e-Tools: Assistive Technologies for the disabled and for the new generation of senior citizens. A Review.

Ulises Cortés [a], Roberta Annicchiarico [b], Javier Vázquez-Salceda [a], Cristina Urdiales [c], Lola Cañamero [d], Maite López [e], Miquel Sànchez-Marrè [a] and Carlo Caltagirone [f]

[a] *Technical University of Catalonia. c/Jordi Girona 1 & 3. 08034 Barcelona, Spain. E-mail: {ia,jvazquez,miquel}@lsi.upc.es*
[b] *IRCCS S. Lucia. Via Ardeatina 306. 00179 Roma, Italy. E-mail: r.annicchiarico@hsantalucia.it*
[c] *Departamento de Tecnología Electrónica, Universidad de Málaga. Campus de Teatinos. E-mail: cristina@dte.uma.es*
[d] *Adaptive Systems Research Group, University of Hertfordshire. email:L.Canamero@herts.ac.uk*
[e] *Intelligent SOftware COmponents S.A. (ISOCO) E-mail: maite@isoco.com*
[f] *Clinica Neurologica. Universtità Tor Vergata. Roma, Italy. E-mail: c.caltagirone@hsantalucia.it*

In this paper we present our exploratory ideas about the integration of agent technology with other technologies to build specific *e*-tools* for the disabled and for the new generation of senior citizens. In particular, we aim to explore the benefits of the concept of *situated intelligence* to build intelligent artifacts that will enhance the autonomy of the target group during their daily life.

Keywords: Assistive Technologies

* *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.

AI Communications
ISSN 0921-7126, IOS Press.

1. INTRODUCTION

Nowadays it is clear the growing importance of the role that Artificial Intelligence and Knowledge-Based Systems (KBS) are playing in medicine for supporting medical practitioners in making decisions under uncertainty (see [14]). Also in those medical scenarios, where many individuals are involved in a decision-making process or when their decision and actions have to be coordinated, the agent-based technology is getting an increasing role to

a) model the processes (see [10], [20]), and b) model the decision making processes (see [13]). Most of this work has its roots on the seminal ideas of G.A. Aga [2].

Most of the actual agent-based technologies in medicine could be classified, following [26], as:

- Patient centered information management
- Cooperative patient management
- Patient monitoring and diagnosis
- Remote care delivery

but all those applications are centered in the information dimension of the health care management.

There are also some few research efforts on the use of Autonomous robots technology for disabled and elderly people. Most of them are devoted to the creation of electric wheelchairs that can autonomously navigate through an environment (just as a robot would do) [31]. But there are also some promising uses of technology created in the robotics field (sensors, artificial vision) to create other services such as patient position tracking.

This paper is about envisioning the future use of all these technologies in which software agents, robotics' hardware and information networks will be integrated into everyday environment, rendering access to a multitude of services and applications through easy-to-use interfaces, specially designed for the disabled and the senior citizens.

We are clearly thinking in applications that can be circumscribed to well-know quasi-structured domains (ie. places with predefined components such as a house, a hospital floor, etc) assuming that they are stable, that there exists enough information about them and that the environment somehow is able to interact with a computational system (for instance, by providing information to the system). Recent advances in embedded computing and wireless communications make it possible to think in putting *intelligence* in every appliance, into the structure of hospitals, homes and, in the long term, even on every street corner (see [15]).

Specifically, the long term objectives of our research are:

- To develop the medical and social understanding necessary to apply Heterogeneous Embedded Intelligence technology to problems faced by the disabled and senior citizens population.
- To develop assistive technology for disabled and senior citizens.
- To investigate mechanisms by which physical and software agents effectively and securely coordinate sensing, cognition, reasoning, and actuation in well-known environments to support the target population.
- To investigate mechanisms to build flexible interfaces to support the interaction of people with different capabilities and needs.
- To disseminate information and promote the exchange of ideas and create awareness among relevant actors.

The use and creation of new technologies for the disabled is crucial, as for this group of people, it 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.

1.1. Organization

The organization of this paper is as follows. In §2 we address the possible uses of assistive technologies in building services for the senior citizens, and give our own proposals for this field. In §2.3 we present some of the technologies to be used, and then in §2.4 we describe the wish list of problems that we are willing to solve. In §2.5 we will discuss the interaction problem of senior and disabled people with such technological devices.

