Mobile Interface for a Smart Wheelchair

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Abstract. Smart wheelchairs are designed for severely motor impaired people that have difficulties to drive standard -manual or electric powered-wheelchairs. Their goal is to automate driving tasks as much as possible in order to minimize user intervention. Nevertheless, human involvement is still necessary to maintain high level task control. Therefore in the interface design it is necessary to take into account the restrictions imposed by the system (mobile and small), by the type of users (people with severe motor restrictions) and by the task (to select a destination among a number of choices in a structured environment). This paper describes the structure of an adaptive mobile interface for smart wheelchairs that is driven by the context.

1 Introduction

Smart wheelchairs are designed to improve the mobility of users with severe motor impairments that experiment difficulties to drive traditional electric-powered wheelchairs. The techniques used to automatically drive wheelchairs come from the Mobile Robotics and the Automated Guided Vehicles fields [1]. Smart wheelchairs are usually provided with a number of sensors and the necessary software for control, to be able to automatically follow a path from a starting position to a destination without human intervention [2, 3, 4]. Even if the user of a smart wheelchair does not need to carefully drive it, he or she must be provided with an adequate interface to be able to give the necessary orders for the wheelchair control.

The design of an interface for a smart wheelchair faces diverse problems due to the special characteristics of the user, the system and the task. Smart wheelchair typical users are severely motor –and sometimes voice– impaired people that can not handle a standard interface. On the other hand, the computing capacity of the system is conditioned by the fact that usually it is run by an embedded computer mainly devoted to real time control of the vehicle. In addition, people with disabilities need frequently diverse devices that assist them for everyday tasks. Nevertheless, they can not easily switch from a device to other. Therefore, all these devices tend to be integrated together sharing an interface that gives access to all the functions required by the user: wheelchair movement control, environmental control (usually through a *domotic* system) and, frequently, personal direct or remote communication via computer. Among the diverse tasks that the user can perform form that interface, in this paper we will only analyse the control of the wheelchair movement, because communication and environmental control are well documented [5]. Therefore, the main interface design problem is to give the user the possibility to select a destination among a relatively large number of choices requiring the minimum effort. Next section presents the project were this interface was developed.

2 The *TetraNauta* System

TetraNauta[1] project developed a controller for standard electric-powered wheelchairs that allows users with very severe mobility restrictions (such as people with quadriplegia) to easily navigate in closed structured environments (home, hospital, school, etc.). The main goal of this project was to design a non-expensive automatic driving system to help this kind of users to employ the wheelchair with the minimum effort, but maintaining the user as active as possible –to benefit his or her rehabilitation. For this reason the design of an adequate adaptive mobile user interface was a key factor in *TetraNauta* architecture.

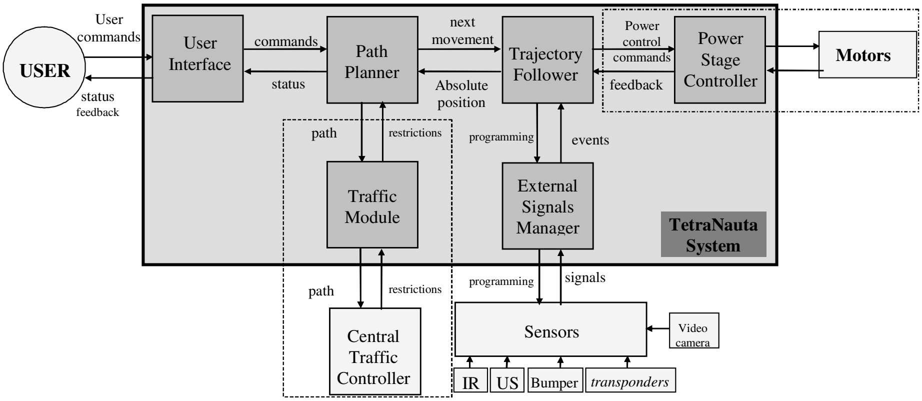

Fig. 1. Architecture of the *TetraNauta* System

From the point of view of the navigation, two main sections can be distinguished in *TetraNauta* architecture (fig.1), the Control Section and the User Interface. The first deals with automatic operations -such as signals handling, control of the motors, etc.- while the second manages user dialogue. Due to already mentioned user motor restrictions, many operations that usually are done by the user, must be transferred to the automatic controller, thereby decreasing the effort made by him or her. Hence, modules for path planning and guidance must be added. The path planning sub-

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[1] *TetraNauta* is a research project developed by the National Hospital of Paraplegics; Bioingeniería Aragonesa S. A.; the Group of Robotics and Rehabilitation Technology of the University of Seville and the Laboratory of HCI for Special Needs of the University of the Basque Country.

