A SHARE-it service to elders' mobility using the i-Walker.

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Abstract— **In this paper we focus on the development of an intelligent pedestrian mobility aid that we call i-Walker. i-Walker is a robotically augmented walker to reduce fall risk and confusion, and to increase walker convenience and enjoyment. SHARE-it is an FP6 EU Funded project that provides an Agent-based Intelligent Decision Support System to aid the elders.**

I. INTRODUCTION

THE goal of SHARE-it, a EU FP6 funded project (http://www.ist-shareit.eu), is to develop a scalable, adaptive system of add-ons to sensor and assistive technology so that they can be modularly integrated into an intelligent home environment to enhance the individual's autonomy. In this paper we focus on the development of an intelligent pedestrian mobility aid that we call i-Walker (see figure 1). SHARE-it will provide an Agent-based Intelligent Decision Support System to aid the elders. In the personal autonomy and disability context, two different scenarios of the shared autonomy can be elicitated.

A. Motivation

People presenting mainly physical impairments are able to define their own goals, but due to their restrictions they usually are not able to execute them, suffering a limitation in their autonomy. In this scenario the contribution of Assistive Technologies (AT) focus on physical devices, mostly mobility hardware, that allows them to reach their objectives. We propose that those devices may be controlled by multiagent systems or through an agent supervised shared control if the user motor capabilities are not severely damaged. In this scenario, user interfaces are crucial to detect user's intention, which is critical to define goals for the wheelchair to be able to assist him/her.

People presenting mostly cognitive impairments may require a different kind of assistive aids, which may lead even a more relevant role in the sharing of personal autonomy. In this scenario the user probably does not have very clear goals or is unable of achieving them because he/she cannot remember how to do them. In these cases, AT may empower and complement their autonomy using agents that offer them a set of services, like reminding what kind of activities they can or should perform at a certain moment of the day or pointing them out how to achieve these activities. The main idea is to offer the users a set of cognitive aids, either rational or memory based, that can ease their daily living.

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Roboticists have developed a number of mobility-enhancing assistive technologies. Most of these are active aids, meaning that they share control over motion with the user. Most are aimed at obstacle avoidance and path navigation. New generations of technologies promise radical advances in ICT support for European elderly citizens with disabilities.

Assistive engineering and design is a field at the intersection between technology, the natural sciences, the humanities, the social sciences, and medicine. Assistive Technologies are of special interest, as the average age of the population increases fast [3, 11]. Clearly, societal resources will not be sufficient to assist all elderly or people with disabilities, so IST are expected to play a key role in this respect. ICT can help people to remain active and productive as they age while improving work-life balance.

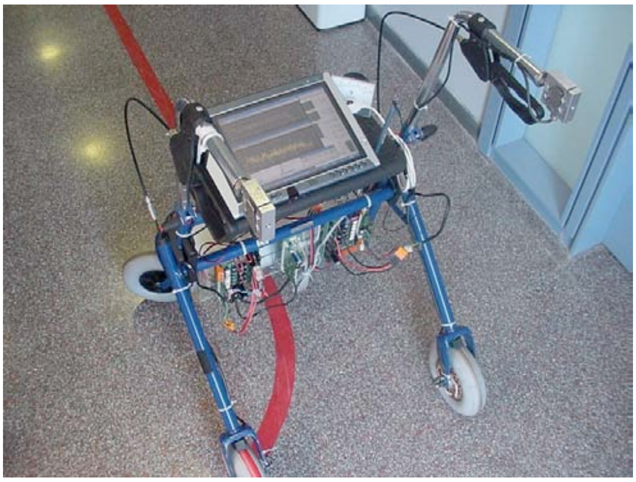

Figure 1: The i-Walker

The power of AT is still under-recognized by physicians and its potential as an aid to patients is under-exploited. These technologies could be seen as a therapy or as a commodity. There are limits to the extent to which rehabilitation professionals can help to improve the skills of impaired people and the broader environments in which they live, and AT provide powerful means to overcome those limitations.

One of the most important factors in quality of life for the older adults is their ability to move about independently. Not only is mobility crucial for performing the activities of daily living (ADLs), but for maintaining fitness and vitality.

Lack of independence and exercise can lead to a vicious cycle. Decreased mobility due to a perceived lack of safety can cause muscular atrophy and a loss of the feeling of empowerment (both of which contribute to further decreased mobility).

Many older adults use walkers to improve their stability and safety while walking. A Walker, may support up to 50% of the user's body weight, are ideal for weak knees or ankles or severe balance problems. Another related problem is the lack of strength in target population. Doctors make us conscious of the possible uneven loss of strength in the extremities. This of course is the main reason for having troubles in arising from a chair, in walking, being unable to steer a normal walker, being unable to standing still, etc. We have developed a robotically augmented walker to reduce fall risk and confusion, and to increase walker convenience and enjoyment. One of the SHARE-it objectives is to build different Intelligent Walkers (i-Walker) workbench platforms, oriented to demonstrate their feasibility, and gain the confidence to support the specific disabilities [4]. Two inspiring works in this line for intelligent pedestrian aids are [6, 14]. Those propose intelligent robotics agents but the main difference in our approach is the use of intelligent software agents to support decision-making and to help in the interfacing with the user.