Afterwards, in §3 and §4 we will introduce some futuristic but feasible (and very appealing) applications of assistive technologies, presented from the technical and the social and healthcare perspectives.

In §5 we address the issues of safety and soundness of the integrations of the various technologies in a single platform.

And, finally, in §6, we make some reflections about the future of this technology .

2. ASSISTIVE TECHNOLOGIES AND THE SENIOR CITIZENS

2.1. Ageing and disability

The senior citizens represent a fast growing proportion of the population in Europe and other developed areas [8].

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 (2002) the number of persons aged 60 years or older is estimated to be 629 million[1]. That number is projected to grow to almost 2 billion by 2050, when the population of older persons will be larger than the population of children (0-14 years) for the first time in human history. Fifty-four per cent, the largest share of the world's older persons, live in Asia. Europe has the next largest share, with 24 per cent. Around the world, the population of older persons is growing by 2 per cent each year, which is considerably faster than the population as a whole. The older population is expected to continue growing more rapidly than other age groups for at least the next 25 years. The growth rate of those 60 or older will reach 2.8 per cent annually in 2025-2030.

The world has experienced dramatic improvements in longevity. Life expectancy at birth has climbed about 20 years since 1950, from 46 years

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

to its current level of 66 years. Of those surviving to age 60, men can expect to live another 17 years and women an additional 20 years. The older population is itself ageing. In fact, the fastest growing age group in the world is the oldest-old, those aged 80 years or older. They are currently increasing at 3.8 per cent per year and comprise 12 per cent of the total number of older persons. By the middle of the century, one fifth of older persons will be 80 years or older [23]. Such rapid growth will require far-reaching economic and social adjustments in most countries.

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 in the developing world. In fact, according to the World Health Report 2001, non-communicable diseases now account for 59 per cent of all deaths globally.

Two examples of highly invalidating diseases requiring medical assistance and/or institutional care [16] 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. Problems occur with naming and word-finding, and later with verbal and written comprehension and expression. Visuo-spatial, analytic and abstract reasoning abilities, judgment, and insight become affected. Behavioral changes may include delusions, hallucinations, irritability, agitation, verbal or physical aggression, wandering, and disinhibition. Ultimately, there is loss of self-hygiene, eating, dressing, and ambulatory abilities, and incontinence and motor dysfunction. Last stages of the disease use to lead to an institutionalization in some kind of facility specialized to treat such cases. But this solution not only has a high cost (institutionalization accounts for more than 66% of the costs associated to people with severe dementia), but also is harmful for the patient, that is placed in a unknown environment with unknown people.

Stroke is the most disabling chronic condition. It has this dubious honour because the sequelae of stroke 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 (i.e. haemorrhages, vasospasms). Therefore, in each case case the retraining and adaptation process to neurological handicaps depend on the nature of the underlying anatomic abnormality (i.e. what part of the brain is injured) and not on the cause of such abnormality (i.e. the origin of the injury). Its impact on individual patients, their families, and society as a whole is immense. About 200 people per 100.000 population will have a first ever stroke every year. Their mean age is about 72 years, and men and women are affected in roughly equal numbers. 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. As a consequence, disabled people are a very a heterogeneous group, comprising a wide spectrum of function. This ranges from mild impairment and/or disability to moderate to severe limitations [7]. Moreover, the concept of disability itself is not always precise and quantifiable. The concept of disability itself is not agreed upon by person who consider themselves to have a disability, professionals who study disability, or the general public. This lack of agreement is an obstacle to all studies of disability and to the equitable and the effective administration of programs and policies intended for people with disabilities. To facilitate agreement about the concept of disability, the World Health Organization (WHO) has developed a global common healt language-one that is understood to include physical, mental, and social well-being. The WHO first published the *International Classification of Impairment, Disabilities, and Handicaps (ICIDH)* in 1980 as a tool for classification of the "consequence of disease". The newest version, *International Classification of Functioning, Disability and*

Health, known as *ICF*, like its most recent predecessor *ICIDH-2*, moves away from a "consequence of disease" classification (1980 version) to a "components of health" classification. This latest model is designed to provide a common framework and language for the description of health domains and health-related domains. Using the common language of *ICF* can help healthcare professionals to define the need for healthcare and related services, such as the provision of assistive technology (AT), for person with diseases that affect them at all levels.

