. medical doctors, nurses, etc.), where the collected data and the recommendation, from the RS, are presented, a decision is deliberated and two actions are taken: an ambulance is sent to the Supported User location (House in this casa) and the lights in the division where the Supported User is are turned on.

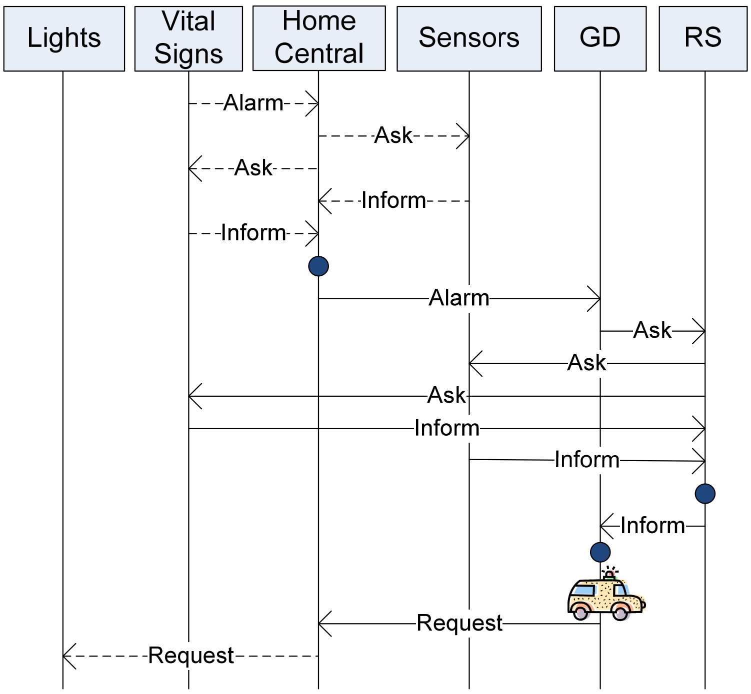

Figure 35 - Example of a communication sequence diagram.

In Figure 35 dashed arrows represent R-OSGi services being invoked, regular arrows stand for FIPA ACL messages being exchanged through WS and circles represent some major processing or communication with local bundles using OSGi.

The Recommendation System

Idea Generation

The ***Group Decision System*** module, as it was said before, is a major module of our system. This fact, associated with the importance of decision-making in today business activity and with the needed celerity in obtaining a decision in the majority of the cases that this key module will be defied to resolve, requires a real effectiveness of the decision making process. Thus, the need for an Idea Generation tool that will support the needed meetings, being those face-to-face, asynchronous or distributed, becomes crucial.

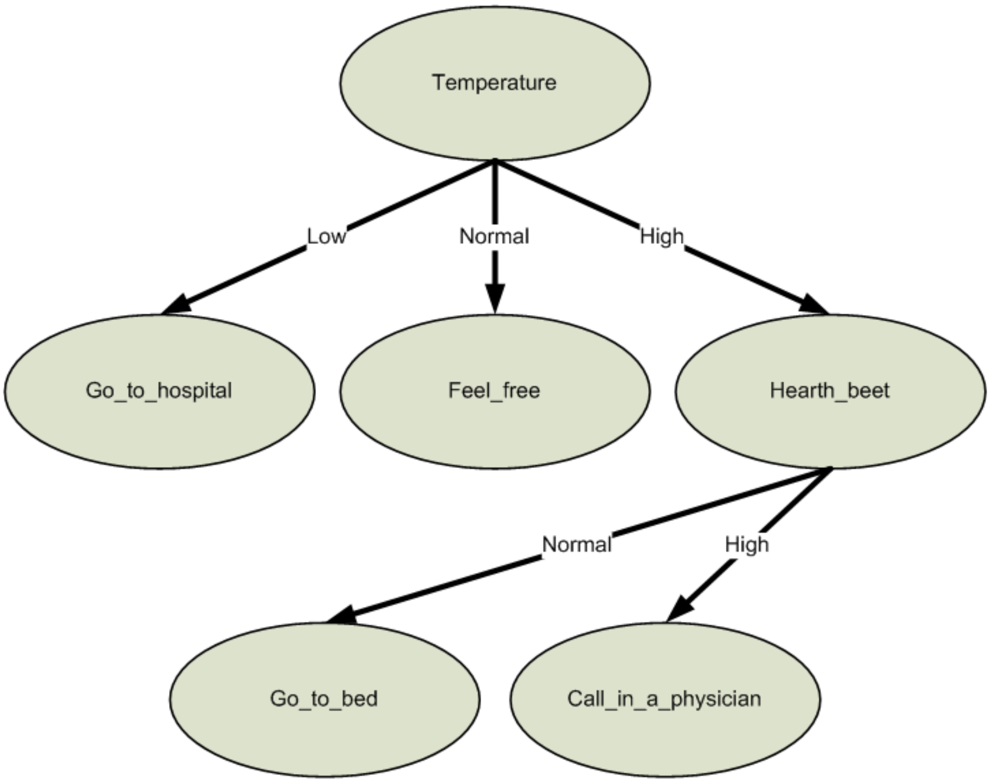

Figure 36 - A decision tree of a specific problem.

The flow of new ideas is central in an environment as the one presented above. Several idea generation techniques were popularized during the early 1950's in order to assist organizations to be fully innovative. These techniques, although primarily born and used in the advertising world, can be applied to an infinite number of emerging areas. Many idea techniques emerged from that time and continue to current days, such as Brainstorming, Nominal Group Technique (NGT), Mind-mapping and SCAMPLER, among others.

In order to face the real challenges that this module have to deal with, we selected two idea generation techniques for different situations:

- **Brainstorming** as it is probably the best-known creative tool. It can be used in most groups, although in most cases the rules that oversee it must be perceived by the group elements. It comes with all its potential when and independent facilitator manages the process (so the group can focus on the creative tasks). Normally a brainstorming takes somewhere between 30 minutes to 1 hour, depending on the difficulty of the problem and the motivation of the decision group. Due to this fact it cannot be used in situations of life or death, but it can and is going to be used in assessing patients quality of life;

- **Mind-mapping** as it is best used when one needs to explore and/or develop ideas for a specific problem, or when we need to take notes and/or summarize meetings. It can be used to obtain immediate answers in critical situations.

In Mind-mapping the specific problem is presented in the form of a decision tree, being the vital data obtained, for instance, from the sensors attached to the **supported user** (Figure 36).

Argumentation Module

After establishing individual ideas (through the above presented tools, or simply by intuition) the participants are expected to “defend” those ideas in order to reach consensus or majority. Each participant will, therefore, and in a natural way, argue for the most interesting alternatives or against the worst alternatives, according to his/her preferences and/or skills. By expressing their arguments, participants expect to influence the others' opinions and make them change their own [152].

This module is based on the IBIS (Issue Based Information System) argumentation model developed by Rittel and his colleagues in the early 70's [153]. The core of this methodology is based on the matrix of questions, ideas and arguments that, all combined, represent a dialogue. According to this model, an argument is a statement or an opinion, which may support or pointed out one or more ideas.

Among the three elements of the IBIS model, there exists nine possible links, as it is depicted in Figure 37.

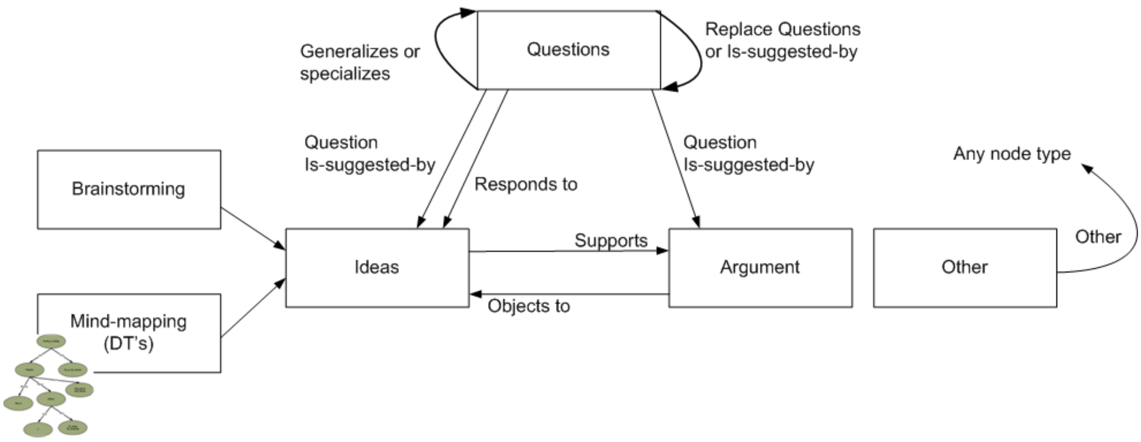

Figure 37 - IBIS model adapted from Conklin and Begeman.

In the implementation process of the Group Decision apparatus, and the respective support software, some modifications to the model have been made:

- The **question** in the IBIS model is, in the Group Decision apparatus, the **goal** of the meeting;
- **Ideas** are the alternatives of the multi-criteria decision problem and arise from the idea generation tool throughout brainstorming or through mind mapping;

- **Arguments** in IBIS can be pros or cons vis-à-vis a given idea. In the Group Decision module they are based in two types of information: Patient Electronic Clinical Profile and a set of Decision Trees. Additionally, the possibility for one participant to argue using an argument from another member is real.

This module is paramount on the in-meeting phase. It is used by the participants to defend their positions, but can also be used in the post-meeting phase by the facilitator (e.g. if the group does not reach a solution, the facilitator may use this module to check which is the most consensual alternative).

The IBIS model has been often used in the development of GDSSs, the first implementation being gIBIS [154]. By adopting this model, the Group Decision module should enable a better organization of the arguments exchanged by the participants. This may facilitate opinion convergence, and at the same time to reduce the meetings “noise”.

The Group Decision System

To model the call centres it is necessary to establish the steps for the creation of a virtual community of agents, i.e. a Multi Agent System (MAS). The importance of maintaining a community of agents is directly related to the need of obtaining information, among others, about their credibility, reputation, as well as their past behaviours, i.e.:

```
Agent(Id)::area_of_expertise ∧ organizational_factors ∧
interest_topics ∧ disponibility ∧ credibility ∧
reputation ∧ availability.
```

where *Id, area_of_expertise, organizational_factors, interest_topics, disponibility, credibility, reputation* and *availability* denote, respectively, the identification of the agent, the set of areas where the agent is an expert, the information about the institution where the agent is enrolled (e.g. employee numbers), the interest topics for the agent, the disponibility, credibility, reputation of the agent and its availability at a given moment. The community of agents is given as a set of N agents, {AgP_1, AgP_2, … AgP_N}, denoted by AgP. The availability of each agent can be classified according to three states: **uncommitted**, **committed**, or **in action**. An uncommitted agent stands for someone that may or may not join the MAS. A committed agent has agreed to be part of the MAS, but the inclusion process has not yet started. At last, an agent in action is someone involved in a task that already began.

Incomplete Information

The agent`s KB has two different types of knowledge: the positive knowledge (that is known to be *true*), and the negative one (that is known to be *false*). All the rest is *unknown* [155]. Indeed, the view of logic programming accepted in this paper is strictly declarative. The adequacy of a body representation of knowledge in a logic programming language means adequacy with respect to the declarative semantics of that language. Given a First Order Language (FOL), an Extended Logic Program (ELP) is a set of rules and invariants of the form:

$H \leftarrow B_1 \wedge \ldots \wedge B_n \wedge \neg C_1 \wedge \ldots \wedge \neg C_m (m > 0, n > 0)$	(6)

where H, B_1, …, B_n, C_1, …, C_m are objective literals, and, in integrity rules, H is ⊥ (contradiction). An objective literal is either an atom A or its explicit negation ¬*A*, where ¬¬ *A = A.* ¬*L* is called a default or negative literal. Literals are either objective or default ones. The default complement of objective literal L is ¬*L*, and of default literal ¬*L* is L. A rule stands for all its ground instances wrt (with respect to) FOL. A set of literals S is non-contradictory iff there is no $L \in S$ such that $\neg L \in S$. For every pair of objective literals {L, ¬L} in FOL we implicitly assume the integrity rule $\perp \leftarrow L, \neg L$. The main idea here is to compute all consequences of the program, even those leading to contradiction, as well as those arising from contradiction. Suppose that in the KB of the AgR the information related to the areas of expertise of the AgP_i identified as Peter, is represented in Program 7 [155].

```
area_of_expertise('Peter', pediatrics).
¬area_of_expertise('Peter', oncologist).
```

Program 7 - It contains information related to the expertise areas of a specific agent.

If the KB is questioned if the area of expertise of Peter is Pharmacy the answer should be unknown, because there is no information related to that. On other hand, situations of incomplete information may involve different kinds of nulls. The ELP language will be used for the purpose of knowledge representation. One of the null types to be considered stands for an unknown value, a countable one (i.e. it is able to form a one-to-one correspondence with the positive integers). As an example, let us suppose that one of the agents that belong to the agent community AgP, at the registration phase, does not specify its interest topics; it just informs that it has interest topics. This means that the interest topics of the agent are unknown (Program 8).

```
¬skill(A,B) ← not skill(A,B) ∧ not
exceptiontskill(A,B).
exceptionskill(A,B) ← skill(A, something).
skill('John', something).
```

Program 8 - Information related to the agent interest topics.

Another type of null value denotes information of an enumerated set. Following the previous example, suppose that an agent does not give information related to its availability, but its state of affairs is one of the three: **uncommitted**, **committed** or **in_action** (Program 9).

```
¬availability(A,B) ← not availability(A,B) ∧ not
exceptionavailability(A,B).
exceptionavailability('John',committed).
exceptionavailability('John',uncommitted).
exceptionavailability('John',in_action).
¬((exceptionavailability(´John´,A) ∨
exceptionavailability('John',B)) ∧
¬((exceptionavailability(´John´,A) ∧
exceptionavailability('John',B)).
/* This invariant denotes that the agent states of
committed, uncommitted and in_action are disjointed */
```

Program 9 - Information related to the agent's availability.

Quality of Information of the Agent`s Profile

The quality of information about an asset *K* (given in terms of the quality of information that emerges from the extension of predicate *K*) is given by $Q_K = 1/Card$, where *Card* denotes the cardinality of the exception set for predicate *K*, being *K* disjunctive. One the other hand, if *K* contradicts disjunction, $\binom{Card}{1} + \binom{Card}{2} + \ldots + \binom{Card}{Card}$ will stand for the cardinality of the combined set of terms that make the extension of predicate *K* (with respect to a particular asset *K)* (where $\binom{Card}{p} = \frac{Card!}{p!(Card - p)!}$ gives the number of combinations of *Card* elements, taken *p* to *p*, where $o \le p \le Card$ *).* Q_K is, in this case, given in the form:

$$Q_k = \frac{1}{\binom{Card}{1} + \binom{Card}{2} + \ldots + \binom{Card}{Card}}$$	(7)

The quality of the information that the system detains about agent AgP_j, may now be defined as follows [156]:

$$Q^{AgP_i}(Profile_{AgP_j}) = \frac{\sum_{k=1}^{N} Q_k^{AgP_j} * W_k^{AgP_i}}{\sum_{k=1}^{N} W_k^{AgP_i}} \tag{8}$$

where *N* stands for the number of assets of the profile, Q_k^{AgPj} is the quality measure of K and W_k^{AgPi} denotes the contribution of K to the agent's profile. It is now possible, based on a set of (evolving) Decision Trees (DTs), to follow, day in, day out, the elderly. However, DTs are not simple representations of a decision making process, they may also apply to categorization problems, i.e., for example, instead of saying that one wish to represent a DT to plan what to do, on a weekend, we could ask what kind of weekend is to be expected. This could easily be phrased as a question of learning a DT to decide in which category a weekend fits in (e.g., *if* it rains and it is windy *then* it is a weekend not to be remembered).

