e-Tools: The use of Assistive Technologies to enhance disabled and senior citizens' autonomy.

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Abstract. In this paper we present our preliminary ideas about the integration of several technologies to build specific *e*-tools for the disabled and for the new generation of senior citizens. '*e*-Tools' stands for *Embedded Tools*, as we aim to embed intelligent assistive devices in homes and other facilities, creating ambient intelligence environments to give support to patients and caregivers. In particular, we aim to explore the benefits of the concept of *situated intelligence* to build intelligent artefacts that will enhance the autonomy of the target group during their daily life. We present here a multi-level architecture and our preliminary research on navigation schemes for a robotic wheelchair.

1 INTRODUCTION

Nowadays it is clear the growing importance of the role that Artificial Intelligence (AI) – specially Knowledge-Based Systems (KBS) – is playing in medicine to support medical practitioners in making decisions under uncertainty (see [13]). Also, in medical scenarios where many individuals are involved in a decision-making process or when their decisions and actions have to be coordinated, *Agent-Based Technology* (software systems composed of intelligent *Software Agents*) is getting an increasing role to a) model the processes, and b) model the decision making processes (see [12]). However most of the current applications are centred in the information dimension of health care management (see §3.2).

Robotics is another field with growing applications. Robots are moving away from factories into environments such as private homes, in order to assist people in (very simple) daily routines. However, there are fewer projects investigating the use of autonomous robots technology for disabled and elderly people. Much of this work is devoted to the creation of electric wheelchairs that can autonomously navigate through an environment (just as a robot would do) [26]. Nevertheless, there are also some promising uses of robotics' technology (sensors, artificial vision) to create other services such as patient position tracking.

Ambient intelligence (AmI) builds on three recent technologies: *Ubiquitous or Wearable Computing*, *Ubiquitous Communication* and *Intelligent User Interfaces*. *Ubiquitous Computing* means integration of microprocessors into everyday objects like furniture, clothing, white goods, toys, etc. *Ubiquitous Communication* enables these objects to communicate with each other and the user by means of *ad-hoc* and wireless networking. Finally an *Intelligent User Interface* enables the inhabitants of the AmI environment to control and interact with the environment in a natural (voice, gestures) and personalised (preferences, context) way [10].

The senior citizens represent a fast growing proportion of the population in Europe and other developed areas [5]. This paper presents some of our ideas about the use of all these technologies, integrating them into everyday environments and rendering access to services and applications through easy-to-use interfaces, especially designed for the disabled and the senior citizens. The use and creation of new technologies for the disabled is crucial, as for this group of people assistance is not merely a matter of *doing* the same things more quickly or in a simpler way with the aid of an *e*-tool. For them it is a matter of *being able* to perform those tasks independently and, maybe, to learn how to perform new tasks in order to enhance their own autonomy.

The rest of this paper is organised as follows. In §2.1 we introduce the problem of disability and give some figures of its impact on society. Then in §2.2 we will discuss the interaction problem of senior and disabled people with technological devices. In §2.3 we address the issues of safety and soundness that are mandatory in systems integrating various technologies in a single platform. In §3 we address the possible uses of assistive technologies. Afterwards, in §4 we will introduce the *e*-Tools architecture and an intelligent robotic wheelchair as an example including most of our ideas. Finally, in §5, we make some reflections about the future of this technology.

2 DISABILITY AND THE SENIOR CITIZENS

2.1 Ageing and disability

The ageing of the population today is without parallel in the history of humanity. Increases in the proportions of older persons (60 or older) are being accompanied by declines in the proportions of the young (under age 15). Nowadays, the number of persons aged 60 years or older is estimated to be 629 million[8]. By the middle of the century, one fifth of older persons will be 80 years or older [16].

The increasing number of people affected by chronic diseases is a direct consequence of the ageing of the population. Chronic illnesses, such as heart disease, cancer and mental disorders, are fast becoming the world's leading causes of death and disability, including the developing world. Two examples of highly

[8] According to the Second World Assembly on Ageing Madrid, Spain 8 -12 April 2002

invalidating diseases requiring medical assistance and/or institutional care are represented by *Alzheimer's disease* and *stroke*.