2.2. AT applications

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[2], 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 pospone 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.

There are some open and promising lines of research [3] in this field as:

– Assistive technology: devices that aid with mobility [18] [28], medication management, and household tasks.
– Cognitive Aids: technology that supports declining cognitive skills, including reminders, task instruction, and methods to reduce cognitive effort.
– Passive Monitoring: devices and reasoning systems that recognize the elder's activity and learn to detect abnormal situations (see §3).
– Decision-making: 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.
– Human factors: interfaces that meet senior citizen's needs and capabilities - motor, sensory and cognitive (see §2.5).
– Adaptation: techniques to recognize the elder's changing capabilities.

2.3. Integrating technologies to create intelligent assistive devices

There are several technologies that are useful to provide supportive services for physical or mental-disabled people.

2.3.1. 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 [30] [29]. Such agents can be either physical (robots) or software components.

Autonomous Robots are physical agents that perform tasks autonomously in the real world. One of such tasks is to navigate freely in an unknown, constrained or unconstrained environment. Different navigation techniques are available (indoor navigation, outdoor navigation, navigation with maps, reactive navigation) usually assisted by a variety of devices (sonar, ultrasonic and infrared sensors, pressure switches, wheel encoders or even vision systems capable of tracking landmarks). Although many research efforts have been undertaken in this direction, few of them have focused so far on disabled or elderly people [19].

Software intelligent agents are entities that interact with a *virtual* environment, obtaining information and exchanging it with other agents. Their

[2] 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.

[3] One good example is the AAAI2002 workshop on automation as Caregiver [1], which is focused in uses of AI in Elder Care

reasoning capabilities allow them to do complex tasks such as allocate resources, coordinate the action of heterogeneous systems or the integration of information from different sources. Until now the applications of autonomous agents to senior citizens or elderly people have been directed towards its integration in society via the use of virtual communities, trying to make the Internet technology accessible to them (ie [6] [11] [8]). These efforts are in line with the Promoting an Information Society for Everyone (PROMISE) EU initiative [24].

The use of this agent-based technology could be easily conceived to help solving other problems that at first look are very small and easy but that could help to enhance the quality of life of some people. Consider for example the following situation where someone is able to *Remember what but not where*[4] it is located. In a restricted environment 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 the last time it has been used and/or placed. This may require a shared memory between the intelligent agent and the environment, in a way that allows the agent to use some pointers in the environment to *remember* how things were the last time without having a complete memory of the whole scenario.

2.3.2. 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 adventage of other classical AI techniques. One of the most important features is adaptation (*learning*) to the user, as well as supporting the adaptation of the user to the new technology. Learning is also valuable to extract knowledge from current and past experiences (an example of this approach is Case-Based Reasoning) in order to remember past usual situations (*episodes, cases*), avoid past mistakes or reuse plans that were succesful in similar situations.

2.3.3. Affect-aware interfaces

Affect-aware interfaces are increasingly regarded as a key element to achieve natural, user-centered and adapted Human-Machine Interaction that promotes user acceptance. The use of affective computing and emotion modelling techniques permits to develop interfaces that can detect and respond to the user's affective state in an appropiate way. They enhance interaction with users by allowing new tasks such as detection of user fustration or anxiety, development of a user's affective profile related to task achievement, or management of the user's emotions through expressive agents that tailor their responses to the user's affective state.

2.3.4. Wireless devices

Wireless technologies have created a revolution not only in technology achievement but also in social behaviours. Such technologies are daily used to control machines (remote controls), to bring communication to any place (mobile phones, beepers) or to provide services at any location (wireless network connections). The evolution in communication channels (to send and receive the maximum information with the minimum bandwidth use) has also came along with the evolution in computational power inside small devices (PDA's, laptops, last-generation mobile phones).

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 with their environment.

2.4. Wishing upon a star

The kind of services that we are aiming 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, with a sound reasoning method, 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 disfunctions, 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.