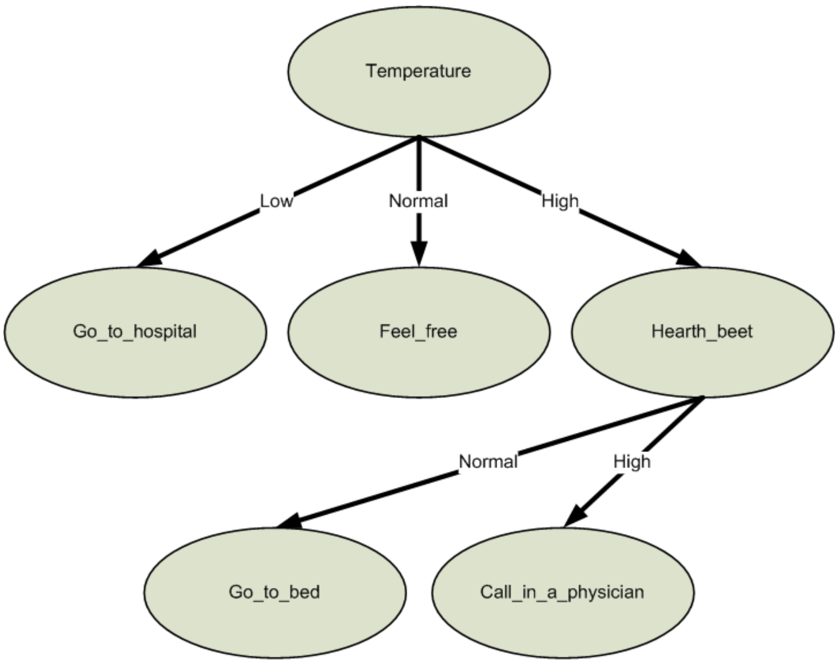

Figure 38 - Decision Tree to watch the Elderly State of Health.

One may now look to the process of DTs construction (e.g., to decide what to do at the weekend). One may use some background information as axioms and deduce what to do (e.g. one can know that the family is in town and that they like going to the cinema). Then, using, for example, Modus Ponens, we may decide to go to the cinema. Another way to stand around, it is by generalizing from previous experiences (e.g. let us consider all the times we had a really good weekend). If this is the case, one is using an inductive, rather than deductive method to construct the DTs (in this case one is using, for example, Modus Mistakens). Therefore, one may have Figure 38 and Figure 39.

On the other hand, there is a link between decision tree representations and logical representations, which can be exploited to make it easier to understand (to read) learned DTs. If we think better about it, every DT is actually a disjunction of implications (i.e., *if* ... *then* statements), and the implications are Horn clauses, i.e. a conjunction of terms implying a single term (Program 10).

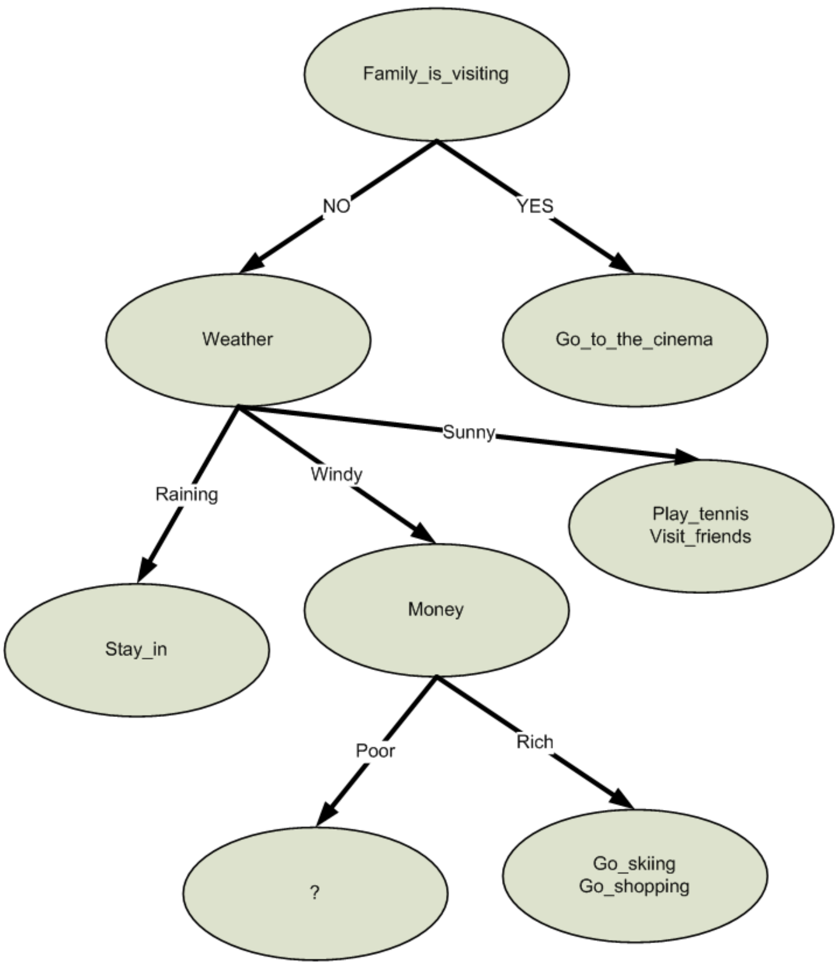

Figure 39 – Decision Tree to gaze at the Elderly Weekend Planning.

```
if family_is_visiting then go-to-the-cinema ∨ if
¬family_is_visiting ∧ weather_is_sunny then play_tenis
∧ visit_friends ∨
…
```

Program 10 - Reading from the root node to each leaf node.

The DTs depicted in Figure 38 and Figure 39 may now be given in terms of logic programs or theories. For Figure 39 one may have (Program 11):

```
if family_is_visiting then go-to-the-cinema.
if ¬family_is_visiting ∧ weather_is(weather, sunny)
then play_tenis.
if ¬family_is_visiting ∧ weather_is(weather, sunny)
then  visit_friends.
…
if ¬family_is_visiting ∧ weather_is(weather, windy) ∧
money_is(money, rich) then go_shopping.
if ¬family_is_visiting ∧ weather_is(weather, windy) ∧
money_is(money, rich) then go_skiing.
¬((go_shopping ∨ go_skiing) ∧ ¬(go_shopping ∧
go_skiing)).
/* This invariant denotes that the options of going to shop or
going to skiing are disjointed */
…
family_is_visiting.
¬family_is_visiting.
¬((family_is_visiting ∨ (¬ family_is_visiting)) ∧
¬(family_is_visiting ∧ (¬family_is_visiting))
/* This invariant denotes that the occurrences family_is_visiting
and ¬family_is_visiting are disjointed */
…
¬weather_is(weather,X) ← not weather_is(weather,X) ∧
not exceptionweather_is(weather,X).
weather_is(weather,sunny).
weather_is(weather,windy).
weather_is(weather,raining).
…
¬money_is(money,X) ← not money_is(money,X) ∧ not
exceptionmoney_is(money,X).
money_is(money ,rich).
money_is(money ,poor).
```

Program 11 - Decision Tree Meta-Logic Program to gaze at the Elderly Weekend Planning.

The call centres (i.e. the ServiceCallCenter and the CareCallCenter) may now receive from the premises under monitoring the elderly plans for the weekend, knowing also how good or bad they are, being therefore in a position to make the right judgments (Figure 40).

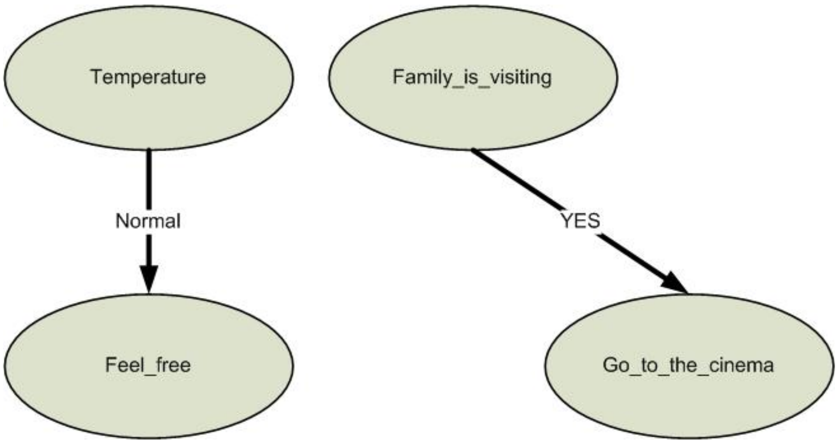

Figure 40 – Messages sent to the call centers.

An advice is got in return (e.g., you may go with your family to the cinema). This advice is given not only in terms of the factual information gathered by the sensors, in terms of the DT or corresponding logical formulae depicted in Figure 38, but also attending to an evaluation of the quality of information of such formulae [66].

5.4. The Simulation

Simulation consists of creating an alternative reality to represent a real object. When making a simulation, generally one expects to predict how a given object or system behaves in the real world. This way, it is possible to draw conclusions about the behaviour of the system and about its feasibility without having to actually physically build it. It is obvious that one has to select the most relevant features or behaviours of the system under simulation, so that the results are as accurate as possible. Obviously, despite the quality of the simulation, this cannot be seen as ideal, as in field testing is still, more than, necessary to make all the final adjustments.

However this is the ideal situation we have find to delineate paths to pursue without the physical deployments delays and costs.

In order to evaluate and better understand the limitations of the above presented infrastructure and respective architecture we have developed a simulation platform. This platform reproduces all the necessary components of the house module (Figure 41) thus creating an Ambient Assisted Living (AAL) simulated environment.

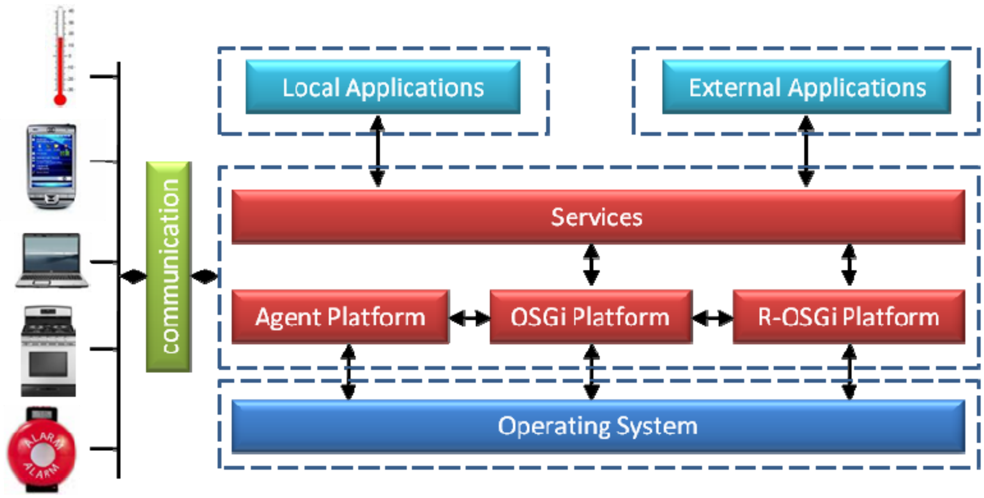

Figure 41 - House module architecture.

To obtain trusted results from a simulation environment it is very important to select the most important characteristics or behaviours of the system to simulate so that the results are as accurate as possible. These parameters to select may comprise, not only the object being simulated, but also the environment that surrounds the object. In the last years this technique has grown a lot mainly due to the advances in computer systems performances. Simulation is used to model complex systems that are either: too expensive, too dangerous or simply impossible to assemble in the real world due to its characteristics. Some of the common uses of simulation are the modelling of natural systems (e.g. weather forecasts, storm evolution, and earthquake damage), testing and optimizing new technologies, construction of new or special buildings (e.g., the new skyscrapers, dams).

In order to achieve this functional simulated environment, the first step was to select which parameters to simulate. Our simulation consists of a house with four rooms, the environment around the house and the user itself and, in this case, we clearly need to study the behaviour of the system when specific cases occur, ranging from the reactive cases (e.g. react to a temperature change) to the more complexes (e.g. there is no movement in the last room the person was spotted for a long period of time) [128]. We also want to know how the house will react in case some component malfunctioning or if all the alarms went on at the same time. This is in fact one of the main advantages of simulation: it enables us to study specific scenarios that can hardly occur but are possibly, without having to face the consequences of them really happening. We are therefore using simulation for studying the behaviour of the future house and improve it before all the equipment is acquired. However, we are already using some real physical devices, like sensors, in our simulated environment. This allows us to start making the transition from a totally simulated environment to a mixed one in order to simplify the final transition to a non simulated one [129].

Chapter 6

Study Cases

and

Results

6.1. Introduction

In this chapter we are going to present the VirtualECare study cases in the ambit of this thesis. There are 3 major study cases: The Simulation Platform, The Monitoring Platform and the iGenda sub module. The two first ones are in a very advanced stage of development, and inclusive, ready to face real life tests while the third one, is still in a more previous phase.

The chapter is organized as follows: Section 6.2 presents and explains The Simulation Platform; Section 6.3 presents and explains The Monitoring Platform; and Section 6.4 presents some relevant aspects about the iGenda sub module.

6.2. The Simulation Platform

Before implementing the above presented complex architecture, we first opted to create a simulation environment that allowed us to test and assess our system. Above all, we clearly needed to study the behaviour of the system when specific cases occur, ranging from the reactive cases (e.g. react to a temperature change) to the more complex ones (e.g. a long period of time as passes since movement was detected in the last room the user was spotted). We also wanted to know how the house would act in case of malfunctioning of some components or if, although a remote possibility, all the alarms went on at the same time. This is in fact one of the main advantages of simulation: it enables us to study specific scenarios that can hardly occur but are possible, without having to face the consequences of them really happening. We are therefore using simulation for studying the behaviour of the future house and improve it before all the equipment is acquired and deployed.

Our simulation consists of a fully configurable house, its surrounding environment and the user itself [129]. Before the implementation phase, we had to select which parameters we were going to simulate. After some internal debate, we opted for the ones that were present in a real house and that may contribute (positively or negatively) for the safety and well being of its users. We them opted for divide them in two major groups:

- **Sensors**, temperature, luminosity, movement and humidity;
- **Alarms**, fire, flood and gas;

However, simulating sensors and alarms was not enough. We started to realize we must simulate much more variables in order to achieve a, as close to reality as possible, truthful simulation platform. We also needed to simulate the actuators side, basically all kinds of home appliances, ranging from an oven or a coffee machine to lights or a HiFi device. We them added the possibility to simulate rooms, with very different characteristics, and the user actions and movement inside the house. At last, we needed the user vital signs, so we also simulate his heart beat rate, body temperature, respiratory rate and blood pressure. Later on we will explain in more detail how all of this is achieved.

Although this was a simulation platform, our objective was to build it as close as possible of our idealized architecture and respective framework. By doing this, we believed that, when the time came, we will be able to remove the simulated components and replace them with real ones, thus achieving our final results, without having to mess around with the rest of the system, which will remain the same and that has already been hardly tested, giving us great confidence on the final system performance.

Simulating the Environment

The environment itself is the main component of the simulation platform. It is where the user takes his day-to-day actions, it influents the user safety and well being and it is also object of user interaction. We can think of it as our own homes or our work place. As obviously, it is composed by one or more division (rooms), in which its individual characteristics (e.g., insulation, percentage of glass, window blinds, capacity of air conditioning, etc.) interfere with the environment as a whole. Each room will also have its own environmental specificities that will directly interfere with the user safety and/or well being. For instance, in a sunny day, the temperature inside a specific room will generally vary according to the percentage of glass in the walls or according with the room insulation. Even the geometry of the rooms can influence the house environmental parameters: the temperature or humidity in specific room will influence the temperature and humidity of the nearby rooms, especially if there is some kind of interconnection (e.g., a door). The simulation of the environment, in each room and as a whole, is, therefore, mandatory and of crucial importance, as well as the capability of being fully configurable in order to be able to cover and test a wide range of different ones.

Having all the above presented variables and the respective path in mind, the very first part of the simulation platform was created (Figure 42).

This first part consisted of the simulation platform setup, in where we set up the, to be simulated, house configuration. As said before, a house is made of divisions (rooms). In the green area we can draw several rooms and dispose them in any way we like. When each room is draw, its name and characteristics must be defined and configured according to four parameters: the level of insulation, the percentage of glass that covers the walls, the capacity of the air conditioning and the existence or not of window blinds, all of them quantified from 0% to 100%. These four, demanding default, parameters where selected as being the most important ones in a house where we want to be able to adequate control the environmental parameters inside it.