This work proposes a shared control framework for the i-Walker, which provides situation-dependent synthesis of control signals from both human and machine. Our shared control system architecture integrates information from different sources including environment perception system.

B. *Plan of the paper*

The rest of this paper is organized as follows: In section II we introduce our ideas on Shared Autonomy related with the support to the elders. In section III we introduce the basics of our intelligent pedestrian mobility aid that we call i-Walker. We also introduce in this section the agent-based control elements. Which is a central part in our approach. In section IV we introduce the generic scenarios where the i-Walker is currently in limited testing, to assure its safeness and soundness, before to go to a full-scale testing with real users. In section V we present our conclusions and future plans for this research in the frame of SHARE-it.

II. Shared autonomy: a way to do it right

To support autonomous life in well-known and preferred environment is one of the main aims of the new generation of Assistive Tools. Autonomy for the elderly or people with disabilities does not only rely on mobility terms, but on a set of domains influenced by functioning, activity limitations, participation restrictions and environmental factors. Life areas related to activities and participation are such as learning and applying knowledge, general tasks and demands, communication, mobility, self-care, interpersonal interactions and relationships as well as community and social life. All these domains can be affected by aging or disabilities and are the base of personal autonomy and the satisfactory participation on them reflects on the self well-being. AT can participate in these activities in order to enhance the user's autonomy, gathering all the environmental information and making use of it properly.

A. *Shared Autonomy*

Our ideas to design new Assistive Tools are based on the notion of *Shared Autonomy* between the user and its own agent-based mediator with any information system at hand. Existing telematic healthcare systems that provide integrated services to users are not, to our taste, enough flexible to allow a real personalization and maybe now it is too expensive to change them.

The shared autonomy concept is scarcely explored in literature and often it is misunderstood as shared control (e.g., [13, 7]). In the personal autonomy and disability context, two different scenarios of the shared autonomy can be elicitated**.**

- People presenting mainly physical impairments are able to define their own goals, but due to their restrictions they usually are not able to execute them, suffering a limitation in their autonomy. In this scenario the contribution of AT focus on physical devices, mostly mobility hardware, that allows them to reach their objectives. These devices may be controlled by multiagent systems or through an agent supervised shared control if the user motor capabilities are not severely damaged. In this scenario, user interfaces are very important to detect the user intention, which is critical to define goals for the mobility platform (*i.e.* the i-Walker) to be able to assist him/her.
- People presenting mostly cognitive impairments may require a different kind of assistive aids, which may lead even a more relevant role in the sharing of personal autonomy. In this scenario the user probably does not have very clear goals or is not capable of achieving them because he/she cannot remember how to do them. In these cases, AT may empower and complement their autonomy using agents that offer them a set of services, like reminding what kind of activities they can or should perform at a certain moment of the day or pointing them out how to achieve these activities. The main idea is to offer the users a set of cognitive aids, either rational or memory based, that can ease their daily living.

Roboticists have developed a number of mobility-enhancing assistive technologies. Most of these are active aids, meaning that they share control over motion with the user. Most are aimed at obstacle avoidance and path navigation [12, 6, 8]. A main drawback of most of those is that they are not designed to adapt themselves to the user's conditions and therefore are not always acceptable.

III. I-walker

With this context in mind, we introduced in [4] the design of an integrated architecture aimed at helping citizens with disabilities to improve their autonomy in structured, dynamic environments. The main element of this architecture is an intelligent agent layer that mediates between different technology components (robotic devices –as the i-Walker– ubiquitous computing, and interfaces) in order to provide the subject with the necessary degree of independent mobility to benefit from different assistive services and to reach goals determined by either the subject himself/herself or by medical staff.

The agent based control system provides an excellent means to model the different required autonomous elements in the patient's environment (from control elements in the i-Walker to care-giving services). Agents probe to be efficient in coordinating heterogeneous domain-specific elements with different levels of autonomy. Addressing the mobility problem and keeping in mind that different users need different degrees of help, a part of this agent based control layer has been focused on the development of a shared control for the i-Walker that adapts to the user needs [9, 2].

The i-Walker is an assistive device 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. 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 i-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 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 Intelligent 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 user's behavior and his/her perception of the followed path. For safety reasons, these motors will never result in pulling the i-Walker by themselves.

A. *I-Walker Control Concept*

The walker has been designed to be passive, cooperative and submissive.

The manual brakes have also been replaced with an automated braking system. The 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 walker will turn in the opposite direction.
- Applying of equal force on both handles will move the walker straightforward or backward (which direction can be determined by the i-Walker's wheel encoders).