Alzheimer's disease (AD) is the principal cause of dementia in the elderly, affecting about 15 million people worldwide. The earliest symptom is usually an insidious impairment of memory. As the disease progresses, there is increasing impairment of language and other cognitive functions. Last stages of the disease use to lead to an institutionalisation in some kind of facility specialized to treat such cases. But this solution not only has a high cost, but also is harmful for the patient, that is placed in a unknown environment with unknown people.

Stroke is the most disabling chronic condition. Its effects impact on virtually all functions: gross and fine motor ability, ambulation, capacity to carry out basic and instrumental activities of daily living, mood, speech, perception and cognition. Stroke represents a heterogeneous category of illness that describes brain injury, usually sudden (e.g. haemorrhages, vasospasms, thrombosis). Therefore, in each case the retraining and adaptation process to neurological handicaps depend on the nature of the underlying anatomic abnormality and not on the cause of such abnormality. Stroke may have a devastating impact of patients' lives.

In both developed and developing countries, chronic diseases are significant and costly causes of disability and reduced quality of life. An older person's independence is threatened when physical or mental disabilities make it difficult to carry out the basic activities of daily living such as bathing, eating, using the toilet and walking across the room, as well as shopping and meal preparation. One or more diseases can be involved in causing disability; at the same time, a single illness can produce a high degree of disability. Therefore, disabled people are a very heterogeneous group, comprising a wide spectrum of function. This ranges from mild impairment and/or disability to moderate to severe limitations. However, the concept of disability itself is not always precise and quantifiable. [9]

A related concept is the one of health environmental integration (HEI). [22] This concept has been expanded recently: originally it was presented as a framework to study how humans and machines interact and complement each other along the ICIDH-2. Now-a-days, AT therapeutics are directed at both the person and the environment. The objective is to enhance HEI by using devices to neutralize impairments. By neutralizing impairment, there is an expansion of people's potential to enter into, to perform major activities within, and to fully participate according to the structure of the surrounding physical and social environments.

2.2 The interaction of disabled people with technology

In the analysis, design and final creation of disabled-oriented devices, it is mandatory to keep in mind the interface problem, either because of a severe mental

[9] To facilitate agreement about the concept of disability, the World Health Organization (WHO) has developed the *International Classification of Impairment, Disabilities, and Handicaps (ICIDH-2)* and the *International Classification of Functioning, Disability and Health* (*ICF*).

or mobility dysfunction or the usual complex relationship among elder people and new technologies [20]. The Rehabilitation Engineering Research Center on Technology Evaluation and Transfer (RERC-TET) has focused on consumer-identified needs and preferences regarding several categories of assistive technologies. According to the classification of Batavia and Hammer [2], 11 criteria have been identified that disabled patients consider important: among others, *Effectiveness*, *Reliability* and, mainly, *Operability* – the extent to which the device is easy to use, is adaptable and flexible.

Fig. 1. An example of modern electric-powered wheelchairs.

The extreme difficulty with which persons with severe disabilities have been taught to manoeuvre a power wheelchair is an example of difficult interaction with AT: 9 to 10% of patients who receive power wheelchair training find it extremely difficult or impossible to use the wheelchair for activities of daily living; 40% of patients reported difficult or impossible steering and manoeuvring tasks; 85% of clinicians reported that a number of patients lack the required motor skills, strength, or visual acuity. Nearly half of patients unable to control a power wheelchair by conventional methods would benefit from an automated navigation system. These results indicate a need, not for more innovation in steering interfaces, but for entirely new technologies for supervised autonomous navigation [11].

2.3 Safety and Soundness

Even though the domain of application is restricted to a quasi-structured, *situated environment* where the most important landmarks will remain stable, *unexpected* changes may arise; therefore, the system needs to solve these unforeseen situations without entering in malfunctioning states. This implies that these systems need to exhibit an intelligent goal-oriented behaviour and yet still be responsive to changes in their circumstances.