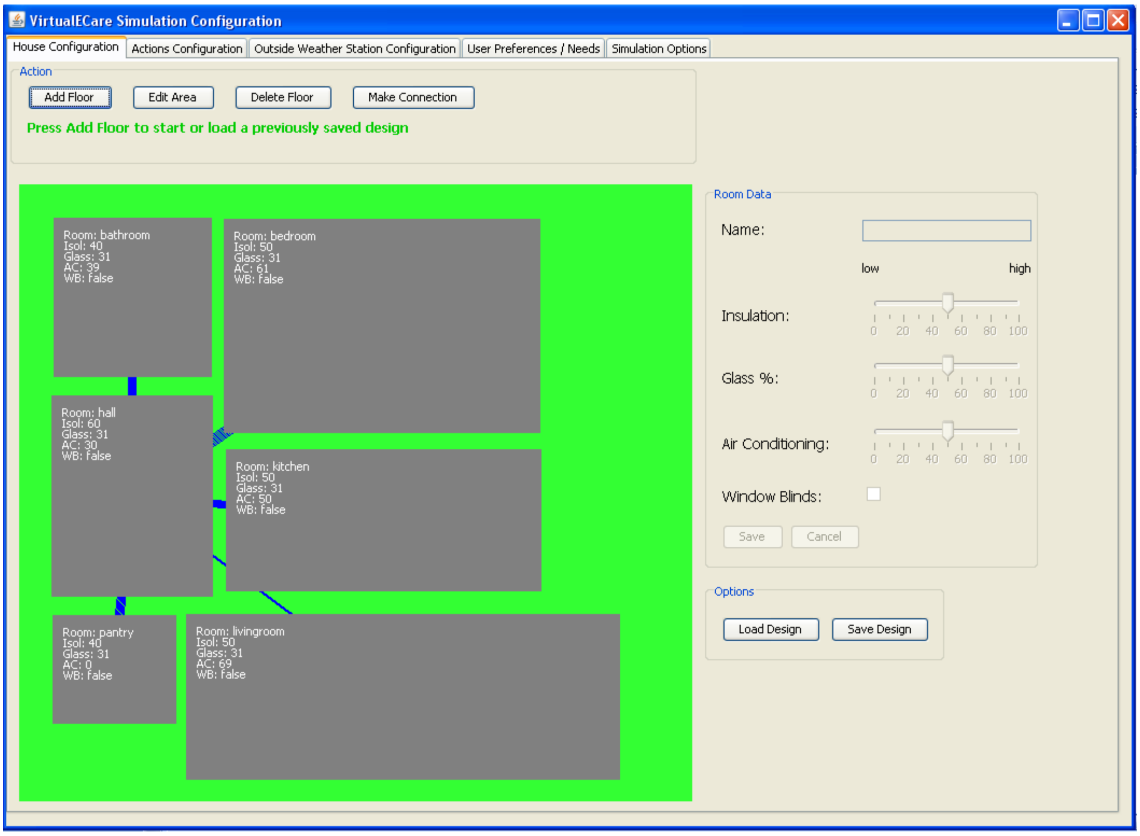

Figure 42 - The Simulation Environment Configuration Screen.

As a simple example, the temperature in a room with 0% of insulation would be the same as the outside temperature. On other hand, this implies that the temperature in a room with 100% insulation would not be influenced by the outside temperature and only depends on the devices and user actions inside it. This means that if no heat source exists inside that room, it temperature will be an absolute zero. Of course, in real houses or rooms, this is not a reality.

The air conditioning capacity represents, in a general way, the capacity of interfering with the temperature of that room (and consequently with neighbours rooms). However, this parameter should not only have in consideration the air condition capacity, but also, any other heating or cooling device (e.g., central heating, gas heater, fans, etc.). With a 0% capacity we cannot influence the temperature inside the room while with 100% capacity we can greatly influence this parameter.

The percentage of glass in a room represents the amount of glass (e.g., windows) that covers its walls. This has great influence in the temperature and in the luminosity inside the room. If a room has a low percentage of glass, it will be less influenced by the outside temperature, since glass usually has a higher heat capacity[18] than normal walls. On another hand, if the percentage of glass is higher, the temperature will be more dependent on the outside temperature. The luminosity inside the room will also be, more or less, related with the outside luminosity in function of the percentage of glass.

The luminosity inside a room is also greatly influenced by another parameter, the existence, or not, of window blinds. We may say that, in a room without blinds, its luminosity will depend on the external luminosity and in the existent lights. If the room has window blinds, the luminosity would also depend on the position of them.

Additionally, we can establish connections between the rooms that have already been draw. These connections represent, for instance, doors between those rooms. They are, mainly, used in two cases: to simulate the movement of the user inside the house and to simulate the influence of environmental parameters that each room has on the nearby rooms.

At last, we can save or load a previously saved design so that each time a new simulation is started we do not have to draw a new house configuration.

Simulating Sensors

In order to obtain data concerning the environmental parameters, there is also a group of different sensors that are being simulated. Basically, we are simulating an outside (as in exterior to the house) virtual weather station that can, and will, be later replaced by a real one, pre-assembled with one 1-Wire sensors (Figure 50 and Figure 51). This weather station, just like a real one, can provide information about the wind (speed and direction), temperature, humidity, barometric pressure, rain fall, sunlight intensity and lightening allowing us to have access to the needed information

[18] Heat capacity is a measure of the energy required for change the temperature of an object by a certain interval.

about the environmental parameters in the exterior of the house. This kind of information is useful, not only for informing the user about the outside weather conditions, but also to be provided to the GDSS module, allowing better and more accurate recommendation to the user (for instance, it will not recommend the user to take a walk if it is raining). In fact, all the simulated data can be remotely accessed by external, duly authorized, entities. In the presented simulation platform, the weather station has a very important role, we may inclusive say it is the key factor of all the simulation, has the simulated parameters inside the house depend, on top of all, on the values of the same parameters outside it, much like it happens in real life. The exact way that the external environment affects the inside environment may vary, and depends on factors like insulation, house sunlight exposure, among others.

As for the vital signs of the user, we intend to use the Vital Jacket developed in the University of Aveiro (Figure 10). By now, we are also simulating these values and this data is mainly to be used remotely by, for instance, the GDSS module, among others (alarms can also be raised in case of dangerous or abnormal readings).

One of the problems we found was how to generate the simulated values. They could be strictly random, follow some kind of function or a mixture of both. On top of that, we wanted to be able to create and simulate specific scenarios, so, we should also be able to set the values manually and to let them evolve in a natural way. As already said, the base of the house simulated sensors is the outside weather station, making these the only configurable ones. We can then implement scenarios using XML files. Each XML file starts with the address of the simulated sensor and is followed by a list of pairs of the type <tick, value>. Whenever a sensor bundle is started in the scenario mode, it searches for XML files that refer to any of the virtual sensors it controls. Let’s say that we are talking about a temperature bundle and it finds a XML file that refers to temperature sensors it controls. The bundle starts counting the seconds since it started and whenever the value of the seconds passed is equal to tick, the value of the simulated sensor becomes the value present in the XML file. A sample of one of these XML file can be found bellow:

```
<?xml version="1.0"?>
<scenario>
  <address> 1AB2CD44200A1 </address>
  <events>
    <value tick = "500"> 20 </value>
    <value tick = "1000"> 22 </value>
    <value tick = "1500"> 24.5 </value>
  </events>
</scenario>
```

This XML file will set the temperature of the sensor to 20 degrees 500 ticks after starting the bundle, to 22 degrees after 1000 ticks and to 24.5 degrees after 1500 ticks, remaining like that until the bundle is stopped. This same methodology, with the values adequate to each simulated sensor, is used for any of the other sensors. If we do not want to set up static scenarios and we want to let the values flow and see what happens, we can use values generated recurring to a Gaussian distribution. This distribution was selected due to its ability to shape natural phenomena. So, when configuring the simulation, in the "Outside Weather Station Configuration" tab, we select for each simulated parameter the mean value and the variation that may occur, which, all together, will define the weather that will occur during the simulation (Figure 43). It is, therefore, possible to create a more stable weather or, in another hand, create a weather configuration that can change rapidly and unexpectedly (unstable).

Let us now see how the values inside the house are generated. The first step is to identify the main parameters that stand between the outside environment and the inside environment. These parameters, already mentioned on the previous section, are the parameters used when configuring each room (e.g. insulation, glass percentage, etc) that will influence the generated values. Two additional parameters are, although, used when generating values: the previous values and the number of adjacent rooms. When developing the simulation tool, we realized that the temperature inside the house would change immediately after according to the state of the air conditioning, which does not correspond to the reality. In reality, when we change the state of the air conditioning, the environment takes a while to change. To deal with this situation we added a time factor to add some delay to some parameters (e.g. temperature or humidity). Luminosity, on another hand, changes instantly so the factor time is not necessary.

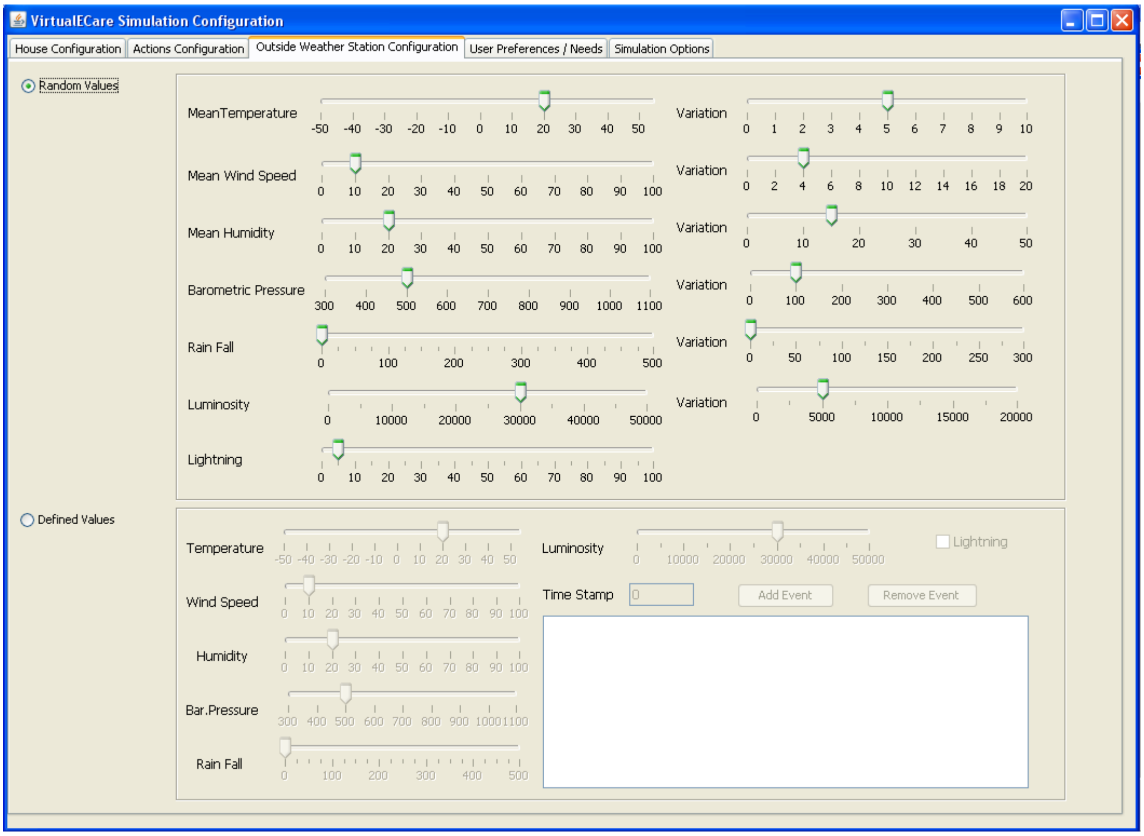

Figure 43 - Configuration sample of the outside weather station.

As for the number of adjacent rooms, it is known that the environment in a room is affected by the environment in the rooms that share a connection with it. The simulation of the effects of the outside weather in each type of room is achieved by the different characteristics assigned to each one. For better understand, let us consider an example: the luminosity inside a room. In this specific case, the luminosity depends on three factors: the outside luminosity, the position of the window blinds and the fact of the lights being on or off. The values of the outside luminosity, in its normal mode, are also generated by a Gaussian function and are provided by the weather station bundle. The state of the lights and the window blinds is a service provided by the X10 bundle. So, if the lights are on, the luminosity level is high. If they are off, it depends on the existence of windows and, if they exist, in the position of the window blinds. If they are down or no windows exist, the luminosity is low. If they exists, if windows blinds are up and if it is day outside, the luminosity may vary from medium to high. Similar processes occur for the rest of the sensors. While the weather station is ruled by Gaussian functions that can be configured when the simulation starts, the values of sensors inside the house depend on those external values and the other factors mentioned.

Simulating Actuators

Actuators in the house will be responsible for controlling the existent appliances. As already said, they will be X10 actuators. However, the actuators must be simulated in order for the actions resulting from the simulated sensors have any effect. We are able to simulate lights, window blinds, coffee machines, HiFi systems, televisions and air conditioning systems. The simulated lights enable us to send commands to turn the lights on or off. The window blinds simulation enables us to pull the blinds up or down. The control of the coffee machine, HiFi and television are essentially used to turn them on or off according to the policies of the house (e.g. when the room is empty, at given hours, etc). As for the air conditioning simulation, it allows us to turn it on, off, cooler and hotter. In our simulation, all of these virtual X10 actuators allow for their state to be checked, i.e., we can read the position of the window blind or the actual temperature of the air conditioning system. Although this is possible in some recent X10 modules, it is not possible on the older ones.

As we did with the sensors, we defined two ways of simulating the virtual appliances. We can either generate specific scenarios or they can run in what we call normal mode. In the scenarios, the methodology used is the same that was used for the sensors. We create a XML file for a specific X10 address which represents an appliance and that has a list of valid states. In the correct time, the state for that appliance is active. In the normal mode, the actuators behave much like they behave when controlled by a human. This means that their state will only change when told so by the system, unless there is some malfunction. Therefore, when the system tells the lights to be on, they will remain on until told otherwise.

Simulating Users

In every environment, there must be users (in order to all this to make sense). More than that, the users have to interact with the system and are, probably, the most unpredictable part of it. A user can change the environmental parameters of the house in two ways: using the actuators or through his day-to-day actions. For instance, if he decides to take a bath, he is increasing the temperature and humidity on the bathroom. The simple fact of interacting with certain devices will interfere with the environmental parameters: if the user turns on the oven to cook a meal, the temperature in the kitchen will rise. This, solemnly, already justifies the importance of simulating the user and its actions inside the house. In the created simulation platform, it is possible to simulate a wide range of common actions that we generally perform inside a house (Figure 44).

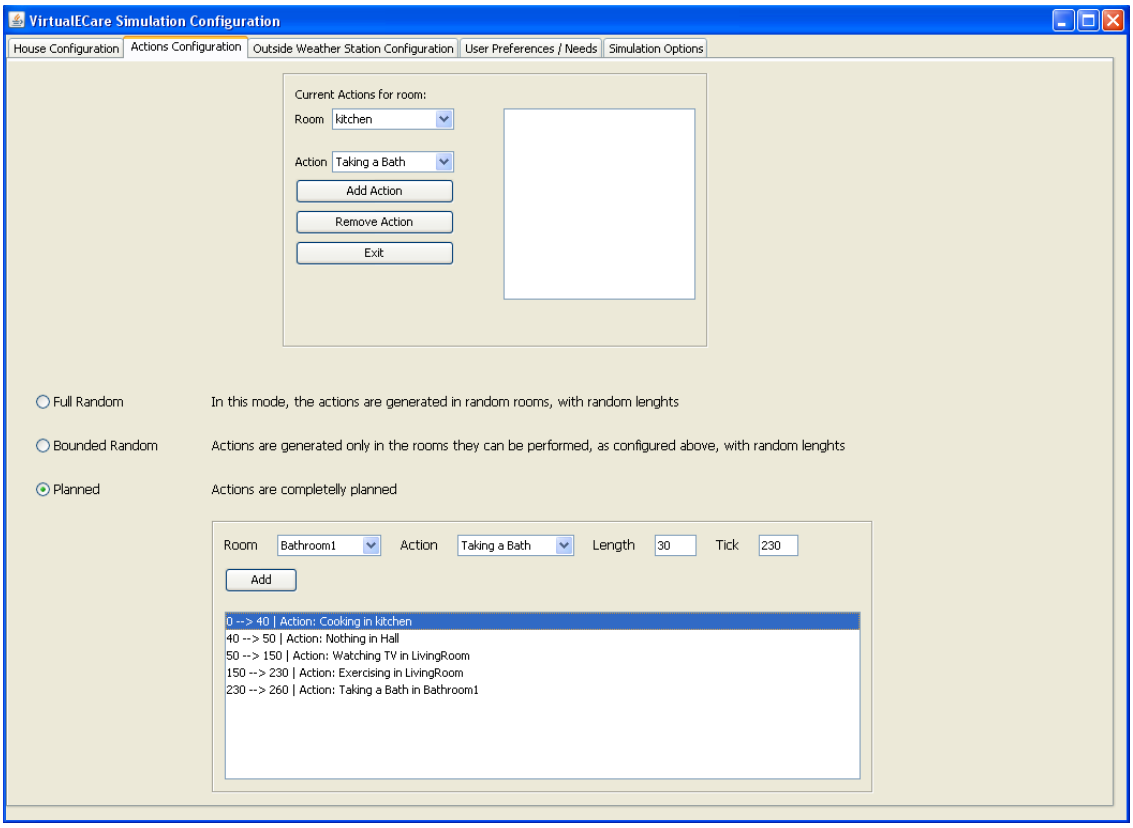

Figure 44 - User Actions Configuration: Planned Mode is selected.

