Towards an Intelligent Service to Elders Mobility Using the i-Walker

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Abstract

The *SHARE-it* architecture is designed to inform and assist the user and his/her caregivers through monitoring and mobility help. Thus, we plan to contribute to the development of the next generation of assistive devices for older persons or people with disabilities so that they can be self-dependent as long as possible. In this paper we focus on the development of an intelligent pedestrian mobility aid that we call *ı-Walker*. *ı-Walker* is a robotically augmented rollator to reduce fall risk and confusion, and to increase rollator convenience and enjoyment. *SHARE-it* provides an Agent-based Intelligent Decision Support System to support elders with cognitive and/or motorial problems.

The main goal of the *SHARE-it* (SHAREit 2007), an EU FP6 funded project, is to contribute to the development of the next generation of intelligent and semi-autonomous assistive devices for older persons and people with disabilities (both cognitive and/or motor) so that they can be self-dependent enough to autonomously live in the community, staying at home as long as possible with a maximum safety and comfort; this possibility would increase their quality of life, and, at the same time, delay their institutionalization. At least in part, *how well* these elders live and their abilities to maintain independent life styles will depend on their health and the degree to which they have remained totally able or *frail* or *disabled*. When we talk on frailty and disability we refer to the most recent definition, in particular *frailty* is described as: *A state of increased vulnerability to stressors that results from decreased physiological reserves and multi-system dysregulation, limited capacity to maintain homeostasis and to respond to internal and external stresses. Frailty is an aggregate expression of risk resulting from age- or disease-associated physiologic accumulation of subthreshold decrements affecting multiple physiologic systems resulting in adverse health outcomes* (Fried et al. 2004). Disability is defined as the difficulty or dependency in carrying out activities necessary for independent living, including roles, tasks needed for self-care and household chores, and other activities important for a persons quality of life (Fried et al. 2004).

This in turn, will depend to at least some extent on *how well* the artificial and built environments in which they live conform to their needs and their age-related losses in abilities and somatic integrity.

There are consequently two important targets in future research focused on ageing population:

- to develop consistent and valid methods for assessing frailty and disability in order to individuate the main areas in which this target population needs help;
- to design environments appropriate for the proportion of elders who are increasingly frail and disabled but whose Life Expectancy expectancy continues to grow

Different groups of elders are characterized by large variations in health, well-being, disability, and health care needs. Since Assistive Technologies (AT) major purpose is represented by the possibility of assisting people - elderly and/or disabled - to stay or to get back to their home, a target population - in terms of functional, social, and clinical features - has to be individuated so that a number of individuals as large as possible can achieve benefits as effectively as possible (Mittal et al. 1998). According to these premises, *SHARE-it* Target Population will operatively be individuated through the assessment of the presence of:

- Mild functional impairment: older and/or disabled populations are made up by individuals who present widely different and heterogeneous functional profiles. Considering the more prevalent diagnosis in this group of persons (stroke, Parkinsons disease, Alzheimers disease), impairments range from extremely mild (people able to walk with a cane or affected by such a mild memory loss that allows them to live on their own) to extremely severe (persons bedridden or completely unable to understand a simple order). In the first case we are in the realm of prevention, in the second in that of palliative care or institutionalization. People with mild functional impairment those in the middle area of impairment are expected to have the best results through the use of proper assistive technology and are the target of the assistive intervention.
- Possibility of changing functional profile: mild disability is characterized by the possibility of increasing the functional level according to proper assistive or rehabilitative interventions. Users of a flexible assistive device can benefit from its adaptation so that it could help to improve

their condition as a result of rehabilitation treatment, or can prevent the decrease of their autonomy due to intervening conditions or diseases.

This paper considers the definition of *SHARE-it* users and those Activities of Daily Living (ADL) where *SHARE-it* hardware devices can offer some kind of personalized support to them. The considered elderly population is assessed through the multidimensional geriatric approach. Users are classified on the basis of their functional impairment as suggested by World Health Organization (WHO). Furthermore, since one of the parameters that affect the user's performance in a specific task is the *emotional reaction*, we are considering the alarm reaction as an aspect to be detected and to be used as the basis on the elaboration of the decision to give or not support to the user. Also, it will be used to decide which kind of support to give to each individual.