[4] A related neuropsychological study has been carried out in [9]

– *Cognitive problems*: the creation of devices that can assist the patient to recover from small memory loss, such as where do they placed some item (like the *Remember what but not where* example mentioned before). This is one of the most thrilling problems to be solved, as it requires a combination of technologies (eg. a set of software agents monitoring the user actions and linked with sensors and positioning systems installed in the room, all them interacting through wireless communications).

The use of this kind of tools may ease the healthcare and social interaction of a senior citizen person alone. Also it may delay their institutionalization by prolonging the period of relative independence of individuals.

2.5. *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 or mobility disfunction or the usual complex relationship among elder people and new technologies [25]. The Rehabilitation Engineering Research Center on Technology Evaluation and Transfer (RERC-TET) (Buffalo, NY, USA) has focused consumer-identified needs and preferences regarding several categories of assistive technology. According to the classification of Batavia and Hammer [5] have been identified 11 criteria disabled patients considered important when selecting assistive devices; among others *Effectiveness*, *Reliability* and, mainly, *Operability* - the extend to which the device is easy to use, is adaptable and flexible, and affords easy access to controls and displays. A listing of product categories wich RERC-TET's consumers determined to be in high need of new or improved products comprises:

– Related to wheeled mobility:
    * Manual wheelchairs
    * Wheelchair cushions
    * Battery chargers
    * Wheelchair tires
    * Wheelchair tiedowns
    * Van lifts and ramps
– Other devices
    * Voice input interfaces
    * Voice output reading machines
    * Portable ramps
    * Workstations

The extreme difficulty with which persons with severe disabilities have been taught to maneuver 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 maneuvering tasks; 85% of clinicians reported that a number of patients lack the requisite 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 [12].

Our main target is to address the needs of the future generation of senior citizens. It is of our believe that this new generation will be technological savvy [5] and because of this fact will be more demanding. This represents in itself a challenge and an opportunity to further develop new AI technologies and tools and to integrate them assuming that the new future will bring a real Ambient Intelligence that will incorporates properties of distributed interactivity (ie, multiple interactive devices, remote interaction capabilities), ubiquitous computing, and nomadic or mobile computing (ie, location awareness as explained in §4).

3. INTELLIGENT ASSISTIVE DEVICES FOR PATIENT MONITORING

One of the most promising uses of the current technology is the creation of intelligent monitoring systems. Such systems track several body signals and have the reasoning capabilities to decide whether the patient is in a normal or acceptable

[5] A promising example that supports this claim is Japan, where nowadays even the elder people in the countryside areas have adapted to technologies such as the last wave of mobile phones, attracted by the appealing services that are provided by the phone companies through their wireless network.

state or if it is entering into a *danger zone*, even building a diagnosis of the possible causes.

With such devices, residential care facilities for elderly and disabled people can be provided with intelligent beds equipped with embedded instruments for acquiring not only vital parameters (blood pressure, glycaemia, pO2) but even with sensors to evaluate pressure at the body-bed interface to prevent pressure-ulcers.

A mobile version of the same technology consists on the creation of a portable device to do the tracking in people that can move within an area. Such systems could track body signals and trigger alarms when a danger situation has been detected, even sending an automatic call to the caregivers by the use of automatic phone dialers and voice synthesizers. Another use of such portable devices, wirelessly interacting with devices attached to the room walls, is to monitor the patient movement inside the room, and identify behaviors like wandering as a symptom of dementia, or even detecting equilibrium loss to prevent falls.

4. AN INTELLIGENT WHEELCHAIR

The scenario presented in this section applies almost all the solutions presented in previous sections and is based on a daily problem. Many disabled people[6] of all ages base their mobility in the use of a wheelchair and some times it is an 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 wheel chair. Common manoeuvres are not at all easy (ie. 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. Our proposal is to install on top of the hardware of a electric-powered chair an intelligent autonomous agent with a flexible interface that gives to the users, 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 Tin Man series of robotic wheelchairs [18] are on the origin of many of these ideas. Similar ideas have been funded by the National Institute on Disability and Rehabilitation Research [22]. Yanco elaborated a complete survey of this kind of assistive robotic wheelchairs [31].