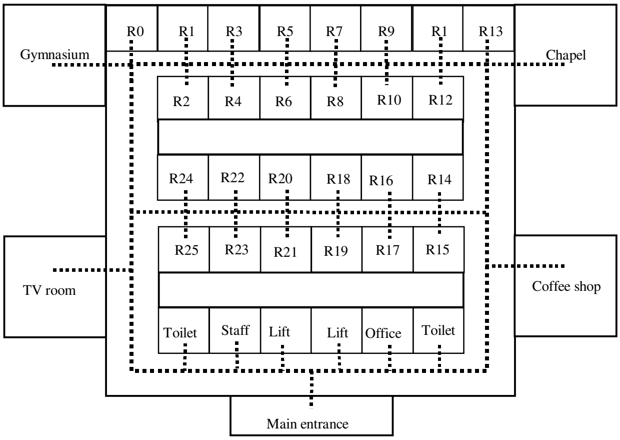

Fig. 2. A graph (dotted lines) representing a plant.

system finds a path free of obstacles between two points on a topological map (a graph, see fig 2), whilst the guidance sub-system drives the wheelchair along the trajectory calculated by the path planning module while estimating its absolute position. The path planner is implemented by means of a search algorithm that finds a path that links two nodes of a graph. A detailed description of that algorithm can be found in [6, 7].

A number of beacons are disseminated in the environment to allow absolute positioning. When the wheelchair approaches one of them it recalibrates its position. There is a command to automatically find a track or beacon to acquire the current position when it is unknown by the system. It is also possible to manually drive the wheelchair to a track or beacon.

3 Interface Structure

The user controls the system through a very intuitive graphical interface that translates his or her orders (e.g. the desired destination) into commands for the Trajectory Planner (that calculates a quasi-optimal trajectory). It also gives feed-back to the user about the current operation.

The input device for *TetraNauta* interface is typically the same used to drive the wheelchair: a joystick, mouth-stick, or any other alternative input system used in Assistive Technology [5]. The output is a small colour display (that currently has been ported to a PDA). Due to the user motor restrictions the selection of the desired command is usually done either by *scanning* a matrix of icons and selecting them with a pushbutton; or by means of *directed scanning* where the user goes through the matrix using a joystick[2].

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[2] Depending on the user characteristics other input/output devices are possible: for input purposes touch-screens, voice recognition, etc., while, besides a display, synthetic voice can be used for output in some cases. Here we only present the most common choice.

Simplified Task Model

For navigation purposes the user can perform the following tasks (see fig. 3): when the vehicle is stopped, if the current position is not known by the system, the user can automatically find a track (or manually drive the wheelchair to a track). If the current position is known by the system, the user can select a destination or go to a given destination (from the current localization). While the wheelchair is going to a destination, the user can change the current destination (which stops the wheelchair and pass to “select a destination”). In addition, the user can always switch to manual control that stops the wheelchair and leaves the control to a human).

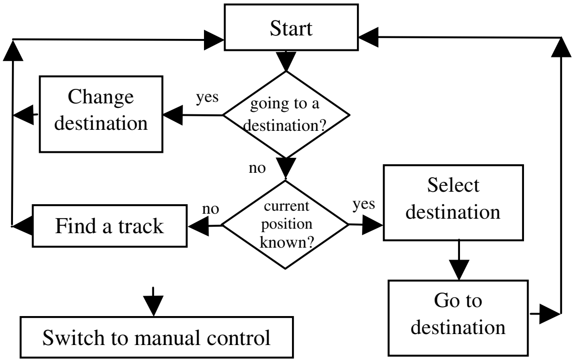

Fig. 3. Simplified task diagram

As it is sown previously, most of the tasks can be represented by icons in a simple interface. Nevertheless, when the user has to select a destination, the number of nodes in a graph representing a structured closed environment (see fig. 2) is usually too large for the display mounted in the wheelchair, making the selection difficult. To avoid this trouble, the interface makes use of the information the system has about the task that it is performing [8]: the current position and the map of possible destinations. Therefore, the same data structure (a multi-layered map) used for trajectory planning is used for display purpose, due to the information management facilities that it provides. In fact, the hierarchical map model is very suitable for compact menu-based displays (do not forget that our implementation of menus is based on *scanning and selection*). Therefore, each abstraction level can be included in a menu and a selection may be carried using a small number of menus.

In addition, user adaptation allows the optimization of the choices. When the user is choosing a destination, the selection set is composed only by the reachable destinations from that point, ordered by frequency of use. In this way, only possible destinations -in order of probability- are offered, minimizing the selection effort.

Other important characteristic of *TetraNauta* interface is that it is not intrusive. The system does not take decisions when the user is able to take it, which is very important to facilitate the user rehabilitation process. Since the abilities of the user can change with the training it is necessary to build an incremental user model, to be able to determine what decisions are in the hands of the user.

More details about the *TetraNauta* interface can be found in [9].

4 Conclusion

The design of an adaptable mobile interface for a smart wheelchair heavily depends on the tasks that this device performs. The knowledge that the system has about the current position and the points that are reachable from this point allows the design of a simple and effective interface that takes into account the context. The interface of *TetraNauta* system is also adaptable and accessible to severely motor impaired people. In addition, it helps to the rehabilitation of the user giving to the user as much decisions as he or she can take.

Acknowledgments

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