Many older adults use walkers to improve their stability and safety while walking. A walker, may support up to 50% of the users body weight, are ideal for weak knees or ankles or severe balance problems. Also, if some individuals, in this population, do not need to lean on their walker for balance, they might be able to walk faster with the aid of a walker and then they might improve their autonomy. However, there are many subjects that can not use a walker for risks related to a particular mobility impairments or at the presence of a cognitive disorders. The traditional walker is prevented for people who suffered from lack of strength in their arms or legs (tipically subjects affected by stroke, a cardiovascular impairment that, as mobility damage, can affect half part of body). The correct instruction to use a walker is to move pushing the device but this situation is not safe in this population because the different degree of strength in two sides of walker create an uncorrected trajectory, a balance problem and an high risk of fall. About cognitive problems difficulties in orientation is one of the most frequent reason to prevent the use of walker.

In order to help this population the same target population of SHARE-it - we have developed a robotically augmented rollator. This device is aimed to reduce fall risk and confusion, and to increase users convenience and enjoyment and finally and most important aspect to increase autonomy in persons prevented to use a traditional walker.

ı-Walker is designed to be *situated* in the user's preferred environment (**?**). This *strong* constrain implies both that the user knows this space – s/he lives there – and, also, that the *SHARE-it* agent-based platform is deployed in this environment (Barrué et al. 2005). Thus the *ı-Walker* is *situated* and *knows* this space. An important lesson learned while developing *ı-Walker* is that the elderly population requires techniques that can cope with individual differences. We choose intelligent agents as the *adaptation* element.

Among of the *SHARE-it* objectives is to build different *ı-Walker* workbench platforms, oriented to demonstrate their feasibility, and gain the confidence to support the specific disabilities (Cortés et al. 2003). Two inspiring works in this line for intelligent pedestrian aids are (Glover et al. 2003) and (Wasson et al. 2001; 2003). Those propose intelligent robotics agents to support elders mobility but the main difference in our approach is the explicit use of intelligent software agents to support decision-making and to help in the interfacing with the user.

More modern lines of research in the field of pedestrian mobility are represented by (Cheng, Bateni, and Maki 2008) and (Kulyukin et al. 2008). The first is more oriented to avoid the fall risk and the second culminates a line of walkers developed at CMU. The Kulyukin *et al*'s iWalker is intended to guide elders in an Small World (SW) and it is not prepared to avoid unexpected obstacles in that environment. Other walkers incorporate robotic aids that are prepared to help users to change their position as from sit-to-stand (**?**). Standing up motion is one of the most serious and important operations in daily life for elderly person who does not have enough physical strength.

An important issue to be considered is that before starting experiments with elders the whole system has to be approved by a Ethical Committee. We had use the original agent-based control elements in an experiment with volunteer inpatients in Fondazione Santa Lucia, Rome, using *Spherik* an intelligent wheelchair (Annicchiarico et al. 2007). In this paper, we generalize the agent-based system to be used in the *ı-Walker*. Although, the experimentation with elders has to start the whole system is already in place in *Casa Agevole* (Vescovo 2005).

Autonomy and Disability

According to prevailing models of the disablement process, disability results when these diseases and conditions, via specific impairments and functional limitations, lead to limitations in the ability to perform basic social roles. Hence, disability is usually defined as the degree of difficulty or inability to independently perform basic activities of daily living (ADL) or other tasks essential for independent living, without assistance.

In order to quantify residual autonomy and level of disability of individuals, it is commonly accepted to talk in terms of Functional Disability and Functional Status. In fact, Functional Status is usually conceptualized as the *ability to perform self-care, self- maintenance and physical activities*.

Behind that, physical, neurological, and mental functions, and conditions and diseases affecting such functions are to be taken into account as well.

Multiple chronic degenerative diseases (stroke, arthritis, hypertension, cancer, degenerative bone/joint disease, coronary artery disease) may lead to either sensory loss or physical impairments that limit mobility, impair cognition, or reduce the ability to perform daily activities. Evidence shows that older and/or disabled populations are made up by individuals who present widely different and heterogeneous functional profiles. Impairments range from extremely mild (people able to walk with a cane or affected by such a mild memory loss that allows them to live on their own) to extremely severe (persons bedridden or completely unable to understand a simple instruction).