There are also the passive robots that are robots that can steer their joints, but require a human to move them. Wasson *et al* have been working in the development of a personal mobility aid: the *Assistive Robotic Walker* [28]. Exactly which capabilities the walker exhibits at any time depend on the will and abilities of the user.

Among the ideal features of the flexible interface we should include:

- A voice interface,
- A touch pad interface, and
- 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 §5). 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 user's commands that could be noisy, imprecise and/or incomplete and transform them in *plausible* orders and plans (§4.1). 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 (by the creation of a shared memory as mentioned in previous sections) 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 [19] different approaches to interfaces are presented.

Other existing approaches to create interfaces with an electric wheelchair are exploring the use of computing the face expression of a person to guide the chair and in this way take advantage of the user's non-verbal behaviors [21].

To build the appropriate software and hardware support for such autonomy and also to provide healthcare management (embedded monitoring and diagnosis functionalities), we propose

[6] In 1997, there were over 1.4 million wheelchair users of which 75% used manual versions. The remaining 25% used power wheelchairs. Power wheelchairs are used predominantly by people with both lower and upper extremity impairments resulting from cerebral palsy, high-level spinal cord injury, or muscular dystrophy.

the integration of various technologies and AI paradigms as: Agent-technology, Situated intelligence, Heterogeneous Embedded Intelligence, Machine Learning, Robotics, etc. This integration should provide the agents with a set of strategies entailing them to know *what* to extract, *where* to get it, and *how* to get it. For example, the system should be able to communicate with other agents (some of them placed in the environment), to get *relevant* information and be able to decide whether or not that piece of information is useful and should be incorporated in its own knowledge base or not.

There are several advantages in using several heterogeneous agents for solving a task instead of a single one. As an example: a larger range of possible tasks, robustness, lower economic cost, ease development and, reusability.

4.1. The yellow brick road

Although we are thinking of a controlled situation and well-known environment, structural elements like corridors, rooms, or halls may differ. Corridors in different places in the same building may have a 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. The indoor and/or outdoor environment have to be considered differently. Depending on the user, cognitive tasks such as positioning or obstacle avoidance should be delegated to the intelligent agent.

The navigation problem is to build a plan from the actual position to the destination (target). This could be done by using solutions from the Robotics area such as following a map or keeping track of the landmarks or signposts available in the environment (the building) and use them to locate the destination site [4,27]. Usually the landmarks are passive and it is the mobile entity the one that should recognize them and use them for positioning purposes. But an alternative that we propose here is to use active landmarks, that is, small wireless machines installed in some strategic places of an area to transmit local information to the mobile entity. Similar initiatives and ideas could be found in the design of intelligent buildings for the disabled and elderly people (see for example [3]) or the last generation of road traffic support systems.

Plans to achieve particular goals in this environment need also to be devised (may be off-line using, for instance, a machine learning algorithm as `CANDID` [17]) and whilst these plans are being executed, they need to be continuously monitored. Relevant information extracted from the monitoring of the chair movements could be used to adapt or to refine the plans. These original plans are in some way the set of abilities that the system should exhibit. A first ability that this kind of artifacts have to exhibit is an effective obstacle-detection and avoidance (*reactive navigation*) that will ensure a high level of occupant safety (see 5). And they have to be able to report to their human supervisor and ask for help when encountering problems they cannot handle.

Another AI techniques can be very useful in planning. For instance, Case-based reasoning could be used to adapt or re-use past solutions to face new problems (like, for instance, the set of movements used to cross a narrow door when faced with another one).

5. SAFE AND SOUND

As mentioned above, one of the most relevant properties of the domain of application is restricted to a quasi-structured, *situated environment* where *small* changes may appear but agents should expect that the most important landmarks will remain stable for long periods. This does not exclude that the domain remains dynamic and therefore *unexpected* changes may arise so the system needs to solve these unforeseen situations. This kind of systems need to exhibit an intelligent goal-oriented behavior and yet still be responsive to changes in their circumstances.

However, as observed by Fox & Das [13], the use of heuristics of 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 –may be off-line– to assure effectiveness and performance.