However, as observed by Fox & Das [12], the use of heuristics or rules of thumb to solve problems seems unlikely to inspire confidence. In this domain the safety of users imposes bigger restrictions and the systems must be extensively tested – possibly off-line – to ensure effectiveness and performance of the devices. Therefore, *safety* should be one of the main concerns in the design of disabled-oriented devices. One possible option is to add a safety management layer in those systems. Likewise, the creation of safety plans is mandatory. That is a set of procedures and criteria that specify *what* the system is supossed to do when, but it deals specifically with hazardous circumstances and events [12].

3 ASSISTIVE TECHNOLOGIES

Assistive technology devices can be very useful to provide supportive services for individuals who require assistance with the tasks of daily living. Their use can be not only applied to people with cognitive impairment caused by aging factors but it can be extended to any disabled and handicapped people[10], in order to ensure an acceptable level of autonomy. By proposing *substitutes for* (or rather *extensions to*) nursing homes (i.e. Assisted Care Facilities), such assistive devices will help to reduce the patient's dependency (even from the psychological point of view) specially regarding the activity of daily life and improving his/her quality of life. Such supportive services are also helpful to the caregivers of those patients. In the patient's home environment, technology may aid non-professional carers (relatives, friends) in their efforts, contributing to lengthen the time spent by disabled and elderly individuals in their own home and to postpone the need for institutionalisation. In the hospital environment, such technologies may lead to a reduction of expenses, as increased autonomy of patients would lead to reduced nursing costs, and to a better use of the time and expertise of qualified nursing personnel.

3.1 Issues to be solved

Services targeted to disabled people should be capable of solving the following problems:

- *Monitoring problems*: the creation of devices that can track several signals from sensors placed in the patient and autonomously decide if the patient is in a safe condition or there is something abnormal that recommends to call for assistance (an alarm in the case of a Care Facility, an automatic phone call with an synthetic voice in the case of the patient's home).
- *Mobility problems*: The creation of devices (power wheelchairs) that are easily driven by people with mental and physical dysfunctions, and that are capable of autonomously taking decisions about *where* and *how* to go with the limited, even noisy inputs from the user and from the environment.

[10] From now on, we will use terms such as *patient* or *user* to refer not only to people with cognitive impairment caused by ageing factors but to the disabled and handicapped people.

- *Cognitive problems*: the creation of devices that support declining cognitive skills, including reminders, task instruction, and methods to reduce cognitive effort. A good example is the (quite frustrating) situation where the patient is able to *Remember what but not where* it is located. This is one of the most thrilling problems to be solved, as it requires a combination of technologies (e.g. a set of devices monitoring the user actions and linked with sensors and positioning systems installed in the room, all them interacting through wireless communications).
- *Human factors*: interfaces that meet senior citizen's needs and capabilities – motor, sensory and cognitive (see §3.2).
- *Decision-making problems*: reasoning systems that respond to situations and the elder's needs by interacting with devices in his normal environment, interacting with the elder, or contacting caregivers.

3.2 Integrating technologies to create intelligent assistive devices

There are several technologies that are useful to provide supportive services for physically or mentally disabled people.

Autonomous Agents *Autonomous intelligent agents* are capable of understanding their environment and of independently determining and reasoning how to use their own resources in order to reach a desired goal [25]. Such agents can be either physical (robots) or software components.

Autonomous Robots are physical agents that perform tasks in the real world autonomously. They differ from classical and industrial robots in that they do not have a fixed sequence of actions previously programmed but a set of possible actions that are chosen to be performed depending on given goals or/and information about the environment.

In the case of robots, *autonomy* is often related to *mobility*, and thus, the main task performed by autonomous mobile robots is considered to be navigation. Different techniques are applied to solve navigation problems depending on the different features of the environment such as its nature (indoors, outdoors, underwater or even planetary), the information available (map known or unknown, changes traceable or not) and the level of control over it (remains stable or is highly dynamic, landmarks can/cannot be added).