There are three running modes for the user actions simulation: Full Random, Bounded Random and Planned. In the Full Random mode, we have no control over the user actions being performed inside the house. The only restriction is the user level of activity, which dictates the rate at which new actions are generated when no action is being performed and the maximum length of the action. The resulting behaviour is actions being performed in random rooms, with random lengths and starting at random. In this mode, the oddest things can occur, like the user having a bath in the hall. In the Bounded Random mode, the actions are generated randomly, with random lengths, just like in the Full Random mode, but, in this mode, it is possible to configure which actions can be performed in which room. This mode enables a more realistic simulation without however having to worry about completely specifying what is going to happen in what time in which room. When configuring the simulation, we choose this mode and say that in the bathroom the user can only take baths and make exercise, being these actions the only ones generated for this room, having however random lengths. The last mode is the one where we can completely specify what we want to happen in the simulation, concerning user actions. In the Planned mode, we can select which action will be performed in which room at each time and with what length. This way, it is possible to completely specify the actions of the user during the simulation. As an example we can look at Figure 44 where Planned Mode is selected. When the simulation starts the user will be cooking in the kitchen for 40 ticks, then the user will be in the hall doing nothing during 10 ticks, go to the living room watch TV during 100 ticks and exercising in the same room for 80 ticks. At last, the user will be taking a bath during 30 ticks in the bathroom.

There is, however, some more, important, data being simulated concerning the user. The final system aims to monitor the user vital signs and, for so, these should also be simulated in order to test the inference mechanisms that try to evaluate the health status of the user. By simulating the vital signs, we are able to cause specific cases to occur and see how and how fast the system reacts to them. When configuring the User Vital Signs two modes are possible: the Random mode and the Planned mode (Figure 45). In the first mode, the user vital signs can be configured to run randomly, inside pre-determined values. When using this mode, we select the mean value of each vital sign and the variance it may have. The values are then generated using a Gaussian distribution that uses these values as its mean and standard deviation. As an example, if we configure the heart beat mean to 80 bpm and its variance to 20 bpm, then we would have a simulated heart beat between 60 and 100 bpm, being however a value around 80 much more probable to happen than one around 60 or 100. In the Planned Mode, the vital signs are completely planed and it is possible to determine the exact value of the vital signs at each moment. With this mode we can, for example, simulate a heart attack for a given time and see how the system reacts to it. The final values of the vital signs are, however, not the ones that are generated here. The simulation takes these values and modifies them according to the action the user is performing at that time. This means that if we configure the simulation of the heartbeat to a mean value of 80 bpm and the user is exercising, the heartbeat observed in the simulation will be considerably higher during the time the user is exercising. In another hand, if the user is sleeping, it will be slightly lower. It is important that the system knows which actions influence which vital signs. By knowing that a certain activity influences some vital sign, by a certain amount, we can advise the user to stop doing it or even to take another action that leads to a better state. As an example, in the simulation, the action *exercise* increases the heartbeat, the body temperature, the respiratory rate and the room temperature and humidity. Therefore, if the heartbeat is too high and the user is exercising, the system can advise it to stop or even go rest so that its heartbeat can lower. Similar information is associated to each action that is simulated. Additionally, some more information about the user can be provided. There is the user activity level, already mentioned before, that determines the rate at which new actions are generated when no action is being performed. The user level of richness is used by the system as a factor on the decision making process. When deciding which action to take when the temperature rises in the exterior, the system can decide to lower the window blind or turn on the air conditioning. The most effective action would be to turn on the air conditioning. However, if the user level of richness is low, the system could opt for acting on the blinds. It is at this level that this parameter is used. As for the user needs and preferences, the use is much the same. The user might like a colder environment but the doctor, who also has a word to say, might advise a hotter environment. When the system acts on the environment, all these factors are weighted to try to find the optimal solution that provides both the comfort for the user and the adequate environment.

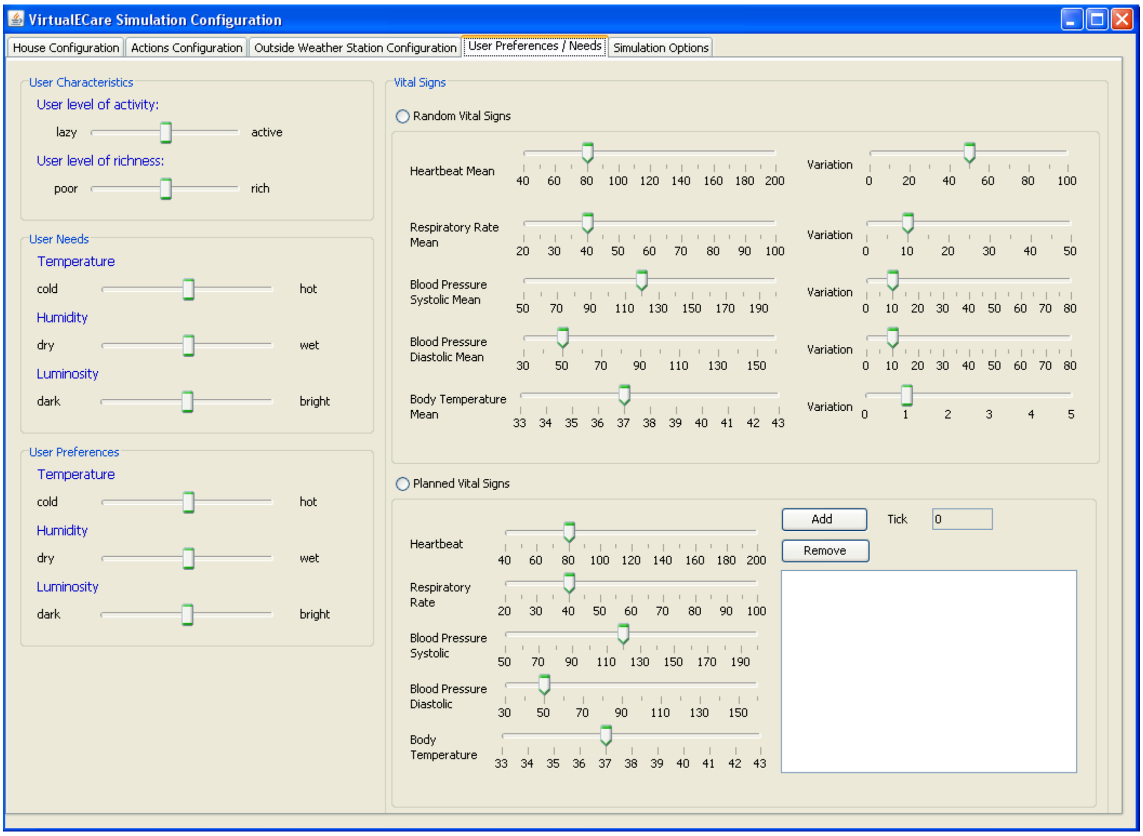

Figure 45 - User Parameters Configuration.

Running the Simulation

In the last phase of the simulation platform configuration process is the Simulation Options tab (Figure 46). In this tab, we can set some additional simulation parameters, as its speed and its length. A log file can also be saved according to the desired verbosity. The values at which alarm goes on can also be set here. Finally, when everything is configured, the simulation can be started.

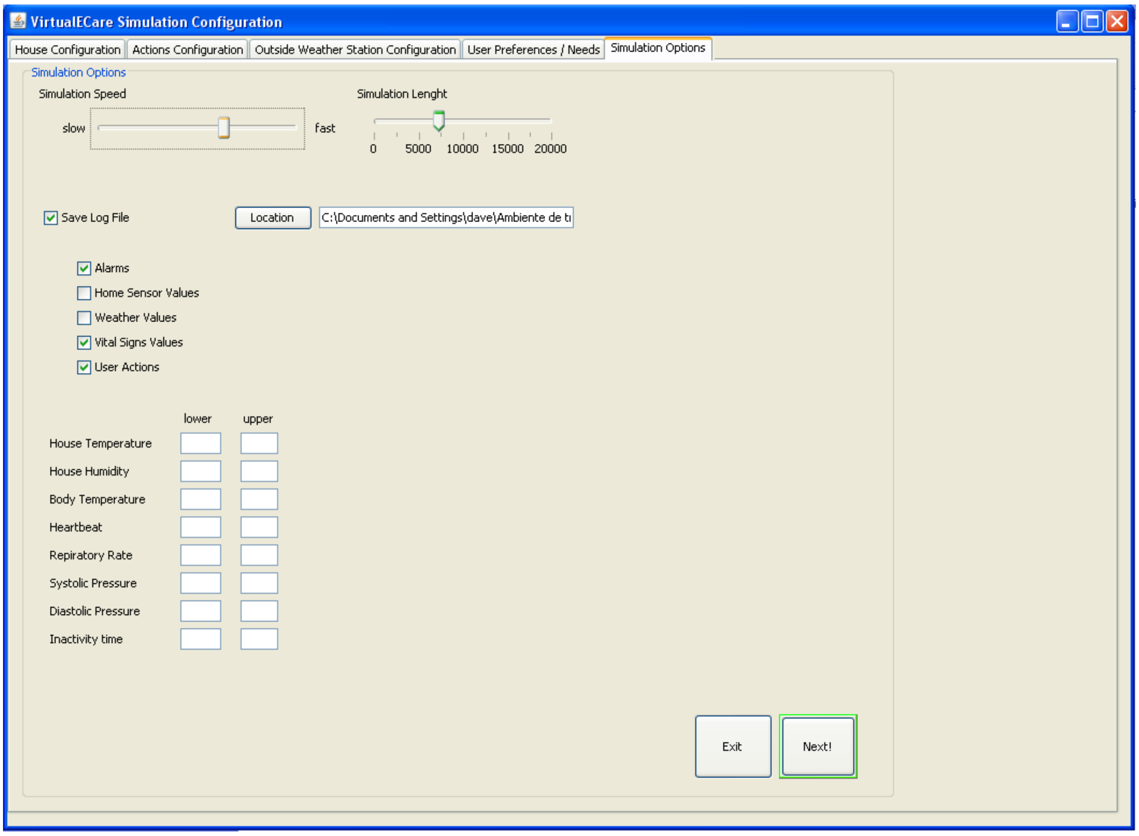

Figure 46 - The simulation platform options tab.

When the simulation starts, a bundle is responsible for controlling its execution. This bundle controls the length of each tick and, by doing so, the speed of the simulation. At each tick, the control bundle asks all the other bundles of the simulation for all their values for the current tick and displays them (Figure 48). It also provides a simple interface for interacting with the simulation (Figure 47) which enables the user to change the simulation related parameters.

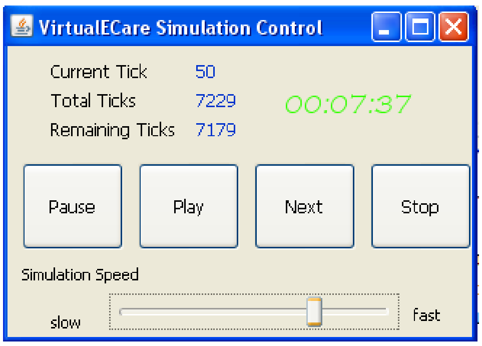

Figure 47 - Control of the simulation.

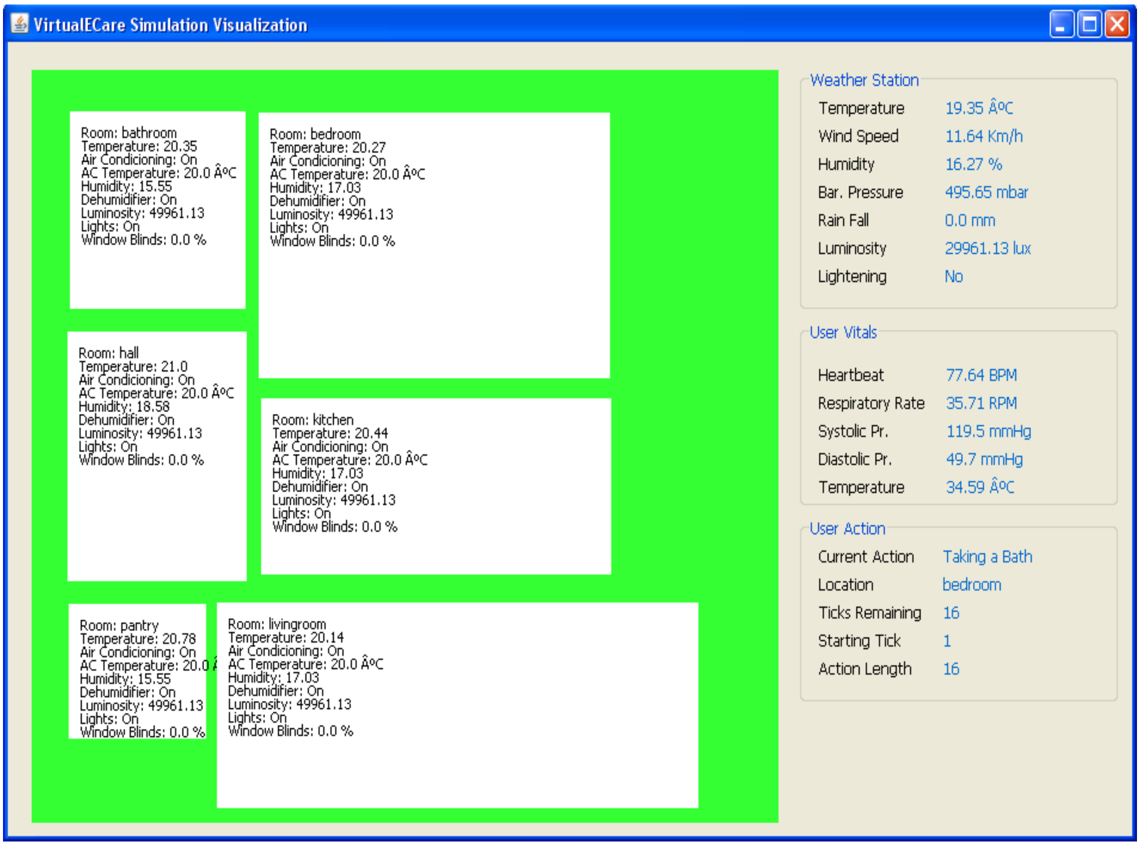

Figure 48 - The simulation visualization.

6.3. The Monitoring Platform

We are now ready to describe the monitoring platform. The monitoring platform was built and improved using the data provided by the above presented simulation platform. However, it also uses data provided by some real 1-Wire sensors already acquired. This platform is composed of some main modules: the Sensor Manager, the Sensor Monitor, the Sensors and the GDSS, all of them, evidently, encapsulated inside OSGi bundles. Additionally, a GUI that allows for all the functionalities to be tested was developed.

Using a wide range of sensors we interpret the user and its surroundings (i.e. its context). This may include information about the environment, other persons present and the relations between them, the economical context, the historic context, geographic context, among others. This data is of utmost importance for describing the user and its surroundings. When interpreting it, we can infer knowledge. Having knowledge we can them assign some meaning to the. At this point the system is ready to act according to the present knowledge and the defined objectives (Figure 49). Basically, the data is acquired from the sensors, it is interpreted and actions are performed on the system according to the knowledge generated and the user preferences and needs.

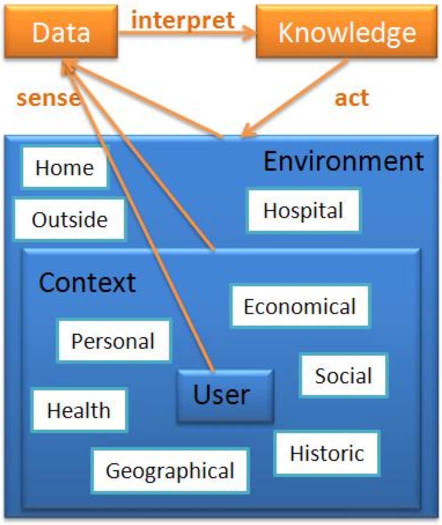

Figure 49 - The data flow in the monitoring module.