Global declines and alterations in motor coordination, spatial perception, visual and auditory acuity, gait, muscle and bone strength, mobility, and sensory perceptions of environmental stimuli (heat, cold) with increasing age are well documented, as are increases in chronic diseases and their disabling sequels (Crews 2005).

The simultaneous presence of cognitive and mobility impairments has a multiplicative effect, worsening global function more than expected by the sum of the single conditions.

Cognition and mobility heavily affect the capacity of daily planning. For an activity to be effective implies that the person is capable of performing it when he/she wants to or when it is *necessary*: the possibility of successfully performing daily life connected activities implies the chance of remaining or not in the community.

As a consequence, the capacity of performing ADLs becomes an important indicator of self-dependency or disability, is used as a comprehensive measure in disabled people, and can be chosen as a marker of Functional Status.

It is then mandatory to consider age-related Functional Status impairment among senior citizens when developing devices to improve disability, and to judge their effectiveness in maintaining and improving self-dependency in terms of ADLs.

i-Walker: an Agent-based service to elders mobility

The Intelligent Walker (*ı-Walker*) is an assistive device, a rollator, with four conventional wheels and two degrees of freedom (see figure 1). Two of these wheels, the ones placed closest to the user, are fixed wheels driven by independent motors embodied in the hub of the wheel. The other two wheels, the ones placed on the front part, are castor-wheels. They can freely rotate around their axis and are self-oriented.

The *ı-Walker* has two handles that the user holds with both hands, to interact with it. The force sensors located in the handlebars will allow knowing *how* the user is exerting forces to the walker, so they provide user's interaction information. There are also a couple of force sensors located on rear wheels for measuring the normal force exerted by the floor on the wheels (*e.g.* useful for detecting overturn risk). The mechanical analysis of the *ı-Walker* is focused on the interaction between a generic user and the vehicle, in addition to how the rear wheel motors -which are the only active control available- can modify the users behavior and his/her perception of the followed path. For safety reasons, these motors will never result in pulling the *ı-Walker* by themselves.

For *ı-Walker* it is necessary to have a redundant set of sensors that allow to validate the motor torques strategies and measure the user's reactions to them in addition to their behavior. The considered set of sensors includes an encoder for each of the fixed wheels for odometry purposes, three strength gauges incorporated to each handle to measure the user interaction with the walker (longitudinal, transversal and vertical user forces), a strengh gauge incorporated to each fixed wheel to measure the wheel normal force (to anticipate and avoid unsafety situations) and an inclinometer placed on the symmetry plan of the vehicle to detect inclined surfaces. The minimum acceptable set of sensors for a standard *ı-Walker* could be reduced to the encoders or to the user longitudinal forces, and the inclinometer. All other magnitudes can be calculated using the information given by these sensors.

Figure 1: *ı-Walker*

The *ı-Walker* sensing devices provide the means to precisely track the user's intention in every situation. We are assuming that the users of the *ı-Walker* follow a daily schedule that include all their ADLs. All the information gathered supports the agent layer that will process this data and use it to provide the services that users might need using the computer device attached to the *ı-Walker*. The agent layer delivers three main kind of services: monitoring, navigation support and cognitive support.

The monitoring services gather all kind of data from the sensors (walking behavior, forces exerted, environment, localization if available, ...). The information related to the user will be processed and analyzed by medical partners with possible rehabilitation uses. Also, with the step behavior and forces on the handlebars observed the agents can determine the user intention, be it in navigation terms or even if the user is trying to get up from a chair or just trying to get the walker closer to the place where they are resting. Monitoring also covers security issues, like being aware if the user or the *ı-Walker* fall to the ground, and taking the according measures.

Among the navigation services the users have on disposal a map of the environment and their localization on it. They can ask for a route to reach some destination and real time indications to follow it. If navigation is interrupted by non avoidable obstacles, the agents can suggest a new route or offer to ask for help to a caregiver. The way help is requested, depends on the environment (tcp, msg, sms,...). The *SHARE-it*project has developed an environment with a set of sensors that allow the monitorization of different parameters *i.e.* localization, presence and activities that provide information to the agent system. Experimentation environment is the so called *Casa Agevole* (Vescovo 2005). In this house all the sensors needed to create the necessary Ambiance Intelligence have been deployed.