A robot interacts with the environment through its actuators and sensors; therefore, navigation techniques also depend on the sensors a robot is equipped with: a) laser, ultrasonic (sonar) and infrared sensors, to measure distances; b) pressure switches and bumpers, to detect collisions; c) wheel encoders and Global Positioning Systems (GPS), to compute location; and d) Vision systems, to recognize landmarks and targets.

Nevertheless, planning and positioning are two key aspects that must always be solved in any autonomous navigation problem. However, although many research efforts have been undertaken in this direction (see [14] for an overview), few of them have focused so far on disabled or elderly people [15].

Software intelligent agents are entities that interact with a *virtual* environment, obtaining information and exchanging it with other agents. Their reasoning capabilities allow them to do complex tasks such as allocating resources, coordinating the action of heterogeneous systems, or integrating information from different sources.

Most of the actual agent-based technologies in medicine could be classified, following [21], as a) *Patient centred information management*, b) *Cooperative patient management*, c) *Patient monitoring and diagnosis*, and d) *Remote care delivery*. However, all these applications are centred in the information dimension of the health care management. Until now, in the case of senior citizens or elderly people, applications of software agents have been directed towards the integration in society of this population subset via the use of virtual communities, trying to make Internet technology accessible to them (e.g. [3]).

The use of this agent-based technology could be easily conceived to help solve other problems that could help to enhance the quality of life of some people. An example is given by cognitive problems such as where the patient placed some item (the *Remember what but not where* issue). In restricted environments such as a house or a hospital, a software agent may help to trace the location of the desired object by keeping track of the *usual* places where this object should be or of the last time it was used and/or placed.

Another important area of application is safety management of technologies applied to health care. Software Agents' *proactiveness* could be used to perform an active safety management layer by the introduction of *guardian agents*, as in [12], that in a proactive way look for possible hazards and anticipate an answer or send an alert signal to the manager. For example, an intelligent wheelchair must never obey an order asking it to drive the user to the stairs nor to allow the composition of a plan to do that. However, it may override other conditions if the manager asks for it or in the case of an emergency – i.e. the agent should be able to recognise an emergency state – or to ask for help in the case of an impasse. To do this, it is necessary to build safety plans and to be able to reason about them.

Machine learning and other AI techniques In addition to Artificial Intelligence (AI) techniques that are used in the Autonomous Agents area, assistive technologies may also take advantage of other AI techniques. These techniques can be applied to face both monitoring and mobility problems originated by elderly or disabled people. Think about the problem of recognising some impasse situations, or even emergency situations where disabled people are completely lost in their everyday environment. There is also the possibility to learn some new tasks or behaviours to enhance the autonomy and good performance of disabled people moving within a particular environment.

All these situations can be solved through some AI techniques such as planning, knowledge acquisition and machine learning tasks. All these tasks can be implemented following several AI approaches, but taking into account the highly advanced technological framework envisioned for the immediate future where ambient intelligence will provide the sensorial systems with large amounts of data and experiences in several forms, Case-Based Reasoning (CBR) seems to be a very promising approach, as it helps in learning new experiences, anticipating problems [18], re-planning, adapting old plans to new situations, and recovering or repairing a plan that might fail at execution time.

Affective Computing Traditionally, technology has been oriented towards supporting, improving or extending human capabilities in physical and "intellectual" (reasoning) tasks, disregarding the affective aspects of human cognition and interactions. This trend has started to change in recent years and a new field, generally known as *affective computing* [17], has emerged, building artefacts that can have (one or several) capabilities, such as recognising, expressing, responding to, facilitating, influencing, and in some sense "having" emotions. Research in this area has been very active in the last years, and numerous models and applications have been developed (see [6, 7] for a selection of representative papers).

The potential benefits of integrating elements of affective computing into assistive technology for disabled and senior citizens are wide-ranging, and can be seen from two perspectives:

Improving the emotional state of the user These users are more prone to experience negative feelings such as loneliness, anxiety and frustration, and (mild or severe) affective disorders, given the increased difficulty they have to carry out daily activities, and the physical and social isolation they often suffer. Assistive technology that effectively *cares* for these users should also be able to recognize and monitor their affective states, respond appropriately to them, and try to elicit positive reactions and feelings from the users.