Software Agents could be used here to perform an active safety management layer by the introduction of *guardian agents*, as in [13], 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 plan to do that. But, it may override other conditions if the manager ask for it or in the case of an emergency –ie the agent should be able to recognize 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 be able to reason about them.

This is an open issue that has to be further discussed and that should be included in the new technologies for the disabled and senior citizens, as well as in any agent application for healthcare tools.

6. CONCLUSION

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 the teleassistance problems, as in [11]. Other just offer specialized information services for the elderly.

We are putting forward these proposals to provide support for disabled and senior citizens people. They may be applicable to a range of levels and kinds of 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 agent systems are devised to provide aid in carrying out activities of daily living, and also performing tasks related to health care maintenance (including standardized behavioral assessments useful in medical monitoring). In addition, they will provide links to the outside world, including entertainment and information, and will facilitate communication with family and the environment. Physical environments that are age-friendly can make the difference between independence and dependence for some older people. Older people who can safely go outside and walk to a neighbour's house or to the park can increase fitness and mobility and are less likely to suffer from isolation and depression.

Among the most important obstacles that new technologies (such as software agents) 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 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 §2.4 in a non-intrusive way and securing the personal information of the users. Also it is important to notice that there are different efforts trying to solve small problems but an integral solution has not been approached yet.

This proposal is in line with the *Ambient Intelligence* key action I in the IST FP5 and the EU Telematics Initiative for Disabled and Elderly people (TIDE) through which the EU has been funding research for creating such an environment with an specific focus in the patient centered healthcare management, the disabled and, the senior citizens. Also, in the USA there is a strong research trend in this line.

In this perspective, the whole range of professionals involved in health care and disability can contribute to a more widespread awareness of the feasibility of newer ways and means of facing the problems connected to old age and disabilities. It is possible to study new ways through which scientific knowledge, the respect of autonomy, the experience of proximity with the patients, the acceptance of citizenship rights and, the application of new technologies will allow the construction of a support network that can change the lives of people who are affected by such devastating condition.

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.

Acknowledgements

U. Cortés, M. Sànchez-Marrè and J. Vázquez-Salceda like to acknowledge the IST-2000-28385 Agentcities.NET project. The views in this paper are not necessarily those of Agentcities.NET consortium.

References

[1] The AAAI-02 Workshop on Automation as Caregiver. http://www.cs.cmu.edu/ khaigh/AAAI02.html.

[2] G.A. Aga, *Actors: A model of concurrent computation on distributed systems*, MIT Press, 1986.

[3] ARIADNE, Access, Information and Navigation Support in the Labyrinth of Large Buildings. http://www.cyber.rdg.ac.uk/DSRG/ariadne/ariadne.htm.

[4] A. Bandera, C. Urdiales, and F. Sandoval, 'Autonomous global localisation using markov chain and optimised sonar landmarks', in *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems, Takamatsu (Japan)*, (2000).

[5] A.I. Batavia and G.S. Hammer, 'Toward the development of consumer-based criteria for the evaluation of assistive devices', *Journal of Rehabilitation Research and Development*, **27**, 425–436, (1990).

[6] M.D. Beer, T. Bench-Capon, and A. Sixsmith, 'Using agents to deliver effective integrated community care', in *Workshop on Autonomous Agents in Health Care*, ed., V. Shankararaman, pp. 35–45. ACM-AAAI, ACM Press, (2000).

[7] D.J. Blake and C. Bodine, 'An overview of assistive technology for person with multiple sclerosis', *Journal of Rehabilitation Research and Development*, **39**(2), 229–312, (Mar-Apr 2002).

[8] L.M. Camarinha-Matos and H. Afasarmanesh, *Virtual communities and elderly support*, 279–284, WSES, 2001.

[9] G.A. Carlesimo, R. Perri, P. Turriziani, F. Tomaiuolo, and C. Caltagirone, 'Remembering what but not where: independence of spatial and visual working memory in the human brain', *Cortex*, **36**, 519–534, (2001).

[10] U. Cortés, J. Vázquez-Salceda, A. López-Navidad, and F. Caballero, 'UCTx: A multi-agent system to assist a transplant coordination unit', *Applied Artificial Intelligence*, (to be appear).