Sensors

The sensors used in the project are all 1-Wire sensors (Figure 50 and Figure 51). Our 1-Wire network uses an adapter as a controller which connects to an USB port of the central computer. A telephone wire then spreads from this point to the house with sensors connected to it through RJ11 connectors. These connectors were used to make the configuration of the network easy. With this intention, the sensors were installed into small boxes with built-in connectors so installing a new sensor in a room is simply connecting a telephonic cable (Figure 51).

Figure 50 - A 1-Wire temperature sensor.

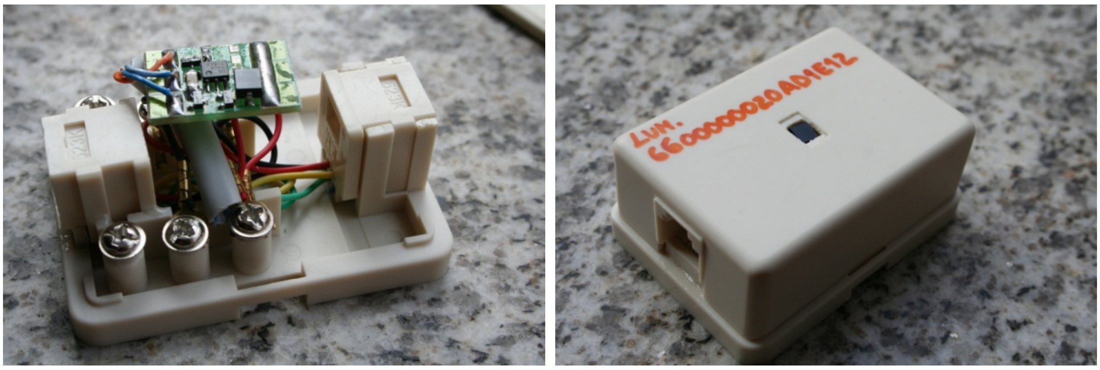

Figure 51 - A luminosity sensor installed inside a small plastic box with its address visible.

The Sensor Manager

The Sensor Manager provides functionalities concerning the configuration of the sensors. Using the Sensor Manager we can associate a sensor to a specific room, move sensors between rooms, remove sensors from the rooms or read detailed information about each sensor. It is also responsible, not only, for constantly check for new sensors in the network (issuing warnings every time a new one is detected), but also to detect if some sensor in use is not reachable. It also allows for conditional searches, like searching for all alarming sensors. It acts as a bridge, automatically issuing all the important commands and making sure no invalid operations are executed. This bundle is also a very important one to our 1-Wire network, as it transforms a regular, static, 1-Wire network in a plug-and-play, dynamic, one. This brings a whole new range of possibilities, making the configuration of the sensor network a much easier task. We just have to lay down the cable and connect the sensors, which is also very simple since they were built into plastic boxes with RJ11 connectors. As we go on connecting new sensors, this bundle asks what to do with them, being them possible to associate them to a room. It also detects when, by some reason, some sensor is registered as being in use but is not reachable, offering the possibility of removing it from the configuration.

The Sensor Monitor

The Sensor Monitor is responsible for providing the values of different sensors to the platform itself, as OSGi services. Basically, what this bundle does is to encapsulate all different types of sensors behind an OSGi bundle so that they are accessible to the other existent bundles. It knows how to communicate with each type of sensor and converts the information received from them into information that can be accessed by any other component of the system. This way, it is possible to hide the singularities of each type of device making it easier to develop applications that uses 1-Wire devices. We do not even need to know neither how 1-Wire technology works nor how to communicate with sensors. Requesting a value is as simple as using an OSGi service. This bundle also has some basic capacities for monitoring the values of the sensors. It constantly measures their values and issues warnings in case they are beyond predetermined values. Using this bundle it is also possible to interact with the sensors the other way around, i.e., to send data to them. For example, one can write in the sensor the Trigger Points (the points at which the sensor enters in the alarm state) or set its resolution. It is also possible to reset the state of the sensors or to write some additional data in some types of sensors.

The Interface

In order to make some testing and improve the architecture, a Interface was created (Figure 52). This Interface is also an OSGi bundle that interacts with the Sensor Manager and Sensor Monitor bundles. It makes possible to manage and monitor the sensors through. We can, for instance, select a sensor and view detailed information about its functionalities. It is also possible through this interface to associate a sensor to a room or to see which rooms have which sensors or see the values from the temperature and luminosity sensors in each room. Finally, this Interface also shows the existent alarms to the user: sensor unreachable, sensor alarming, new sensor added, temperature or luminosity alarm, among others. The information on the event log is also visible.

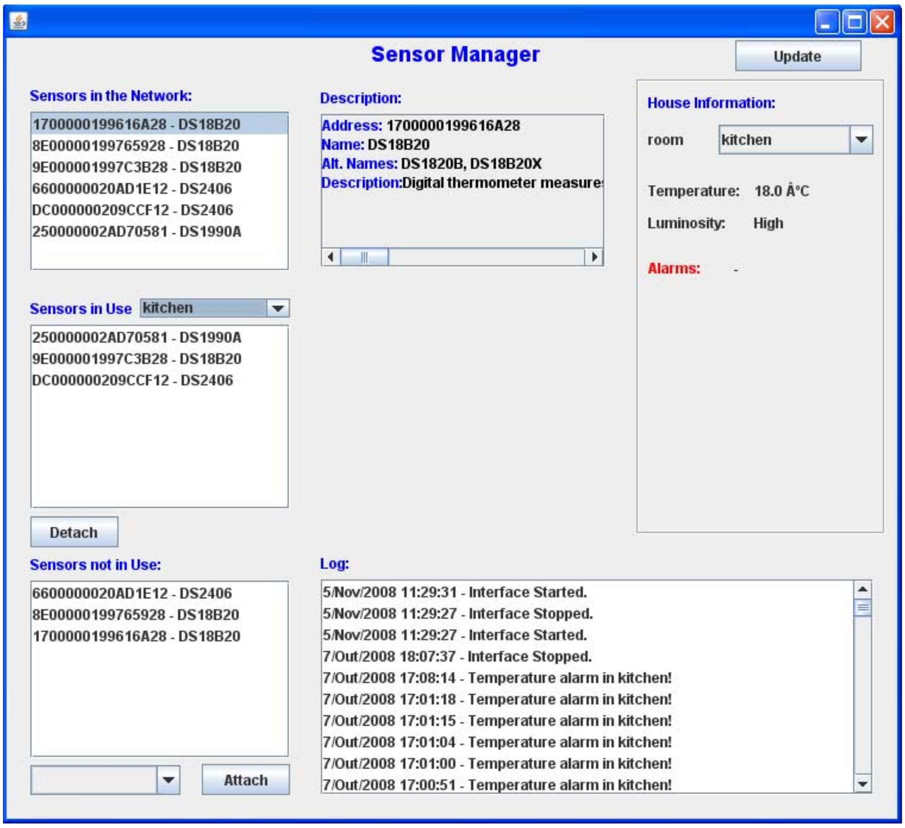

Figure 52 - The Sensor Manager Interface.

The Actuators

As for the actuators, the X10 technology is being used. X10 is a standard for communication between electric devices. The devices supported by this technology are mainly oriented for the home automation area. It uses the power line for carrying the signal to the electric devices but it may also use its own wireless protocol. Other very important features is its low price and its wide spread use. Using this technology, the user or the system can interact with the existent appliances such as lights, dehumidifiers, air conditioning, among others (from distance). To integrate the X10 technology with the rest of the architecture in order for these devices to be used by any of its members, it was necessary to encapsulate them behind OSGi bundles. With that objective, an OSGi bundle was created that is able of interacting with X10 devices. Basically, it provides as services the commands that can be sent to each device it controls. Then, when a service is invoked, the bundle creates the equivalent X10 command and issues it trough the power line network. The X10 commands are the way of communicating with the X10 devices and encode specific actions: on, off, dim, brighten, all lights on and all lights off. These commands can be issued from different kinds of devices. In our case, we can interact with the appliances in two ways: using the PR3130 wireless command or the CM15 computer interface. The wireless command can be programmed and is especially useful for persons with movement limitations, since they can interact with appliances without having to be near them. During the development phase it also had an important contribution which was to test the reception of the commands on the central computer. The CM15, in another hand, connects to the central computer through the USB port. In each case, the wireless commands are received by a transceiver module and then introduced into the power line. This standard allows the control of up to 256 devices, which is enough for the most common houses.

For actually controlling the devices we are using two types of X10 modules: the PR2060 and the PR2025 (Figure 53). The first one is a transceiver that, besides allowing the control of appliances, receives the wireless commands and passes them to the power line. If an incandescent light bulb is connected to the PR2060, the intensity of the light can be controlled. It reacts to the commands On, Off, Dim, Bright, All Units/Lights Off, All Lights On. As for the PR2025, it enables the control of one light bulb and also reacts to the commands On, Off, All Units/Lights Off, All Lights On. Any of these devices are very simple to install, being only necessary to insert the devices on the socket or on the E27 Edison screw base, respectively. This means that if the client wants to extend the system with more capabilities (e.g. control a new lamp recently bought) it is very easy to do it himself. When using the PR3016, the interaction with the devices can be triggered locally or remotely. Locally it starts from the monitoring module, when some event happens and some action on the environment is needed. For example, if the temperature is high, the local monitoring module issues an X10 command to turn on the air conditioning device of the corresponding room. The X10 bundle however also provides the services remotely so that actions on the house can be performed. The objective is to allow that they can be used by members of the GDSS module. As an example, the GDSS module can turn on the lights on the house if it detects that the user is feeling bad during the night. Additionally, using these remote services, more features can be easily developed upon them, like interfaces for remotely interacting with the devices inside the house that can be used by the user.

Figure 53 - Sample of X10 modules used.

Outside Monitoring

As the user sometimes leaves its environment, this project was extended with some ability to monitor the user in the outside. Thru the use of a PDA build in GPS module, the system can know the location of the user at any time, as long as it has a network connection available. The ideal would be to have information about its vital signs as well. That, however, is still in development phase.

The bundle responsible for tracking the user outside the house has some useful services, for the user itself and for the system. The bundle records the user path (Figure 54) so that it can be later analysed in case of need and may also provide the last known location of the user (Figure 55).

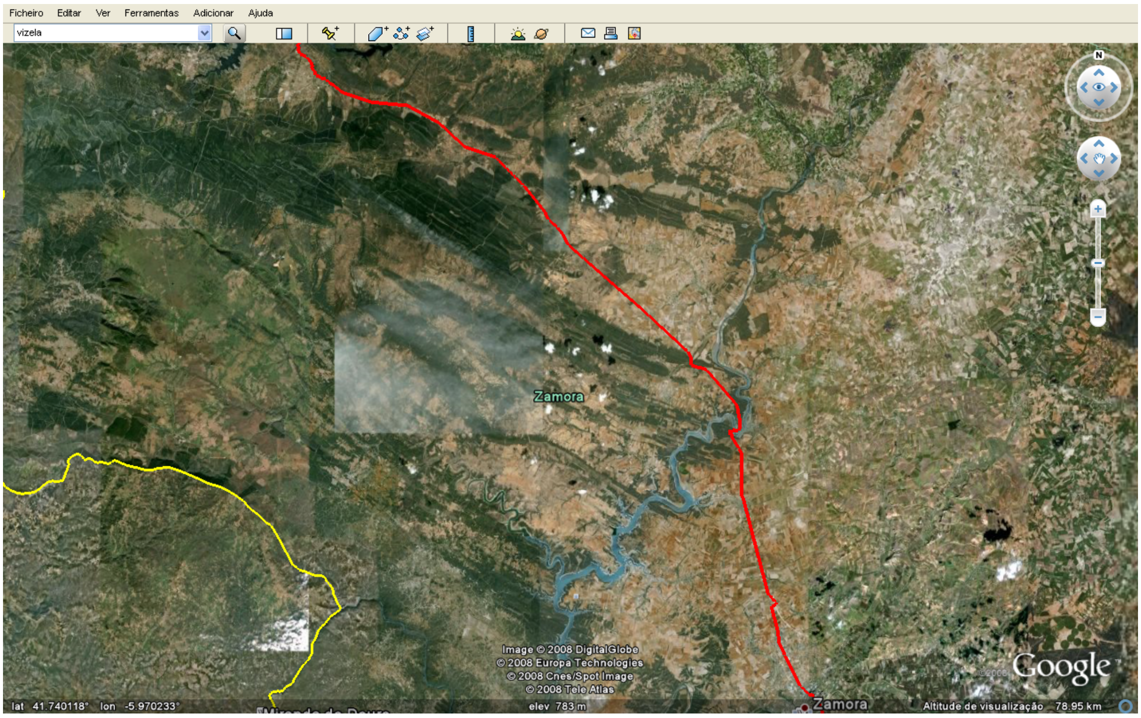

Figure 54 - The KML output file from the recordPath service, visualized on Google Earth. In this case, the client was travelling from Salamanca, Spain to Braga, Portugal.

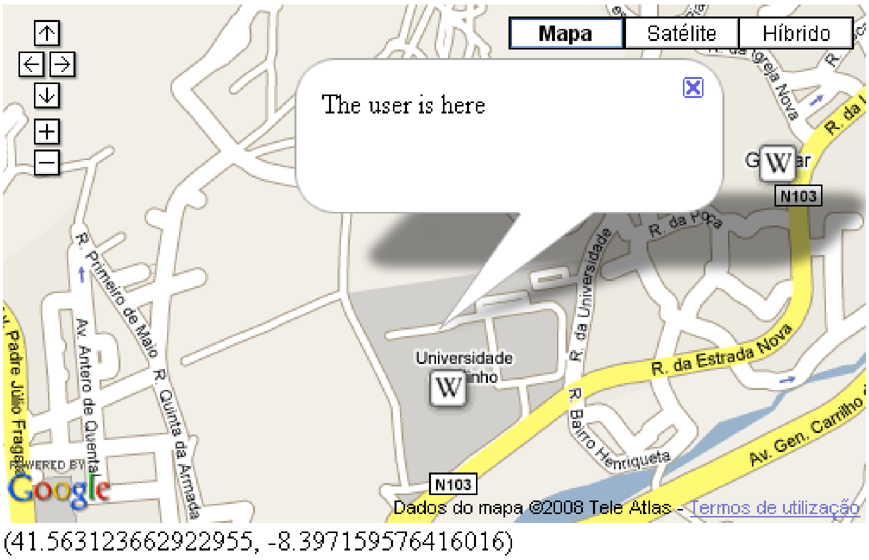

Figure 55 - The output from the getLastKnownLocation service, visualized on Google Maps.

It is also able to calculate the path from a given location to the last known location of a given user. This service is especially useful when there is the necessity to go rapidly to the user location, in cases of emergency. A similar service is also available to the user that consists on providing a path from its current location to a given destination (e.g. a hospital, a relative's house, etc) (Figure 56). The possible destinations are stored in a XML file and all these services are provided using Google Maps API and Google Earth API [157].

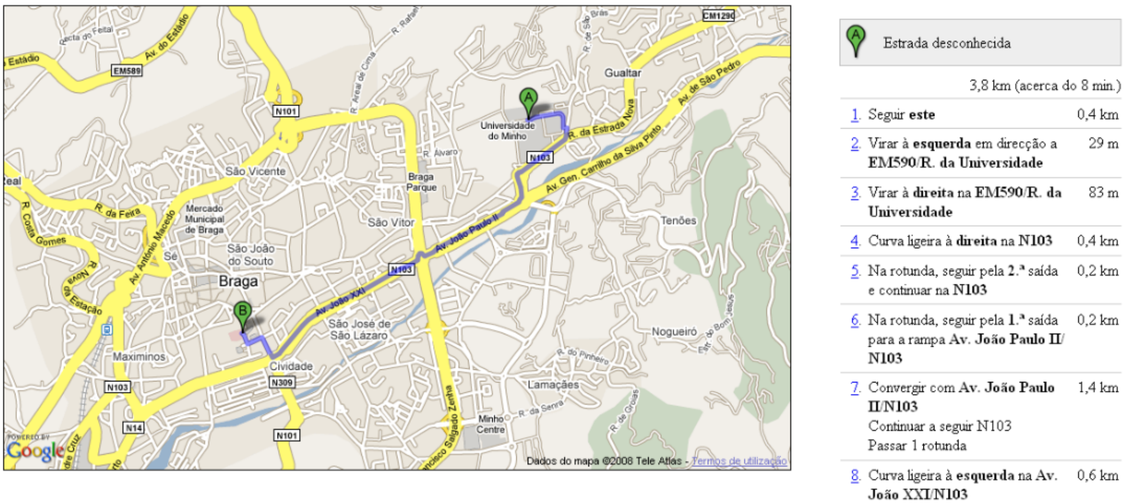

Figure 56 - The output from the GetPathTo service. In this case the client is in University of Minho and wants to go to the nearest hospital in the database which is located at lat: 41.547407, lon: -8.423090.