Using emotions as cognitive aids Recent findings in psychology and the neurosciences have evidenced the fundamental role that emotions play in other aspects of human cognition, even in tasks traditionally considered as being the sole product of reasoning, such as memory (see e.g. [19]) or decision-making [8]. Therefore assistive technology should take into account that some aspects of emotions captured by bio-sensors can be used to influence and facilitate other cognitive tasks by means of user tailored interfaces.

Emotions often act as a memory biases that can reduce cognitive overload (e.g., people tend to remember better situations and events experienced under a similar mood). These affective "markers" could be added to memory aid systems to make recall processes more efficient. Another major problem that can be present in disabled and senior patients is the lack of a good reason or motivation to decide between alternative courses of action. As pointed out by [8], emotions play a major role as value systems that make us prefer one alternative to the rest. In the context of assistive technology, emotions could help to support decision-making processes by a) recalling or making the user aware of the emotional implications of different decisions, and b) endowing assistive artefacts with internal motivational and emotional systems to allow them to make (simple) decisions autonomously.

Wireless devices *Wireless technologies* have created a revolution not only in technological achievement but also in social behaviours. The evolution in communication channels (to send and receive the maximum information with the minimum bandwidth use) has also come along with the increased availability of computational power inside small devices (PDA's, laptops, last-generation mobile phones).

Wireless links are usually based either on infrared or microwaves technologies. We will focus on microwave technologies, as infrared based links a) require direct visibility between transmitter and receiver, and b) transmission speeds are not very high. There are basically three different technologies for microwave based wireless communications: Wi-Fi, GSM/GPRS and Bluetooth. Currently *Wi-Fi* offers the best performance regarding coverage and speed. However, it presents a high power consumption. *GPRS* yields a low bandwidth and it is owned by mobile phone operators. *Bluetooth* is still under research, but it presents an adequate bandwidth and low power consumption. All these technologies allow the creation of many applications and services accessible through small, portable devices, easily carried by people from one place to another, and are the basis of some of the solutions proposed in the following sections to connect patients and caregivers with their environment.

4 THE *e*-Tools ARCHITECTURE

The scenario depicted in this section applies almost all the solutions presented in previous sections and it is based on a daily problem. Many disabled people of all ages base their mobility in the use of a power wheelchair. Usually those are driven using a mouse or joystick that allows the chair to navigate. However some disabled people experience considerable difficulties when driving a power wheelchair. Common manoeuvres are not at all easy (e.g. going out from a room). When the steering commands are not sufficiently accurate (due to spasticity, paresis or tremor in the upper limbs), a collision can result. And there is a group of target users that is unable to even use their hands. For these groups the solution is to provide them *Robotic Wheelchairs* with some reasoning capabilities that allow the Wheelchair to navigate in an area such as the patient's home or a hospital. The idea consists on the installation, on top of the hardware of a electric-powered chair, of a reasoning module that assists the user in the navigation. Most of the times the navigation is completely assumed by the reasoning module. [11]

For people who still can walk there are other alternatives. One of them are the so-called *Assistive Robotic Walkers.* These devices can be seen as passive

[11] Yanco elaborated a complete survey of this kind of assistive robotic wheelchairs [26].

robots that can steer their joints, but require a human to move them. Wasson *et al* [24] have been working in the development of these kind of personal mobility aids. Exactly which capabilities the walker exhibits at any time depend on the will and abilities of the user.

We will use as example the robotic wheelchair scenario, as the wheelchair has to show complete autonomy in tasks such as path planning, and be able to locate itself on an environment. Although we are thinking of a controlled situation in a quite well-known environment, structural elements like corridors, rooms, or halls may differ. Corridors in different places in the same building may have various width, length and illumination sources. The number of rooms and their shapes depend not only on floor but also on the usage of those rooms, etc.