[11] DEFIE. Open architecture for a flexible and integrated environment for disabled and elderly people. http://www.rigel.li.it/rigel/progetti/DEFIE/.

[12] L. Fehr, W.E. Langbein, and S.B. Skaar, 'Adequacy of power wheelchair control interfaces for persons with severe disabilities: A clinical survey', *Journal of Rehabilitation Research and Development*, **37**(3), (May/June 2000).

[13] J. Fox and S. Das, *Safe and Sound: Artificial Intelligence in Hazardous Applications*, AAAI Press/MIT Press, 1^{st} edn., 2000.

[14] J. Huang, N.R. Jennings, and J. Fox, 'Agent-based approach to healthcare management', *Applied Artificial Intelligence*, **9**, 401–420, (1995).

[15] E. A. Lee, 'What's ahead for embedded software?', *IEEE Computer Magazine*, 18–26, (September 2000).

[16] *Atti del Convegno: Il Management Del Paziente Alzheimeriano Oggi*, eds., V. Marigliano and R. Annicchiarico, CNR, 1999.

[17] M. Martin, *Reinforcement learning for embedded agents facing complex tasks*, Ph.D. dissertation, Technical University of Catalonia, 1998.

[18] D.P. Miller and M.G. Slack, 'Design & testing of a low-cost robotic wheelchair', *Autonomous Robots*, **1**(3), (1995).

[19] *Assistive Technology and Artificial Intelligence: Applications in Robotics, User Interfaces and Natural Language Processing*, eds., V.O. Mittal, H.A. Yanco, J. Aronis, and R. Simpson, volume 1458 of *Lecture Notes in Artificial Intelligence*, Springer-Verlag, Berlin, 1998.

[20] A. Moreno, A. Valls, and J. Bocio, 'Management of hospital teams for organ transplants using multi-agent systems.', in *Proceedings of the 8th. European Conference on Artificial Intelligence in Medicine, Portugal, 2001.*, eds., Barahona Quaglini and Andreassen (Eds.), Lecture Notes in Artificial Intelligence 2101: Artificial Intelligence in Medicine, pp. 374–383., (2001).

[21] Y. Murakami, Y. Kuno, N. Shimada, and Y. Shirai, 'Collision avoidance by observing pedestrians' faces for intelligent wheelchairs', in *Proc. of Int. Conf. on Robotics Systems*, pp. 2133–2138. IEEE, IEEE, (2001).

[22] National institute on disability and rehabilitation research. http://www.ed.gov/offices/OSERS/NIDRR/.

[23] United Nations Department of Public Information. DPI/2264, March 2002.

[24] PROMISE: Promoting the Information Society in Europe. http://europa.eu.int/ISPO/promotion/i_promise.html.

[25] M.J. Scherer and J.P. Lane, 'Assesing consumer profiles of "ideal" assistive technologies in ten categories: an integration of quantitative and qualitative methods', *Disability and Rehabilitation*, **19**(12), 528–535, (1997).

[26] V. Shankararaman, V. Ambrosiadou, T Panchal, and B. Robinson, 'Agents in health care', in *Workshop on Autonomous Agents in Health Care*, ed., V. Shankararaman, pp. 1–11. ACM-AAAI, ACM Press., (2000).

[27] C. Urdiales., A. Bandera, J. Casanova, and F. Sandoval, 'Pyramidal path planning algorithm for autonomous robots', in *Proceedings of the 7th Symposium on Intelligent Robotics Systems (SIRS'99), Coimbra (Portugal)*, pp. 447–453, (1999).

[28] G. Wasson, J. Gunderson, S. Graves, and R. Felder, 'An assistive robotic agent for pedestrian mobility', in *International Conference on Autonomous Agents*, pp. 169–173. ACM, ACM, (2001).

[29] *Multiagent Systems*, ed., G. Weiss, MIT Press, 1^{st} edn., 1999.

[30] M. Wooldridge, *Intelligent Agents*, chapter 1, 27–77. In Weiss [29].

[31] H.A. Yanco, 'Integrating robotic research: a survey of robotic wheelchair development', in *AAAI Spring Symposium on Integrating Robotic Research*, ed., H.A. Yanco. AAAI, AAAI., (1998).