One of the main objectives of SHARE-it is helping the users in orienting them when handling the i-Walker in a known environment. The orientation service is provided by an agency already fully described in [1, 2] for a power wheelchair. This is called the SHARE-it agent layer (see §III.B).

The user will receive help from a screen, but the innovative idea will be steering by moderate braking, for helping in navigation. Apart from the multi-modal (in particular speech) interface, we will experiment with moderate brake on the i-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. The main idea is to help target population while driving the i-Walker in normal situations like: uphill, downhill, turning left/right, and/or standing still, standing up, etc.

B. *Agent-Based Control*

The i-Walker sensors provide the means to precisely track the user's intention in every situation. Ambient Intelligence is also available through a sensor network established in the known environment. 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 i-Walker. The agent layer delivers three main kinds of services, monitorization, 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 i-Walker falls to the ground, and taking the according measures.

Among the navigation services the users have 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 non-avoidable obstacles interrupt navigation, 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 agent layer offers a series of cognitive aids focused mainly on memory reinforcements and Activities of Daily Living (ADL) support. The user has an ADL agenda, a skeleton of daily activities that the user performs like waking-up, going to the toilet, having breakfast, etc constructed taking as basis their own daily routine observed through monitoring. 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 his daily behaviour with the user's usual agenda, the agent can send some activity reminders to the user in case he forgot.

The user 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 or dressing-up).

Regarding user-agent interaction, the final interface is still under development but in its definition there are some major concerns: a) It should give access at anytime to any available (and permitted service) b) It should allow the client to select a destination from a list and to change mind; c) It should keep the client informed about his actual position and direction; and d) It should help to avoid confusion modes and impasses.

The i-Walker commands will consist in moderate braking for steering the i-Walker to the right direction. Other information will be shared with the cognitive module like: speed, operation mode *etc*. A walking user can use the i-Walker platform manually, but the platform is also capable of performing autonomous moving. The i-Walker 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 patient's actual location when remotely called.

The ultimate goal of the interaction between robotics, Agent Systems and the user is to enhance autonomy and up-grade the quality and complexity of services offered. Nevertheless, some important topics as safeness and security have to be redefined in the future in order to broaden the applicability of this approach [5].

IV. DESIGNING EXPERIMENTS 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 represent a change and challenge are 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 personal 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. Real world scenarios make it easier to involve people in the experimentation and support better the user's interaction with the technology, in this case with the i-Walker.

Scenarios allow actions to be performed in a given time. For example, Mihailidis *et al.*, in [10], 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.

A. *Experimentation scenarios for the i-Walker*

Experimentation for the i-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 and then get out from the other end (see Fig 2).

The main objective of this experimental scenario is to gather information about the user's gait and the forces s/he exerts on the handlers. 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 2 degrees until a maximum of 16 degrees, unless the doctor considers that an individual should not attempt a trial.

This very simple experminet includes most of the relevant user interactions with the i-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 i-Walker to trace the circles, d) Changes in orientation, etc.

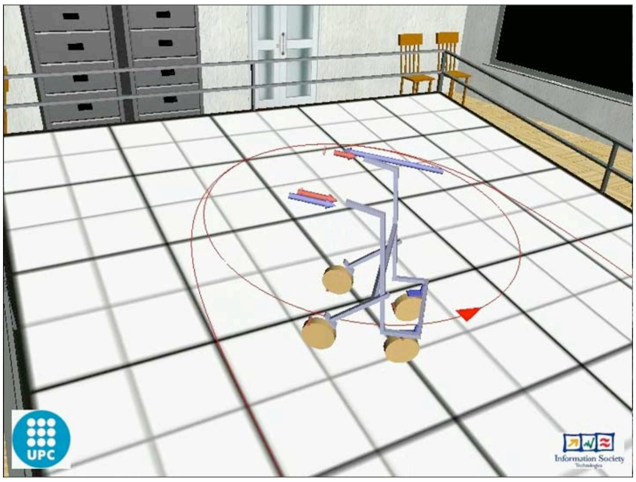

Figure 2: Example of a real path that a user may need to follow

B. *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 individual's 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. That is why among the SHARE-it objectives we pursue the idea of personalization. Personalization implies a large amount of knowledge about the user's 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.

V. CONCLUSION

Assistive robotic agents and associated services 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, in this case the i-Walker. 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 i-Walker are divided in three areas: analysis, support and navigation i-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 i-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 force the patient to apply a forward pushing force in the handlers in a downhill situation instead of pulling force, which can be less safe.

A doctor can determine both the amount of helping percentage and braking force in each hand. Both strategies are not exclusive: we can have the patient pushing the i-Walker going downhill and at the same time the i-Walker relieving him from part of the necessary pulling/pushing force to move around (see Fig. 2). 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. Still, there are open questions as: is it necessary that the i-Walker *knows* the user's intention anyway?

There is a strong case for the use of the i-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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