4.1 The interface with the user

Among the ideal features of the flexible interface we should include a) a voice interface, b) a touch pad interface, and c) a shared memory system. This interface should be able to adapt itself to the different user abilities to allow her to control the chair, navigating as smoothly and safely as possible (see §2.3). For example, the agent controller should be able to react to orders like *Stop!*, *Watch out!* or *No* when it is performing a given plan.

The main task of this interface is to interpret users' commands that could be noisy, imprecise and/or incomplete and transform them in *plausible* orders and plans (§4.3). Most of the times the user would be able only to say *what* is she willing to do, *where* is she willing to go (through a voice interpreter or a touchpad), leaving to the agent controller to figure out *how* to achieve it. These orders have to be integrated in the environment and follow the user's preferences. This implies that the agent supporting the interface should have knowledge about the current status of the world. In [15] different approaches to interfaces are presented.

4.2 The multi-level architecture

In order to provide the proper healthcare management we propose a Multi-Agent System that controls the behaviour of the Wheelchair, monitors the patient's health and interacts with him through a flexible interface that gives to the patient, depending on their individual capabilities, more or less assistance in the navigation. Most of the times the navigation will be assumed by the agent controller. The wheelchair will be wirelessly connected to the environment. In order to filter all the information exchanged, each room is monitored and controlled by a multi-agent system. This agent-based controller can proactively take decisions about the room conditioning or process the sensor signals in order to extract meaningful information (i.e. to track a given person in the room).

Figure 2 depicts an example of architecture. It is composed of three levels:

- In the lowest level there are all the devices that are connected to the environment. This level includes the cameras and sensors attached to the walls,

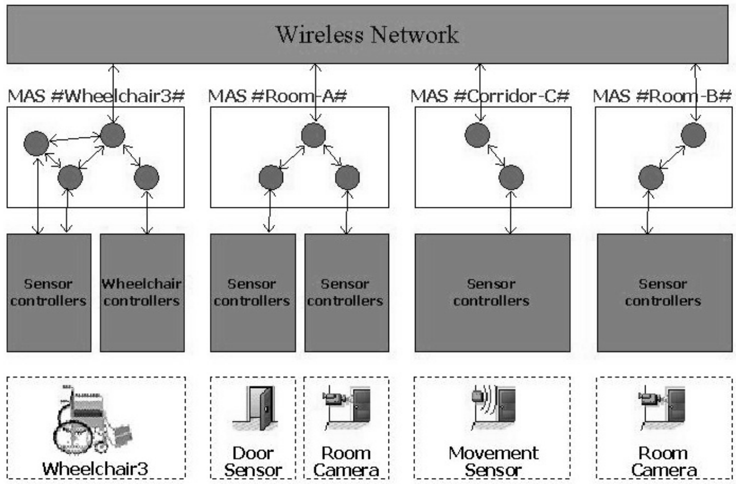

Fig. 2. The proposed multi-level architecture.

patient monitoring systems, PDA's or other portable devices and intelligent wheelchairs.

- The next level is composed by the hardware controllers, that operate the devices and send the information to the next level. In the case of complex devices such as wheelchairs or cameras, this level also should perform tasks that need an immediate actuation of the device (in the case of the camera, a behaviour to follow a person that is being tracked, in the case of the wheelchair, an effective obstacle-detection and avoidance -*reactive navigation*- to ensure a high level of occupant safety).
- The third level is composed by agent-based controllers, which receive the information from the hardware controllers and are then able to reason about the knowledge they have about the state of the system, *what* information they need to improve their knowledge, *where* to get it, and *how* to get it. They can also reason about the *relevance* of the information they receive and distribute it to other agents or controllers that may need it.

This architecture supports the interaction and coordination of all connected entities to solve some of the daily problems patients and care- givers should cope with. For example, the architecture can route alarms when a patient enters (or will enter) a dangerous state as follows:

- Initially, either the caregiver generates a request for information on a given patient or the monitoring system detects a hazardous sensor reading and generates a request for a caregiver. This request is propagated to the third level of the architecture, where it can be handled by the software agents.