6.4. Memory Assistant – iGenda

6.4.1. Memory Assistant

The human memory, or its collective set of memories, is what makes us who we are. These memories are the combining set of experiences of our ongoing life. They provide us with the sense of self, allow us the sensation of comfort with familiar people and surroundings, connect our past with our present and provide us data to idealize our future. Memory is no more than the concept that refers to the process of remembering [158]. Aging, especially if associated with chronic diseases, affects our ability to remember, thus affects our memory. This is something intrinsic to the human being which cannot be reversed but, with the use of the commonly named new technologies, can be minimized. Once again, possible solutions to this problem are supported by technological means, where several memory assistant projects and software exists with the objective of aid our memory [159-165].

6.4.2. iGenda

IDC

The main goal of the iGenda sub module in the VirtualECare project is to improve end user's quality of life allowing them to better enjoy the so-called active ageing.

To better understand the amplitude of the iGenda sub module, let's consider the following scenario [113]:

"John has a heart condition and wears a smart watch that takes his blood pressure three times a day. He also has a PDA, connected with his watch, which reminds him to take his medications, with the proper dosage, his several events,

presents his diet, and presents his, monitored, vital signs statistics. If anything unusual arises, his PDA alerts, both, him and the Group Decision Support System (GDSS) and, at the same time, presents him with a table of possible causes and solutions for the actual condition. The GDSS has, also, access to this table so they can keep it up to date, based on his condition. Currently, John's PDA warns John is time to take 1 pill of his hearth medicament and also detects that his blood pressure is unusually high. The GDSS receives a grade B alert and calls him to check what might be causing his high blood pressure (previous diagnose). At the same time John PDA presents a checklist of possible causes, and possible resolutions, to review. Meanwhile, the GDSS decides John should take 1 additional pill of his high blood pressure medicament and come to an appointment, automatically scheduled in his calendar with high priority. Additionally the GDSS decides that John diet should also be more refined and uploads the new, more refined, diet to his PDA and cancels all the physical exercises activities until the scheduled appointment.

Later on, Laura is at home and decides to phone her dad. During the VoIP phone call she realizes he isn't looking very well. She then decides to review his Electronic Clinic Process and comes to her attention that dad's has being having high blood pressure. However she also realizes that VirtualECare GDSS already has being alerted and is already taking care of it, inclusively that he already as a medical appointment. Laura can know relax, and don't annoy dad with health questions."

In the above presented scenario, we realize how useful the iGenda sub module may be. It allows John to live his life without been worried if he is going to forget something important, as medication, or its proper dosage. It also allows an enormous proximity between doctor and patient, as, for instance, medicament dosage may be altered in "transit" or the taking of SOS medicaments may be ordered in line with the current condition, cancelation of activities, etc. Additionally it will allow relatives to be kept informed of his current condition (Figure 57).

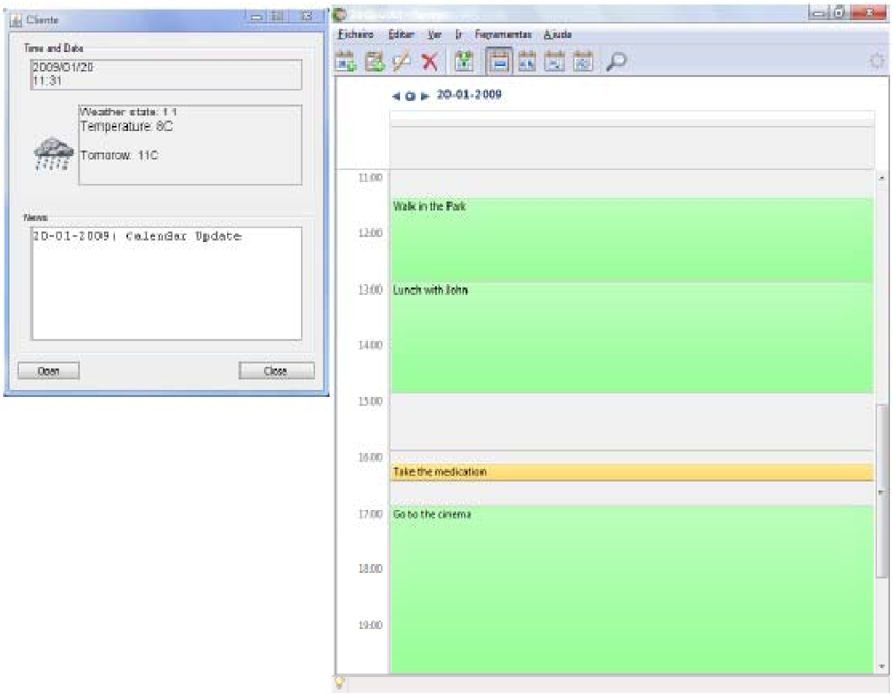

Figure 57 - Client Interface.

6.5. Conclusion

We have presented the study cases achieved inside the VirtualECare project in the ambit of this thesis. The Simulation Platform proved to be a very useful development, as it allowed us to be confronted with problems and situations that we would only realize after a deployment. This allowed us to continuing evolution in our development, thus achieving a much more robust platform, ready for physical deployment and testing. The Monitoring platform allowed us to test the continuous achievement of data from the entities being monitored and/or the providing of specific data when predetermined events occur. It also allowed us to test some of the corrections we have detected in the simulation platform and the use of real sensors, instead of simulated ones. The integration with the GPS module was also a major achievement as it allowed us to provide more user centric services. Finally, the iGenda sub module, which nevertheless being the less developed one, has already proved is usability and attracted some attentions.

Chapter 7

Conclusion

and

Future Work

The generalized unprecedented ageing of the human population and its expected rapid evolution thru all the twenty-first century, associated with the, already existent, lack of specialized human resources will bring the actual social health systems and healthcare provision as a al to a pre annunciate collapse. Adaptations must be made and, although progressive, must be rapidly assumed and deployed. The, so called, new IT technologies in the actual information era, will play a crucial role as a possible provider of some of those, needed, adaptations.

We believe Collaborative Work, and consequently Collaborative Networks and Virtual Organizations, will play a very important role in the health care sector future, providing the necessary means to overcome the expected difficulties. However, any solution must be cost effective, and this is why we must use already usual and available technology, as well as recover, in some way, forgotten concepts, like tele-health, which are much more realistic to be implemented and deployed nowadays than they were first introduced.

In this thesis, and in the execution of the work done, we have demonstrated that is already possible, recurring to widely available technology, to deploy controlled environments with monitoring and assistance capabilities able to receive users with special needs (e.g. health problems, impaired, etc). These, same in concept, environments can also be deployed at their home, thus preventing them from being delocalized and allowing them to remain, among possible, with their normal, day-to-day, activities. In the case of the VirtualECare project, these environments are also enriched by a myriad of available services (e.g. laundry, house cleaning, leisure, etc) and, maybe the most important feature, the full integration with Group Decision Support Systems modules which allows the increasing of the system autonomy and proctiviness.

Synthesis of the work done

In order to accomplish the specific presented objectives the mains contributions of this work are:

- Design and present a Collaborative Network for acting as a support for the above Ambient Assisted Living environment.

  • It was designed, presented and detailed the Collaborative Network as a al, its major components as well as its interconnections [114, 166].

- Design and develop Ambient Assisted Living multi-agent architecture and corresponding framework which will allow the built and deployment of an Ambient Intelligent environment to achieve the previous specific objective.

  • A multi-agent architecture and corresponding framework was proposed, as well as developed, simulated and tested and is now ready for deployment [129, 167].

- Allow the control and quality measure of all the information that flows in the Collaborative Network, namely in the Group Decision Support System module.

  • We have conducted several developments in the quality of information area, and integrated them in the proposed solution. Incomplete information may arise from several sources (e.g. unreachable sensors, incomplete Patient Electronic Clinical Profile) but what is important is to be able to measure the quality of the information we have access to and the quality of the ideas presented by the participants, based in factors like reputation, credibility, namely, in the discussion. However, we are certain, that some vital information, if incomplete, may even so, compromise any suggestion/decision but, in the majority of situations, we believe this will not be the case [168].

- Define the Group Decision Support System which will be responsible for all the decisions make in the Ambient Assisted Living environment.

  •The Group Decision module, which receives the information/data from the other members of the Network, supports asynchronous and distributed meetings set up for solving multi-criteria decision problems. The system supports the meeting participants in constructing and sharing ideas and “defends” those ideas in order to reach consensus or majority. To defend his ideas, each participant, should argue for the most interesting alternatives or against the worst alternatives, according to his/her preferences and/or skills, expecting to influence the others’ opinions and make them change their own [139].

Relevant work

The work developed and documented in this dissertation is, as stated before, integrated in the VirtualECare project. This project is being developed at the Computer Science and Technology Center in the Department of Informatics (DI-CCTC), at the University of Minho. This research project has been submitted to FCT (Foundation for Science and Technology) under the reference *PTDC/SAU-ESA/103755/2008 - VirtualECare - An Ambient Assisted Living* and is now awaiting approval.

The progress of this work was documented on the following publications:

Book Chapters

2009

- Costa R., Novais P., Lima L., Bulas-Cruz J., Neves J., Handbook of Digital Homecare, Yogesan K., Bos L. (eds), Springer, Series in Biomedical Engineering, ISBN 978-3-642-01386-7, October, 2009 (to appear).

Conference Proceedings

2009

- Costa R., Novais P., Lima L., Carneiro D., Samico D., Oliveira J., Machado J. and Neves J., VirtualECare: Intelligent Assisted Living, in Electronic Healthcare, Dasun Weerasinghe (ed.), Springer-Verlag, Series: Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, (Revised Selected Papers of The 1st International Conference on Electronic Healthcare in The 21st Century, City University, London, England, in September 8 - 9, 2008), pp 138-144, ISBN978-3-642-00412-4, 2009;

- Costa Â., Novais P., Costa R., Machado M. and Neves J.: A Memory Assistant For The Elderly, in 3rd International Symposium on Intelligent Distributed Computing (IDC 2009), Ayia Napa, Cyprus, October, 2009 (to appear);

- Costa R., Costa Â., Novais P. and Neves J.: Memory Support in Ambient Assisted Living, in the 10th IFIP Working Conference on VIRTUAL ENTERPRISES (PRO-VE 2009), Springer, Thessaloniki, Greece, October 2009;

- Carneiro D., Novais P., Costa R. and Neves J.: Case-Based Reasoning Decision Making, in Ambient Assisted Living, in IWAAL - International Workshop of Ambient Assisted Living, Part II, LNCS 5518, ISBN 978-3-642-02480-1, University of Salamanca, Spain, June, 2009;

2008

- Costa R., Carneiro D., Novais P., Lima L., Machado J., Marques A., Neves J., Ambient Assisted Living, in Advances in Soft Computing, Vol. 51, Springer- Verlag, ISBN 978 978-3-540-85866-9, pp. 86-94, 2008 (3rd Symposium of Ubiquitous Computing and Ambient Intelligence 2008

(UCAMI 2008),Salamanca, Spain, 22-24 October 2008). (Indexed by ISI Web of Science);

- Carneiro D., Costa R., Novais P., Neves J., Machado J., Neves J., Simulating and Monitoring Ambient Assisted Living, in Proceedings of the ESM 2008 - The 22nd annual European Simulation and Modelling Conference, Le Havre, France, October, ISBN 978-90-77381-44-1, pp 175-182, 2008. (Indexed by ISI Web of Science);

- Lima L., Costa R., Novais P., Analide C., Bulas-Cruz J., Neves J., Quality of Information in the Context of Ambient Assisted Living, in Advances in Soft Computing, Vol. 50, Springer- Verlag, ISBN 978-3-540-85862-1, pp. 624-633, 2008 (International Symposium on Distributed Computing and Artificial Intelligence 2008 (DCAI 2008),Salamanca, Spain, 22-24 October 2008);

- Novais P., Costa R., Carneiro D., Machado J., Lima L., Neves J., Group Support in Collaborative Networks Organizations for Ambient Assisted Living, in Towards Sustainable Society on Ubiquitous Networks, Makoto Oya, Ryuya Uda, Chizuko Yasunobu (eds), Springer-Verlag, Series: IFIP International Federation for Information Processing, ISBN 978-0-387-85690-2, pp 353-362, 2008 (The 8th IFIP Conference on e-Business, e-Services, and e-Society (I3E 2008), Tokyo, Japan, 24-26 September 2008). (Indexed by ISI Web of Science);

- Costa R., Novais P., Neves J., Marreiros G., Ramos C., Neves J., VirtualECare: Group Decision Supported by Idea Generation and Argumentation, in Pervasive Collaborative Networks, Luís Camarinha-Matos and Willy Picard (eds), Springer-Verlag, Series: IFIP International Federation for Information Processing, ISBN 978-0-387-84836-5, pp 293-300, 2008. (The 9th IFIP Working Conference on Virtual Enterprises (PRO-VE 2008), Poznan, Poland, 8 - 10 September 2008);

2007

- Costa R., Neves J., Novais P., Machado J., Lima L. and Alberto C., Intelligent Mixed Reality for the Creation of Ambient Assisted Living, in Progress in Artificial Intelligence, Neves J., Santos M. and Machado J. (eds), Lecture Notes in Artificial Intelligence 4874 Springer, ISBN 978-3-540-77000-8, 2007;

- Costa R., Novais P., Machado J., Alberto C., Neves J., Inter-organization Cooperation for Care of the Elderly, in Integration and Innovation Orient to E-Society, Wang W., Li Y, Duan Z., Yan L., Li H., Yang X., (Eds), Springer-Verlag, Series: IFIP International Federation for Information Processing, ISBN 978-0-387-75493-2, 2007.

In the course of the work developed under the VirtualECare project, I have also been present in:

2009

- Invited talk at 6ª Tertúlia em Inteligência Artificial (TeIA), University of Trás-os-Montes e Alto Douto (UTAD), Vila Real, Portugal, July 2009

- International Workshop of Ambient Assisted Living, University of Salamanca, Spain, June 2009;

2008

- 3rd Symposium of Ubiquitous Computing and Ambient Intelligence and in the International Symposium on Distributed Computing and Artificial Intelligence both held in the University of Salamanca, Spain, October 2008;

- 1st International ICST Conference on Electronic Healthcare for the 21st century, eHealth 2008, City University, London, United Kingdom, September 2008;

2007

- 13º Encontro Português de Inteligência Artificial, EPIA 2007, University of Minho, Guimarães, Portugal, December 2007;

- Doctoral Symposium on Artificial Intelligence, SDIA 2007, University of Minho, Guimarães, Portugal, December 2007;

- 8th IFIP Working Conference in VIRTUAL ENTERPRISES (PRO-VE 2007), University of Minho, Guimarães, Portugal, September 2007.

Future work

Although, in general, the presented main objective and its findings have been achieved, a number of refinements must be done in order to bring out the developed prototype to the real world. On top of that, a number of new door are left open for new lines of research arisen during the duration of this doctoral thesis.

Some further developments can be highlighted:

- **Safety, privacy and security.** It is very important to improve the used safety, privacy and security solutions used in the VirtualECare project. Data confidentiality must be guaranteed and an adequate balance between safety and privacy should be obtained, according to the health condition of the patient but always preserving privacy minimal bounds.

- **Empirically evaluate all the obtained results in real life environments.** We have made, thru simulation several evaluating of our results and have, inclusive, already incorporated some of the obtained results in the presented solution, but testing in real life scenarios is vital to verify the real robustness of the presented system.

- **Collaborative networks in healthcare.** It is necessary to create a new mentality in many, if not even al, of the intervenient in this domain. This can be done, mainly, thru wide exhibitions and guidance about the technical and social advantages obtained from the introduction of novel technologies and techniques.

- **Integration with formal methodologies.** It seems appropriate to perform a detailed study for the integration with formal methodologies (e.g. Gaia, AUML).

- **More effective and precise localization systems.** The used localizations systems, GPS in the exterior and RFID in the interior, may not be, in some situations, accurate enough for real life use.

- **The Evolution of IT technologies.** Keep track of the constant evolution in the IT society, as new ones appear every day and studies its viability to integrate the system, as well as the possible advantages.

- **JADE 3.7 (and future versions).** Although we positively integrate JADE, OSGi and Web Services, version 3.7 of JADE (and future ones) will already, natively, have integration with OSGi technology and dynamic invocation and inspection of Web Services. It would be advised to analyse the needed changes in order to be JADE 3.7 compatible, as the achievement of major robustness improvements may be achieved.