The *SHARE-it*— agent layer offers a series of cognitive aids focused mainly on memory reinforcements and ADL support. Each user has an ADL agenda, a skeleton of daily activities that the user performs like waking up, going to the toilet, having breakfast, etc. The monitoring services keep track of the sequence of places (*i.e.* rooms) that the user has visited, and the order is also tracked, so for instance the agent knows if the user has visited the kitchen for breakfast after waking up. Comparing her daily behavior with the user's usual agenda, the agent can send some activity reminders to the user in case s/he forgot.

The user's agent can also trigger help request messages to the caregivers if some abnormal agenda activities happen, for instance if the user has not visited the kitchen in all the day, probably meaning that the user has not had any meal at all. There will be a special attention to the medical reminders, like having the medication at the right time, RFID tags on some environment items like the medicine box will support this service. Some people with moderate or heavier cognitive problems, can forget how to perform some ADLs or just get confused while performing them, so they can ask their agent a tutorial on how performing a daily activity (*i.e.* washing your hands). Another of those services is the battery status checking that advices about the actual charge of the *ι-Walker*'s batteries. This service schedules the recharging or prevents the use of the *ι-Walker* in the case of of low battery charge.

The ultimate goal of the interaction between robotics, Agent Systems and the user is to enhance autonomy and upgrade the quality and complexity of services offered. The degree of control exhibited by the *ι-Walker* control agent depends on the abilities of the user at each time and situation. Nevertheless, some important topics as safeness and security have to be redefined in the future in order to broaden the applicability of this approach (Fox and Das 2000).

At present the *ι-Walker* has a working advanced prototype that will be used in future experiments, while the agent layer and the interfaces are being developed.

Experimentation scenarios for the i-Walker

Devices have been used to *assist* people with cognitive and/or physical disabilities to complete various tasks for almost 20 years. What represents a change and challenge is the abilities embedded in a new generation of tools that are able to cooperate with the user to complete a task. This implies that these new tools are context-aware and are able to learn from the interaction with the user.

Cooperation for problem solving between users and their *agent* and the cooperation between *agents* among themselves requires some kind of model which at least describes *what to expect from whom* in terms of questions, actions, *etc* and that uses previous experiences and trust.

Scenarios appear to be an easy and appropriate way to create partitions of the world and to relate them with time. Scenarios allow actions to be performed in a given time. For example, Mihailidis *et al.*, in (Mihailidis, Ferniea, and Cleghornb 2000), studied the *hand washing* scenario where a full instrumented environment was used to provide users with cues to support the completion of this task.

As in Mihalilidis' approach we are looking to support those tasks that are needed to perform the most important ADLs. In particular, those related with mobility but not only.

Independent mobility is critical to individuals of any age. While the needs of many individuals with mobility restrictions can be satisfied with use of the *ι-Walker*. This population includes, but is not limited to, individuals with low vision, spasmodic, tremors, or cognitive deficits. In these cases, a caregiver is required to grant mobility. In order to minimize caregiver support requirements for providing mobility, *ι-Walker* can be equipped with an autonomous navigation architecture to assist the user in the control of it.

Experimentation for the *ι-Walker* is to be realized in a 5x5m practicable platform that allows a maximum slope of 16 degrees. The task to be performed is very simple: Starting in one end walk into the platform and, following a path, to describe two complete circles – the circle is 2.5m diameter– and then get out from the other end (see figure 2). The main objective of this experimental scenario is to gather information about the users gait and the forces s/he exerts on the handlers. In figure 3 we show a representation of the forces exerted by the user. In the first we show the longitudinal force in different points of the given path. Points marked as 0^o, 90^o, 180^o and 270^o are of special importance when the slope of the platform is 6 or more degrees (up-to 16 degrees in this case) as this gives information about the forces exerted by the user's arms, depicted in blue in figure 3, and the ones exerted by the the *ι-Walker* , in red in figure 3. We also have the relative position of each foot with respect to the *ι-Walker*. This allows the system to learn about the *normal* situation for each user and, therefore, to produce an appropriate answer for her.