– The third level of the architecture interprets the request and asks for information from the lower levels of the architecture to decide a course of action.
– Despite the goal of the process, the location of either a caregiver or a patient is requested. In a small wireless network of active beacons, a given device is captured at most by two beacons so that its position can be inferred by triangulation. If no precise position information is required, this localization can even be performed by covering each room with a single receiver so that it provides information only on the presence of a given patient or caregiver in the room. The third level of the architecture distributes a request for the position of a caregiver or patient to the first level architecture including the positioning devices of all rooms.
– If the caregiver has requested for information on a patient, a low level request for its monitoring sensors is directed to the located patient. These sensors transmit their readings to the closest node of the wireless network and the top level of the architecture redirects the information to the petitioner. If a danger situation has been detected, the third level of the architecture classifies the located caregivers according to their proximity to the patient in danger and a call is transmitted to the closest one.

Patients may also find the system very helpful. One good example is trying to go where another person (a relative or a caregiver) is. In the case where that person has the PDA connected to the wireless network, the environment may first locate in which room the patient and the person are[12]. Then, if both are in different rooms, the wheelchair multi-agent controller, with the help of the environment, builds a plan to go from one room to the other. The wheelchair then executes the plan, carrying the patient to the room where the target person is. If the target person moves from one room to another, the environment forwards this information to the wheelchair, which adapts the plan accordingly. The wheelchair may also report to a human supervisor and ask for help when encountering problems it cannot handle. This problem is analogue to the previously described one.

A more complex scenario happens when the target person has no connected device to the system, either because it is turned off or it runs out of batteries. In this case, as full recognition is classically a very complex problem, it is easier to keep a history of the position of every possible target in the environment when their devices are off. Basically, if a given device is turned off in a room, a video camera in the room starts to track all mobile objects inside. If a mobile leaves the room, the wireless network in the next room can detect whether it is the one with the device off. If such is the case, its position is updated. Thus, the system has the position of all unidentified mobiles available.

[12] Wireless technologies such as Bluetooth support an inquire protocol to determine if a given node, identified by an unique physical address, is in its covered environment

4.3 The navigation problem

The key piece of the system is the patient's wheelchair. Apart of the connection that provides among the patient and the caregiver, the wheelchair enhances the patient's mobility. Naturally, one of the main advantages of working with a robotic wheelchair is that after the goal of a patient's request has been located in the environment, the wheelchair can move towards it in an unsupervised way. In order to increase the safety of the patient and to choose proper paths, the wheelchair also receives more information from the environment (such as trajectory between the goal and the departing point, provided by the agents in the higher level of the system).

The key issue to solve in the case of the wheelchair is Navigation. The navigation problem is briefed in the following questions: i) *where am I* (localization); ii) *where am I going?* (goal definition); and iii) *how do I get there?* (planning). Localization consists of determining the wheelchair position in a global coordinate system and it is typically solved by measurement, correlation and triangulation. Localization is not easy. Most systems rely partially on odometry. However, slippage errors accumulate in an unbounded way. Furthermore, no odometric information might be available (global localization). Localization can be performed either using on-board or external active sensors (i.e. GPS). In our case we will work with active landmarks (the wireless beacons) to calculate the object position by triangulation.

Planning in the real world is usually complex because of unexpected situations or errors. There are two kinds of schemes [1]: reactive and deliberate. *Deliberative planning* typically relies in a classical top-down hierarchical methodology where the world is represented and processed according to actions and events in a $sense - model - plan - act$ cycle. The main disadvantage of deliberative planning is its inability to react fast. Also, a reliable model of the environment is required. *Reactive schemes* directly couple sensors and actuators [4]. Global actions are the result of combining one or more reactive behaviours. Reactive schemes deal easily with several sensors and goals. They are also robust against errors and noise. However, they tend to be less efficient than deliberative ones and often fall in local traps. We propose a *hybrid architecture* combining deliberative and reactive schemes in order to achieve a better performance. It follows a global plan provided by the agents in the third level but modulated by the reactive modules in the second level of the architecture (that is, the hardware controllers of the wheelchair). Basically, this approach (which extends the work presented in [23]) consists of two stages:

- Calculation of an efficient trajectory joining the current position of the wheelchair and its goal. The robot manages an easy to update metric map of the environment by combining any available map and its sonar readings. Then, we extract a topological map from such a metric one (see figure 3) to reduce the instance of the path-planning algorithm so that it can operate in a very fast way. We can use an A* algorithm to extract a path from the topological map. Following this approach, we can recalculate a path each

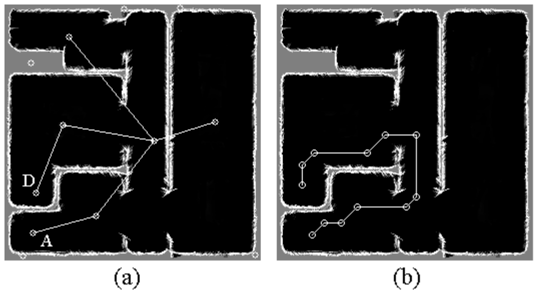

Fig. 3. Deliberative path calculation: a) topological-metrical map, departure and arrival points; b) resulting trajectory and partial goals.

time the goal changes its position or it is impossible to track the previous one further.

– To track the calculated trajectory safely, we have already developed and tested a reactive approach that combines the potential fields approach (goals and obstacles as attractor/repulsor forces) with CBR in order to learn specific solutions to move safely in narrow spaces. [23]

The system described is designed to be placed not only in a hospital (with professional caregivers) but also in the patient's home (where usually relatives play the role of caregivers). The advantages of the system are not limited to the controlled environment where the system runs, though. For instance, when the patient is in a hospital, relatives can be informed of the state of a patient. If the patient is at home, then a doctor may receive periodical reports. To do so, a timer can be set in the higher level to periodically transmit information about the state of the patient. Basically, this service is periodically triggered by an agent in the third level, which can be personalised to set how often the relatives or the doctors want to be updated, but when there's an important change in the state of the patient, the lowest level sends a petition to the third level to send an alert to the relatives. In both cases the agents in the high level filter the sensor information, adapt the information to the accurate level of detail and finally send it to the receiver by means of, i.e., a phone line, an e-mail or even a simple SMS[13] message.

5 CONCLUSION

Assistive Technologies can empower people with disabilities in ways that go far beyond medicine and surgery. The power of AT is still under-recognised by physicians; the potential of AT as an aid to patients is not fully exploited. AT could be seen as a therapy or as a commodity. There are limits on the extent to

[13] Short Message Service, available in mobile phones with GSM technology.

which rehabilitation professionals can help to improve someone's impairments and the broader environments in which he or she lives.

Although existing solutions that increase an independent living for senior citizens are currently available on the market, those are oriented to solve problems in a very poor manner and address a small subset of user's needs. As said in §1, most of them try to solve teleassistance problems, as in [9]. Other just offer specialised information services for the elderly.

We are putting forward this proposal to provide support for disabled and senior citizens. They may be applicable to a wide range of levels and needs, from use by intact healthy people and those with mild cognitive limitation, to providing support for caregivers of elders with moderate impairment and disability. Those systems are devised to provide aid in carrying out activities of daily life, and also performing tasks related to health care maintenance. In addition, they will provide links to the outside world, including entertainment and information, and will facilitate communication with family and the environment.

Among the most important obstacles that new technologies find in real applications in medical informatics we have: user expectations and acceptance, security and trust issues, lack of standards and integration with pre-existing health-care systems. But acceptance of such systems will increase in the future, as senior citizens will be more and more used to interact and rely on advanced technological devices.

We propose here real integration of heterogeneous technologies to serve to disabled and senior citizen with problems as those described in §2 and §3.1 in a non-intrusive way and securing the personal information of the users. It is clear that the use of this new technological devices will help to enhance the quality of life of disabled and senior citizens, their families and reduce institutional and societal costs.

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