- **Evaluation of technology acceptance among users.** We must not forget that the presented systems and solutions are very technological based. A detailed study, and eventual real life testing with real users, should be done in order to obtain credible data about the user’s acceptance of technologies in their day-to-day activities, especially among the elderly.

- **Legal issues.** A deep study must be performed in order to realize the needed adaptations to obey to countries specific laws.

BIBLIOGRAPHY

[1] P. J. Jong-Gierveld and H. v. Solinge, *Ageing and its consequences for the socio-medical system*. Strasbourg, France: Council of Europe Press, 1995.

[2] R. Holliday, "Ageing in the 21st century," *The Lancet,* December 1999.

[3] E. S. Ford and S. Capewell, "Coronary Heart Disease Mortality Among Young Adults in the US From 1980 Through 2002 Concealed Leveling of Mortality Rates," *Journal of the American College of Cardiology,* vol. 50, pp. 2128--2132, 2007.

[4] "Ageing Societies and the Looming Pension Crisis," in *Organization for Economic Co-Operation and Developmen (OECD)*. vol. 2009.

[5] S. J. Brown, "Guest editorial: next generation telecare and its role in primary and community care," *Health & Social Care in the Community,* vol. 11, pp. 459-462, 2003.

[6] "World Population Ageing: 1950-2050," Population Division, DESA, United Nations, New York2001.

[7] "Social Development and Ageing: Crisis or Opportunity?," Geneva, Switzerland, 2000.

[8] "Active Ageing: a Policy Framework," Madrid, Spain: World Health Organization, 2002, p. 60.

[9] "Estatísticas Demográficas 2006," INE, 2006.

[10] A. K. Jha, T. G. Ferris, K. Donelan, C. DesRoches, A. Shields, S. Rosenbaum, and D. Blumenthal, "How Common Are Electronic Health Records In The United States? A Summary Of The Evidence," *Health Aff,* vol. 25, pp. w496-507, November 1, 2006 2006.

[11] D. Gans, J. Kralewski, T. Hammons, and B. Dowd, "Medical Groups' Adoption Of Electronic Health Records And Information Systems," *Health Aff,* vol. 24, pp. 1323-1333, September 1, 2005 2005.

[12] S. H. Walsh, "The clinician's perspective on electronic health records and how they can affect patient care," *BMJ,* vol. 328, pp. 1184-1187, May 15, 2004 2004.

[13] G. Eysenbach, "Recent advances: Consumer health informatics," *BMJ,* vol. 320, pp. 1713-1716, June 24, 2000 2000.

[14] G. Eysenbach and T. L. Diepgen, "The role of e-health and consumer health informatics for evidence-based patient choice in the 21st century," *Clinics in Dermatology,* vol. 19, pp. 11-17, 2001.

[15] T. Ferguson, "Consumer health informatics," *The Healthcare Forum Journal,* vol. 38, pp. 28-33, 1995.

[16] F. Mair and P. Whitten, "Systematic review of studies of patient satisfaction with telemedicine," *BMJ,* vol. 320, pp. 1517-1520, June 3, 2000 2000.

[17] R. Roine, A. Ohinmaa, and D. Hailey, "Assessing telemedicine: a systematic review of the literature," *CMAJ,* vol. 165, pp. 765-771, September 18, 2001 2001.

[18] D. Wright and L. Androuchko, "Telemedicine and developing countries," *Telemedicine and Telecare,* vol. 2, pp. 63-70, 1996.

[19] R. S. H. Istepanian, E. Jovanov, and Y. T. Zhang, "Guest Editorial Introduction to the Special Section on M-Health: Beyond Seamless Mobility and Global Wireless Health-Care Connectivity," *Information Technology in Biomedicine, IEEE Transactions on,* vol. 8, pp. 405-414, 2004.

[20] T. Broens, A. V. Halteren, and M. V. S. Wac, "Towards an application framework for context-aware m-health applications," *International Journal of Internet Protocol Technology,* vol. 2, pp. 109-116, 2007.

[21] C. Poon, Y.-T. Zhang, and S.-D. Bao, "A novel biometrics method to secure wireless body area sensor networks for telemedicine and m-health," *IEEE Communications Magazine,* vol. 44, pp. 73-81, 2006.

[22] P. Tang and T. Venables, "'Smart' homes and telecare for independent living," *J Telemed Telecare,* vol. 6, pp. 8-14, February 2, 2000 2000.

[23] K. Doughty, K. Cameron, and P. Garner, "Three generations of telecare of the elderly," *Telemedicine and Telecare,* vol. 2, pp. 71-80, 1996.

[24] A. F. Jerant, R. Azari, and T. S. Nesbitt, "Reducing the Cost of Frequent Hospital Admissions for Congestive Heart Failure: A Randomized Trial of a Home Telecare Intervention," *Medical Care,* vol. 39, pp. 1234-1245, 2001.

[25] H. Afsarmanesh, V. G. Masís, and L. O. Hertzberger, "Virtual Community Support in TeleCARE," in *4th IFIP Working Conference in Virtual Enterprises (PRO-VE'03)*, Lugano, Switzerland, 2003, pp. 211-220.

[26] K. Kawamoto, C. A. Houlihan, E. A. Balas, and D. F. Lobach, "Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success," *BMJ,* vol. 330, pp. 765-, April 2, 2005 2005.

[27] I. Sim, P. Gorman, R. A. Greenes, R. B. Haynes, B. Kaplan, H. Lehmann, and P. C. Tang, "Clinical Decision Support Systems for the Practice of Evidence-based Medicine," *J Am Med Inform Assoc,* vol. 8, pp. 527-534, November 1, 2001 2001.

[28] A. X. Garg, N. K. J. Adhikari, H. McDonald, M. P. Rosas-Arellano, P. J. Devereaux, J. Beyene, J. Sam, and R. B. Haynes, "Effects of Computerized Clinical Decision Support Systems on Practitioner Performance and Patient Outcomes: A Systematic Review," *JAMA,* vol. 293, pp. 1223-1238, March 9, 2005 2005.

[29] A. Kalache and A. Gatti, "Active ageing: a policy framework," *Adv Gerontol,* vol. 11, pp. 7-18, 2003.

[30] A. Kinsella, "Home telecare in the United States," *J Telemed Telecare,* vol. 4, pp. 195-200, December 1, 1998 1998.

[31] C. Ruggiero, R. Sacile, and M. Giacomini, "Home telecare," *J Telemed Telecare,* vol. 5, pp. 11-17, March 1, 1999 1999.

[32] J. D. Stoeckle and S. Lorch, "Why go see the doctor? Care goes from office to home as technology divorces function from geography," *Int J Technol Assess Health Care,* vol. 13, pp. 537-46, Fall 1997.

[33] B. G. Celler, N. H. Lovell, and D. K. Chan, "The potential impact of home telecare on clinical practice," *Med J Aust,* vol. 171, pp. 518-21, Nov 15 1999.

[34] T. Martin, E. Jovanov, and D. Raskovic, "Issues in wearable computing for medical monitoring applications: a case study of a wearable ECG monitoring device," in *Wearable Computers, 2000. The Fourth International Symposium on*, 2000, pp. 43-49.

[35] S. Mann, "Smart clothing: the shift to wearable computing," *Commun. ACM,* vol. 39, pp. 23-24, 1996.

[36] T. Starner, "The challenges of wearable computing: Part 2," *Micro, IEEE,* vol. 21, pp. 54-67, 2001.

[37] D. Siewiorek, A. Smailagic, and T. Starner, "Application Design for Wearable Computing," *Synthesis Lectures on Mobile and Pervasive Computing,* vol. 3, pp. 1-66, 2008.

[38] M. DeBellis and C. Haapala, "User-centric Software Engineering," *IEEE Expert,* vol. 10, pp. 34-41, 1995.

[39] Z. Zhenmin, S. Xiaoli, J. Faqun, L. Jintao, and Y. Jian, "A User-Centric Pervasive Computing Services Model for Medical and Health-care," in *Grid and Cooperative Computing, 2007. GCC 2007. Sixth International Conference on*, 2007, pp. 841-846.

[40] G. Giorgetti, G. Manes, J. H. Lewis, S. T. Mastroianni, and S. K. S. Gupta, "The personal sensor network: a user-centric monitoring solution," in *Proceedings of the ICST 2nd international conference on Body area networks* Florence, Italy: ICST

(Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2007.

[41] E. Krupinski, M. Nypaver, R. Poropatich, D. Ellis, R. Safwat, and H. Sapci, "Chapter 2: Clinical Applications in Telemedicine/Telehealth," *Telemedicine Journal and e-Health,* vol. 8, pp. 13-34, 2002.

[42] D. A. Perednia and A. Allen, "Telemedicine technology and clinical applications," *JAMA,* vol. 273, pp. 483-8, Feb 8 1995.

[43] J. Grigsby and J. H. Sanders, "Telemedicine: Where It Is and Where It's Going," *Ann Intern Med,* vol. 129, pp. 123-127, July 15, 1998 1998.

[44] D. Bangert and R. Doktor, "Implementing Store-and-Forward Telemedicine: Organizational Issues," *Telemedicine Journal and e-Health,* vol. 6, pp. 355-360, 2000.

[45] L. Camarinha-Matos and W. Vieira, "Intelligent mobile agents in elderly care," *Robotics and autonomous systems,* vol. 27, pp. 59-75, 1999.

[46] R. N. Mayer, "Technology, Families, and Privacy: Can We Know Too Much About Our Loved Ones? ," *Journal of Consumer Policy,* vol. 26, pp. 419-439, 2003.

[47] L. M. Camarinha-Matos, *Virtual Enterprises and Collaborative Networks (IFIP International Federation for Information Processing)*: Kluwer Academic Publishers, 2004.

[48] H. B. Milward and K. G. Provan, "A Manager's Guide to Choosing and Using Collaborative Networks," IBM2006.

[49] R. Linden, "A framework for collaborating," in *The Public Manager*. vol. 2009: FindArticles.com, 2002.

[50] H. Jägers, W. Jansen, and W. Steenbakkers, "Characteristics of Virtual Organizations," in *VoNet - Workshop*, Bern, Switzerland, 1998, pp. 65-76.

[51] H. Afsarmanesh, V. Mařik, and L. M. Camarinha-Matos, "Challenges of Collaborative Networks in Europe " in *Collaborative Networked Organizations*: Springer US, 2004, pp. 77-90.

[52] C. P. Holland and A. G. Lockett, "Business Trust and the Formation of Virtual Organizations," in *Proceedings of the Thirty-First Annual Hawaii International Conference on System Sciences-Volume 6 - Volume 6*: IEEE Computer Society, 1998.

[53] B. R. Katzy, "Design and Implementation of Virtual Organizations," in *Proceedings of the Thirty-First Annual Hawaii International Conference on System Sciences-Volume 4 - Volume 4*: IEEE Computer Society, 1998.

[54] L. M. Camarinha-Matos and H. Afsarmanesh, "The Virtual Enterprise Concept," in *Proceedings of the IFIP TC5 WG5.3 / PRODNET Working Conference on Infrastructures for Virtual Enterprises: Networking Industrial Enterprises*: Kluwer, B.V., 1999.

[55] G. Wasson and M. Humphrey, "Policy and Enforcement in Virtual Organizations," in *Proceedings of the 4th International Workshop on Grid Computing*: IEEE Computer Society, 2003.

[56] L. J. O'Toole, "Treating Networks Seriously: Practical and Research-Based Agendas in Public Administration," *Public Administration Review,* vol. 57, pp. 45-52, 1997.

[57] M. McGuire, "Is it Really So Strange? A Critical Look at the “Network Management is Different From Hierarchical Management” Perspective," in *7th National Public Management Research Conference* Washington DC, 2003.

[58] R. Agranoff, "Leveraging Networks: A Guide for Public Managers Working across Organizations," IBM2003.

[59] H. Rheingold, *The Virtual Community: Homesteading on the Electronic Frontier*: The MIT Press, 2000.

[60] J. Fernback and B. Thompson, "Computer-Mediated Communication and the American Collectivity: The Dimensions of Community Within Cyberspace," in *International Communication Association* Albuquerque, New Mexico, 1995.

[61] C. Carver, "Building a virtual community for a tele-learning environment," *Communications Magazine, IEEE,* vol. 37, pp. 114-118, 1999.

[62] Q. Jones, G. Ravid, and S. Rafaeli, "Information Overload and Virtual Public Discourse Boundaries," in *Eighth IFIP conference on Human-Computer Interaction*, Tokyo, Japan 2001.

[63] H. Rheingold, *The Virtual Community*, 1st ed.: Addison-Wesley, 1993.

[64] David W. McMillan, "Sense of community," *Journal of Community Psychology,* vol. 24, pp. 315-325, 1996.

[65] L. Camarinha-Matos, "New collaborative organizations and their research needs," in *PRO-VE'03*, 2003.

[66] G. Marreiros, R. Santos, C. Ramos, J. Neves, P. Novais, J. Machado, and J. Bulas-Cruz, "Ambient Intelligence in Emotion Based Ubiquitous Decision Making," in *Proceedings of the International Joint Conference on Artificial Intelligence (IJCAI 2007) - 2nd Workshop on Artificial Intelligence Techniques for Ambient Intelligence (AITAmI'07)*, 2007.

[67] R. Bostrom, R. Anson, and V. Clawson, "Group facilitation and group support systems," in *Group Support Systems: New Perspectives*, Jessup and Valachic, Eds.: Macmillan, 2003.

[68] R. M. Schwarz, *The Skilled Facilitator: Practical Wisdom for Developing Effective Groups*: Jossey Bass, 1994.

[69] S. Dubs and S. C. Hayne, "Distributed facilitation: a concept whose time has come?," in *Computer Supported Cooperative Work*, 1992, pp. 314-321.

[70] D. J. Power, "A Brief History of Decision Support Systems. DSSResources.COM, World Wide Web, version 4.0," 2007.

[71] J. Conklin, "Designing Organizational Memory: Preserving Intellectual Assets in a Knowledge Economy," 2001.

[72] J. Conklin, *Dialogue Mapping: Building Shared Understanding of Wicked Problems*: Wiley, 2006.

[73] S. Parsons, "Current approaches to handling imperfect information in data andknowledge bases," *IEEE Transactions on Knowledge and Data Engineering,* vol. 8, pp. 353-372, 1996.

[74] R. J. Cruz-Correia, P. M. Vieira-Marques, A. M. Ferreira, F. C. Almeida, J. C. Wyatt, and A. M. Costa-Pereira, "Reviewing the integration of patient data: how systems are evolving in practice to meet patient needs," *BMC Medical Informatics and Decision Making,* vol. 7, 2007.

[75] G. Eysenbach, "What is e-health?," *Journal of Medical Internet Research,* vol. 3, p. e20, 2001.

[76] U. Hustadt, "Do we need the closed-world assumption in knowledge representation?," in *KI'94 Workshop*, Saarbrüken, Germany, 1994.

[77] C. Analide, "Antropopatia em Entidades Virtuais, Ph.D. Thesis," in *Engineering School*. vol. Ph.D. Braga, Portugal: University of Minho, 2004.

[78] J. Neves, "A Logic Interpreter to Handle Time and Negation in Logic Data Bases," in *Proceedings of the ACM'84, The Fifth Generation Challenge*, 1984, pp. 50-54.

[79] M. Gelfond and V. Lifschitz, "Logic Programs with Classical Negation," in *Proceedings of the International Conference on Logic Programming*, 1990.

[80] S. Parsons, "Current approaches to handling imperfect information in data and knowledge bases," *IEEE Trans. on Knowledge and Data Eng.,* vol. 8, 1996.

[81] A. Dix, J. Finlay, G. Abowd, and R. Beale, *Human-computer interaction*: Prentice hall, 2004.

[82] M. Raisinghani, A. Benoit, J. Ding, M. Gomez, K. Gupta, V. Gusila, D. Power, and O. Schmedding, "Ambient Intelligence: Changing forms of human-computer interaction and their social implications," *Journal of Digital Information,* vol. 5, 2006.

[83] G. Riva, F. Vatalaro, F. Davide, and M. Alcaniz, *Ambient Intelligence: The Evolution of Technology, Communication and Cognition Towards the Future of Human-computer Interaction*: IOS Press, 2005.

[84] G. Riva, "Ambient Intelligence in Health Care," *Cyberpsychology & Behavior,* vol. 6, pp. 295 - 301, 2003.

[85] K. Ducatel, "Scenarios for ambient intelligence in 2010," Office for Official Publications of the European Communities, 2001.