The basic measure for each user will be using the platform as a horizontal plane, and then we will repeat the experiment with an elevation step of 1 degree until a maximum of 16 degrees, unless the doctor considers that an individual should not attempt a trial. This very simple scenario includes most of the relevant user interactions with the *ι-Walker* as for example:

- a) Starting the movement with a clear objective,
- b) Changing slopes from positive to negative simulating walking up-hill and down-hill in a continuous and uniform surface,
- c) Steering the *ι-Walker* to trace the circles and,
- d) Changes in orientation.

Other scenarios are under consideration as new testbeds as performing some paths inside the *Casa Agevole* and after in open, but controlled, environments as garden with clear path walks.

Control Concepts for the i-Walker

The walker has been designed to be passive, cooperative and adaptive (see figure 1).

- Passive because it can only adjust the facing direction of its frontal wheels, *i.e.* it can steer. It has two forward drive engines and so relies not only on the user for motive force. Those motors allow moderate braking the *ι-Walker*. This

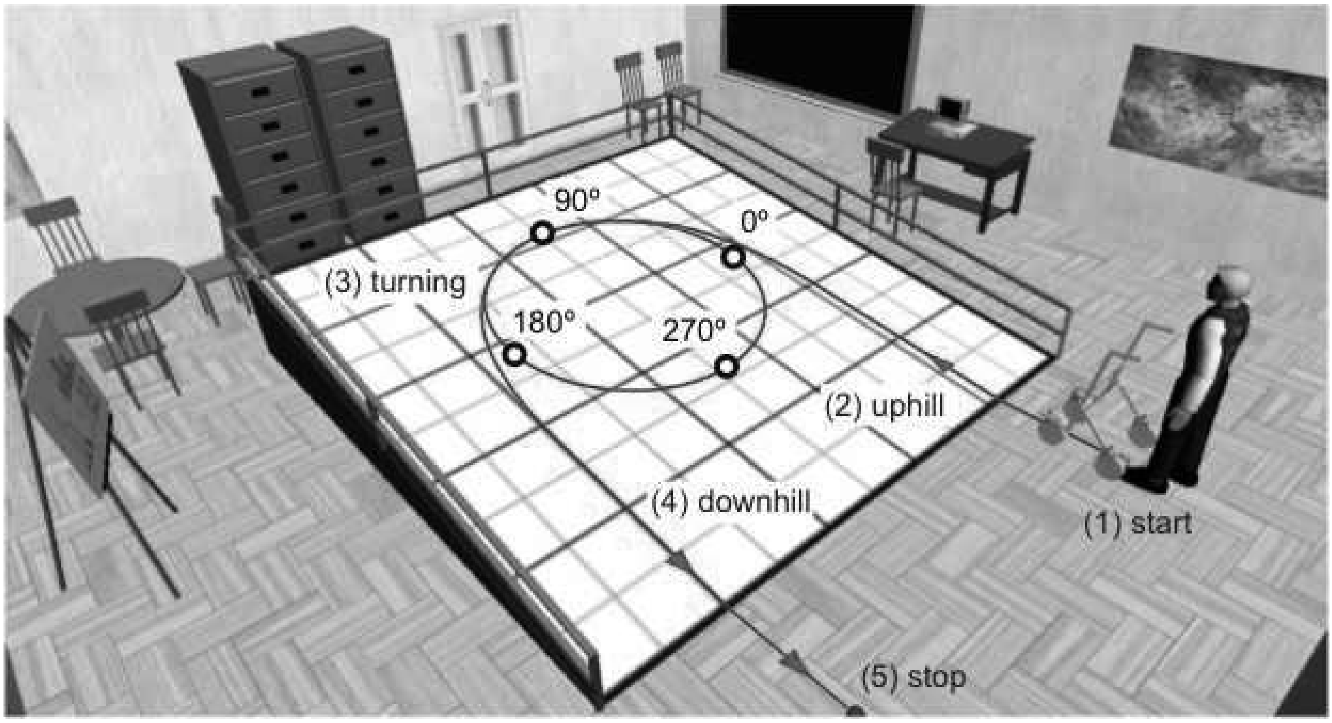

Figure 2: The *ι-Walker* experimentation set

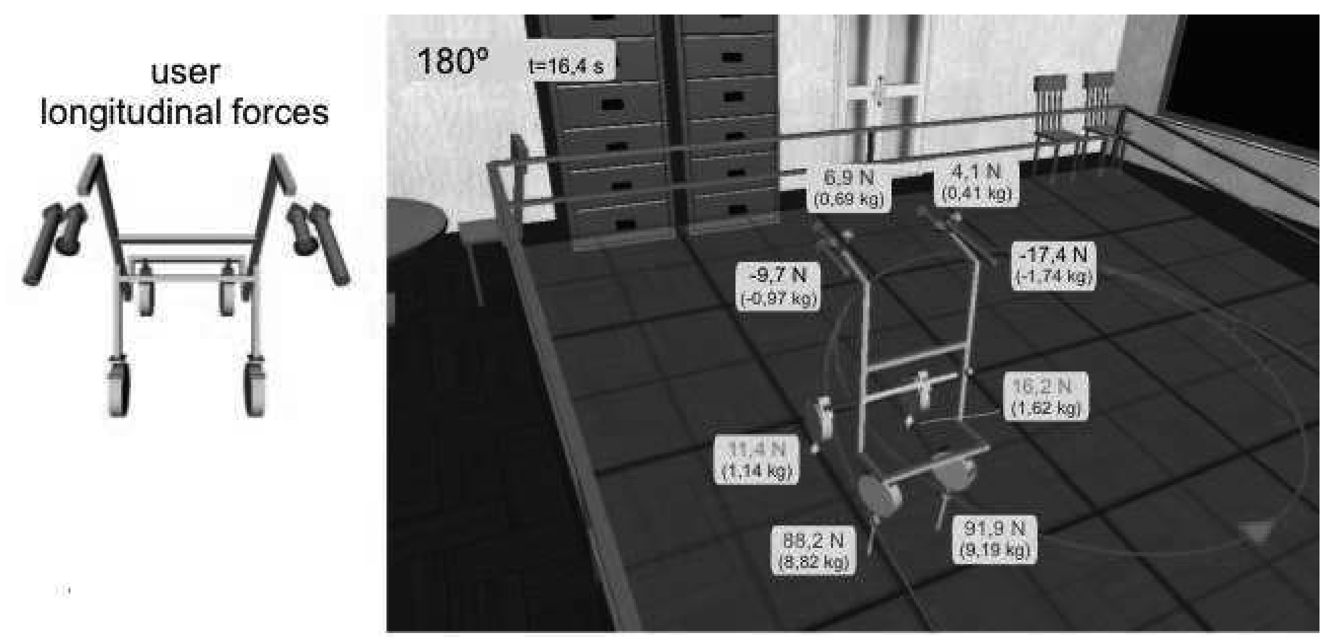

Figure 3: Longitudinal forces

allows the walker to move at the user's pace and provides for the user's feeling of control.

- Cooperative because it attempts to infer the user's path and uses this inference to decide how to avoid any obstacles in the user's path.
- Adaptive because it monitors the users to see if they are resisting the actions (steering/braking) selected by the *ι-Walker*. If they are, the movements are adjusted. This cycle continues until the user agrees with the motion (*i.e.* does not resist it) or manually over-rides it. This interaction forms the basis of the feedback loop between user and agent. Similar approach can be found in (Wasson et al. 2003).

All these characteristics have a special importance when the user is going down-hill: The *ι-Walker* should be able to adapt itself to the user's by moderating breaking itself and avoid the excess of speed. If the user needs to go down an inclined path, without any motor torque, the needed user's longitudinal force should be a pulling force. Due to the action of the motor compensating and braking torques, the user has to make a pushing force, that is approximately the same as the one that it should be done if the user goes up an inclined surface. Navigation guidance by moderate braking. One of the main objectives of *SHARE-it* is helping the users in orienting them when handling the *ι-Walker* in a known environment. The user will receive help from a screen, but the innovative idea will be steering by moderate braking, for helping in navigation. The orientation service is provided by an *agency* already fully described in (**?**) for a power wheelchair.

The manual brakes have also been replaced with an automated braking system. The *ι-Walker* can sense the user's steering input via sensors in the handles that detect the difference in force on the two handles.

- Pushing with more force on one handle (left or right), the *ι-Walker* will turn in the opposite direction.
- Applying of equal force on both handles will move the walker straight forward or backward (which direction can be determined by the *ι-Walker*'s wheel encoders).

Apart from the multi-modal (in particular speech) interface, we will experiment with moderate brake on the *ι-Walker*'s wheels to gain the experience on *how* to better guide the user by allowing s/he sharing with the computer the steering actions.

Acceptability

Finding the right assistive device for each person is not an easy task. Assistive tools have the potential to narrow the gap between an individuals capacity and their environment, and therefore to make it easier for people to remain in his/her preferred environment. The extent to which these tools can narrow the gap depends on elders willingness to use it (McCreadie and Tinker 2005). That is why among the *SHARE-it* objectives we pursue the idea of personalization. Personalization implies a large amount of knowledge about the users abilities and limitations, his/her environment, his/her clinical information, *etc*. Personalization should be a sound, safe and easy and adaptive process. Agents have shown to be a solid option.

An open topic is the acceptability of this technology among elders. Senior citizens facing some disabilities need to find this technology easy to learn to use as well as be confident with its usage in their preferred environment. This implies an effort to provide the appropriate infrastructure elsewhere. Also, it should be easy and affordable to adapt these technological solutions to different environments.

Conclusions

Assistive robotic agents can provide invaluable assistance to their users. The connection between the robotic agent and the user is the key to this. We propose the use of intelligent software agents to provide better means for the communication between user-machine. The primary target of the use of *intelligent* tools in the healthcare domain is to improve the quality of life of the patient/user and of his caregivers, as to say, every person who - in some way - supports his needs (relatives and/or professionals).

The functionalities of the *ι-Walker* are divided in three areas: analysis, support and navigation *ι-Walker* (aid to move in a well-known environment). The *Analysis walker* consists in gathering, real time information coming from different sensors: forces in the handlebars and normal forces from the floor, feet relative position towards the walker, tilt information, speed of rear wheels, mainly. The analysis of this information will allow the study about: the gait, how the patient lays onto the walker and how much force exerts on the handlebars while following a predefined trajectory. The support walker consists in applying two strategies to motor:

- A *helping strategy*. In the normal operation of the *ι-Walker*, the user must apply pushing or pulling forces in the handlers to move around. The strategy of helping the user consists on relieving him from doing a determined percentage of the necessary forces.
- A *braking strategy*. It can oblige the patient to apply a forward pushing force in the handlers in a downhill situation instead of pulling force which can be less safe.

The amount of helping percentage and braking force in each hand can both be determined by a doctor. Both strategies are not exclusive: we can have the patient pushing the *ι-Walker* going downhill and at the same time the *ι-Walker* relieving him from part of the necessary pulling/pushing force to move around.

The *navigation walker* consists in connecting to a cognitive module that gives the appropriate commands to the platform in order to help a user to reach a desired destination indoors.

The *ι-Walker* commands will consist in moderate braking for steering the *ι-Walker* to the right direction. Other information will be shared with the cognitive module like: speed, operation mode *etc*. The *ι-Walker* platform can be used manually by a walking user, but it is also capable of performing autonomous moving. The platform can easily be adapted to accept commands to set a desired speed from a navigation module, when this is completed. Autonomous moving can be useful, for instance, to drive to a parking place for charging battery and returning to the side of patient when remotely called. For example, between two points inside the *Casa Agevole*.

There is a strong case for the use of the *ı-Walker* inside the frame depicted by *SHARE-it* and, therefore, for the use of intelligent agents to support mobility and communication in senior citizens. Moreover, there is a clear evolutionary pathway that will take us from current AT to more widespread AmI where MAS will be kernel for interaction and support for decision-making. The ultimate goal of the interaction between robotics, Agent Systems and the user is to enhance autonomy and upgrade the quality and complexity of services offered.

In our view the *user* should only be assisted according to his/her profile: not more, not less.

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