[86] ISTAG, "Strategic Orientations and Priorities for IST in FP6," European Comission, 2002.

[87] K. Ducatel, M. Bogdanowicz, F. Scapolo, J. Leijten, and J. Burgelman, "Ambient Intelligence: From Vision to Reality," *IST Advisory Group, European Commission,* 2003.

[88] G. Acampora, V. Loia, M. Nappi, and S. Ricciardi, "Ambient intelligence framework for context aware adaptive applications," 2005, pp. 327-332.

[89] E. Aarts, P. Res, and N. Eindhoven, "Ambient intelligence: A multimedia perspective," *IEEE Multimedia,* vol. 11, pp. 12-19, 2004.

[90] M. Weiser, R. Gold, and J. Brown, "The origins of ubiquitous computing research at PARC in the late 1980s," *IBM Systems Journal,* vol. 38, pp. 693-696, 1999.

[91] A. Vasilakos and W. Pedrycz, *Ambient intelligence, wireless networking, and ubiquitous computing*: Artech House, Inc. Norwood, MA, USA, 2006.

[92] M. Friedewald and O. Da Costa, "Science and Technology Roadmapping: Ambient Intelligence in Everyday Life (AmI@ Life)," *Karlsruhe: Fraunhofer-Institut für System-und Innovationsforschung (FhG-ISI),* 2003.

[93] U. Hansmann, M. Nicklous, and T. Stober, *Pervasive computing handbook*: Springer-Verlag New York, Inc. New York, NY, USA, 2001.

[94] M. Satyanarayanan, "Pervasive computing: Vision and challenges," *IEEE [see also IEEE Wireless Communications] Personal Communications,* vol. 8, pp. 10-17, 2001.

[95] C. Ramos, "Ambient intelligence-a state of the art from artificial intelligence perspective," *Lecture Notes in Computer Science,* vol. 4874, p. 285, 2007.

[96] P. Emiliani and C. Stephanidis, "Universal access to ambient intelligence environments: Opportunities and challenges for people with disabilities," *IBM Systems Journal,* vol. 44, pp. 605-619, 2005.

[97] E. Aarts, E. Aarts, and J. Encarnação, *True visions: The emergence of ambient intelligence*: Springer, 2009.

[98] E. Aarts, R. Harwig, and M. Schuurmans, "Ambient intelligence, The invisible future: the seamless integration of technology into everyday life," McGraw-Hill, Inc., New York, NY, 2001.

[99] M. Rocha, P. Cortez, and J. Neves, "Adaptive Learning in Changing Environments," in *ESANN 2003, 11th European Symposium on Artificial Neural Networks*, Bruges, Belgium, 2003, pp. 487-492.

[100] M. Bick and T. F. Kummer, "Ambient Intelligence and Ubiquitous Computing " in *Handbook on Information Technologies for Education and Training*, Second ed: Springer Berlin Heidelberg, 2008.

[101] P. Rubel, J. Fayn, L. Simon-Chautemps, H. Atoui, M. Ohlsson, D. Telisson, S. Adami, S. Arod, M. Forlini, and C. Malossi, "New paradigms in telemedicine: ambient intelligence, wearable, pervasive and personalized," *Stud Health Technol Inform,* vol. 108, pp. 123–132, 2004.

[102] W. Weber, J. Rabaey, and E. Aarts, *Ambient intelligence*: Springer, 2005.

[103] J. A. Jorge, "Adaptive tools for the elderly: new devices to cope with age-induced cognitive disabilities," in *Proceedings of the 2001 EC/NSF workshop on Universal accessibility of ubiquitous computing: providing for the elderly* Alcácer do Sal, Portugal: ACM, 2001.

[104] J. Fink, A. Kobsa, and A. Nill, "Adaptable and adaptive information access for all users, including the disabled and the elderly," 1997, p. 173.

[105] J. Abascal, "Ambient Intelligence for people with disabilities and elderly people," *ACM's Special Interest Group on Computer-Human Interaction (SIGCHI), Ambient Intelligence for Scientific Discovery (AISD) Workshop, Vienna, April,* vol. 25, 2004.

[106] M. Cabrera Giraldez and C. Rodriguez Casal, "The role of Ambient Intelligence in the Social Integration of the Elderly," in *Ambient Intelligence*: IOS Press, 2005, pp. 267-282.

[107] S. Bahadori, A. Cesta, L. Iocchi, G. Leone, D. Nardi, F. Pecora, R. Rasconi, and L. Scozzafava, "Towards ambient intelligence for the domestic care of the elderly," *Ambient intelligence: a novel paradigm. Springer,* 2004.

[108] M. Niemela, R. Fuentetaja, E. Kaasinen, and J. Gallardo, "Supporting Independent Living of the Elderly with Mobile-Centric Ambient Intelligence: User Evaluation of Three Scenarios," *Lecture Notes in Computer Science,* vol. 4794, p. 91, 2007.

[109] L. Ni, Y. Liu, Y. Lau, and A. Patil, "LANDMARC: indoor location sensing using active RFID," *Wireless Networks,* vol. 10, pp. 701-710, 2004.

[110] P. Lukowicz, T. Kirstein, and G. Tröster, "Wearable systems for health care applications," *Methods of information in medicine,* vol. 43, p. 232, 2004.

[111] S. Mann, "Smart clothing: The wearable computer and wearcam," *Personal and Ubiquitous Computing,* vol. 1, pp. 21-27, 1997.

[112] V. V. Badami and N. W. Chbat, "Home appliances get smart," *Spectrum, IEEE,* vol. 35, pp. 36-43, 1998.

[113] A. Björklind and S. Holmlid, "Ambient Intelligence to Go," Santa Anna IT Research Institute AB2003.

[114] R. Costa, P. Novais, J. Machado, C. Alberto, and J. Neves, *Inter-organization Cooperation for Care of the Elderly*. Wuhan, China: Springer-Verlag, 2007.

[115] M. Weiser, "Some computer science issues in ubiquitous computing," *SIGMOBILE Mob. Comput. Commun. Rev.,* vol. 3, p. 12, 1999.

[116] M. Weiser, "The computer for the 21st century," *SIGMOBILE Mob. Comput. Commun. Rev.,* vol. 3, pp. 3-11, 1999.

[117] A. Greenfield, *Everyware: The Dawning Age of Ubiquitous Computing*, 1st ed.: New Riders Publishing, 2006.

[118] K. Lyytinen and Y. Yoo, "Issues and Challenges in Ubiquitous Computing," *Commun. ACM,* vol. 45, pp. 62-65, 2002.

[119] M. Satyanarayanan, "Pervasive computing: vision and challenges," *Personal Communications, IEEE,* vol. 8, pp. 10-17, 2001.

[120] D. Saha and A. Mukherjee, "Pervasive computing: a paradigm for the 21st century," *Computer,* vol. 36, pp. 25-31, 2003.

[121] B. Schilit, N. Adams, and R. Want, "Context-Aware Computing Applications," in *Mobile Computing Systems and Applications, 1994. WMCSA 1994. First Workshop on*, 1994, pp. 85-90.

[122] A. K. Dey, "Understanding and Using Context," *Personal and Ubiquitous Computing,* vol. 5, pp. 4-7, 2001.

[123] G. H. Forman and J. Zahorjan, "The challenges of mobile computing," *Computer,* vol. 27, pp. 38-47, 1994.

[124] H. Steg, H. Strese, C. Loroff, J. Hull, and S. Schmidt, "Europe Is Facing a Demographic Challenge Ambient Assisted Living Offers Solutions," IST Project Report on Ambient Assisted Living, March 2006.

[125] T. Kleinberger, M. Becker, E. Ras, A. Holzinger, and P. Müller, "Ambient Intelligence in Assisted Living: Enable Elderly People to Handle Future Interfaces," in *Universal Access in Human-Computer Interaction. Ambient Interaction*, 2007, pp. 103-112.

[126] J. Nehmer, M. Becker, A. Karshmer, and R. Lamm, "Living assistance systems: an ambient intelligence approach," in *Proceedings of the 28th international conference on Software engineering* Shanghai, China: ACM, 2006, pp. 43-50.

[127] J. M. Corchado, J. Bajo, Y. de Paz, and D. I. Tapia, "Intelligent environment for monitoring Alzheimer patients, agent technology for health care," *Decision Support Systems,* vol. 44, pp. 382-396, 2008.

[128] D. Carneiro and P. Novais, "Monitoring Ambient Assisted Living," in *Departamento de Informática*. vol. MsC Braga: Universidade do Minho, 2009.

[129] D. Carneiro, R. Costa, P. Novais, J. Neves, J. Machado, and J. Neves, "Simulating and Monitoring Ambient Assisted Living," in *ESM 2008*, Le Havre, France, 2008., 2008, pp. 175-182.

[130] G. Demiris, "Smart homes and ambient assisted living in an aging society. New opportunities and challenges for biomedical informatics," *Methods Inf Med,* vol. 47, pp. 56-7, 2008.

[131] N. Georgantas, S. B. Mokhtar, Y. Bromberg, V. Issarny, J. Kalaoja, J. Kantarovitch, A. Gerodolle, and R. Mevissen, "The Amigo Service Architecture for the Open Networked Home Environment," in *Software Architecture, 2005. WICSA 2005. 5th Working IEEE/IFIP Conference on*, 2005, pp. 295-296.

[132] K. Z. Haigh, L. M. Kiff, J. Myers, V. Guralnik, C. W. Geib, J. Phelps, and T. Wagner, "The Independent LifeStyle Assistant (I.L.S.A.): AI Lessons Learned," in *National Conference on Artificial Intelligence*, 1999, pp. 852-857.

[133] A. Feldman, E. M. Tapia, S. Sadi, P. Maes, and C. Schmandt, "ReachMedia: on-the-move interaction with everyday objects," in *Wearable Computers, 2005. Proceedings. Ninth IEEE International Symposium on*, 2005, pp. 52-59.

[134] D. Tapia, S. Rodríguez, J. Bajo, and J. Corchado, "FUSION@, A SOA-Based Multi-agent Architecture," in *International Symposium on Distributed Computing and Artificial Intelligence 2008 (DCAI 2008)*, 2009, pp. 99-107.

[135] D. Tapia, J. Bajo, and J. Corchado, "Distributing Functionalities in a SOA-Based Multi-agent Architecture," in *7th International Conference on Practical Applications of Agents and Multi-Agent Systems (PAAMS 2009)*, 2009, pp. 20-29.

[136] L. M. Camarinha-Matos and H. Afsarmanesh, "Virtual communities and elderly support," *Advances in Automation, Multimedia and Video Systems, and Modern Computer Science,* pp. 279-284, 2001.

[137] L. M. Camarinha-Matos, O. Castolo, and J. Rosas, "A multi-agent based platform for virtual communities in elderly care," in *9th IEEE International Conference on Emerging Technologies and Factory Automation*, 2003.

[138] R. Costa, P. Novais, J. Machado, C. Alberto, and J. Neves, "Inter-organization Cooperation for Care of the Elderly," in *Integration and Innovation Orient to E-Society Volume 2*. vol. 252/2008 Boston: Springer, 2008, pp. 200-208.

[139] R. Costa, P. Novais, J. Neves, G. Marreiros, C. Ramos, and J. Neves, "VirtualECare: Group Decision Supported by Idea Generation and Argumentation," in *Pervasive Collaborative Networks*, 2008, pp. 293--300.

[140] P. Novais, R. Costa, D. Carneiro, J. Machado, L. Lima, and J. Neves, "Group Support in Collaborative Networks Organizations for Ambient Assisted Living," in *Towards Sustainable Society on Ubiquitous Networks*, 2008, pp. 353--362.

[141] O. Alliance, *OSGi Service Platform: The OSGi Alliance*: IOS Press, 2003.

[142] K. Chen and L. Gong, *Programming Open Service Gateways with Java Embedded Server(TM) Technology*: Prentice Hall PTR, 2001.

[143] F. L. Bellifemine, G. Caire, and D. Greenwood, *Developing Multi-Agent Systems with JADE*: Wiley, 2007.

[144] D. Carneiro, R. Costa, and P. Novais, "(R-)OSGi: The VirtualECare Open Framework," 2008.

[145] S. Poslad, P. Buckle, and R. Hadingham, "The FIPA-OS agent platform: Open source for open standards," 2000, pp. 355–368.

[146] Y. Labrou, T. Finin, and Y. Peng, "Agent communication languages: The current landscape," 1999.

[147] G. Alonso, F. Casati, H. Kuno, and V. Machiraju, *Web services: Concepts, Architectures and Applications (Data-centric Systems and Applications)*: Springer, 2004.

[148] E. R. Harold and W. S. Means, *XML in a Nutshell*, Third ed.: O'Reilly Media, Inc., 2004.

[149] E. R. Harold, *XML Bible*, Second ed.: Hungry Minds, 2001.

[150] A. FIPA, "Message Representation in XML Specification," *Foundation for Intelligent Physical Agents,* 2000.

[151] M. Luck, R. Ashri, and M. d'Inverno, *Agent-Based Software Development*, 2004.

[152] L. Brito, P. Novais, and J. Neves, "The logic behind negotiation: from pre-argument reasoning to argument-based negotiaion," in *Intelligent Agent Software Engineering*, V. Plekhanova, Ed.: Idea Group Piblishing, 2003, pp. 137-159.

[153] J. Conklin, "The IBIS Manual: A short course in IBIS methodology," GDSS Inc.

[154] J. Conklin and M. Begeman, *gIBIS: A Hypertext tool for exploratory policy discussion* vol. 6, 1988.

[155] J. Neves, "A Logic Interpreter to Handle Time and Negation in Logic Data Bases," in *The Fifth Generation Challenge*, 1984, pp. 50-54.

[156] G. Marreiros, P. Novais, J. Machado, C. Ramos, and J. Neves, "An Agent-based Approach to Group Decision Simulation using Argumentation," in *International MultiConference on Computer Science and Information Technology, Workshop Agent-Based Computing III (ABC 2006)*, Wisla, Poland, 2006, pp. 225-232.

[157] M. C. Brown, *Hacking Google Maps and Google Earth*. Indianapolis, IN: Wiley Pub., 2006.

[158] R. C. Mohs, "HowStuffWorks "How Human Memory Works" %U http://health.howstuffworks.com/human-memory.htm," 2007.

[159] M. Lamming and M. Flynn, "Forget-me-not: Intimate computing in support of human memory," in *Proceedings of FRIEND21*. vol. 94, 1994, pp. 2-4.

[160] B. J. Rhodes, "The wearable remembrance agent: A system for augmented memory," *Personal and Ubiquitous Computing,* vol. 1, pp. 218-224, 1997.

[161] H. J. Kim, D. T. Burke, M. M. Dowds, and J. George, "Utility of a microcomputer as an external memory aid for a memory-impaired head injury patient during in-patient rehabilitation," *Brain Injury,* vol. 13, pp. 147-50, 1999.

[162] J. Jiang, A. Geven, and S. Zhang, "HERMES: A FP7 Funded Project towards Computer-Aided Memory Management Via Intelligent Computations," in *3rd Symposium of Ubiquitous Computing and Ambient Intelligence 2008*: Springer, 2008, p. 249.

[163] S. Hodges, L. Williams, E. Berry, S. Izadi, J. Srinivasan, A. Butler, G. Smyth, N. Kapur, and K. Wood, "SenseCam: A retrospective memory aid," *Lecture Notes in Computer Science,* vol. 4206, p. 177, 2006.

[164] C. Giraldo, S. Helal, and W. Mann, "mPCA–A mobile patient care-giving assistant for Alzheimer patients," in *First International Workshop on Ubiquitous Computing for Cognitive Aids (UbiCog'02)*, 2002.

[165] R. Costa, P. Novais, Â. Costa, and J. Neves, "Memory Support in Ambient Assisted Living," in *10th IFIP Working Conference on VIRTUAL ENTERPRISES*, Thessaloniki, GREECE, 2009.

[166] R. Costa, J. Neves, P. Novais, J. Machado, L. Lima, and C. Alberto, *Intelligent Mixed Reality for the Creation of Ambient Assisted Living* vol. 4874: Lecture Notes in Artificial Intelligence - Spinger, 2007.

[167] R. Costa, P. Novais, L. Lima, J. B. Cruz, and J. Neves, *Handbook of Digital Homecare*: Springer, 2009.

[168] L. Lima, R. Costa, P. Novais, C. Analide, J. B. Cruz, and J. Neves, "Quality of Information in the context of Ambient Assisted Living," in *DCAI'08 - International Symposium on Distributed Computing and Artificial Intelligence* Salamanca, Spain, 2008.