ENHANCED USER INTERFACE FOR POWER WHEELCHAIRS DEVELOPED IN THE MOVEMENT PROJECT

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Abstract: In the course of the EU funded research project MOVEMENT the need for a highly adaptable and modular user interface for various control tasks arose. This user interface must be able to assist a less skilled or severely impaired user not only to better stay in control of manual driving a power wheelchair but also to initiate various high-level functions to be carried out by the MOVEMENT components in its autonomous mode. The User Interface, therefore, shall enable users with largely different abilities to control a modular set of system components in a unique way. In this paper the concept developed for this user interface and the resulting novel features are described.

Introduction

A traditional input-side User Interface for power wheelchairs comprises mainly of a joystick, optionally head, mouth, suck/puff or chin operated controls and binary switches can be added. This requires the user to be able to perform the steering task with only little assistance by the wheelchair system in a pre-defined way. Output is done via optical indicators or graphically on an LCD [2][3].

In the course of the EU co-funded project MOVEMENT an enhanced and modular User Interface will be developed [1].

Approach

MOVEMENT aims at the development of a modular versatile mobility enhancement system. The core is formed by an intelligent mobile (robotic) platform which can attach to a user definable selection of application modules (e.g. chair, manipulator, information terminal). These modules are more or less inconspicuous mainstream articles but will become powerful assistive devices when the mobile platform attaches to them.

In the past, there where several research projects and groups aiming at the development of smart wheelchairs, FRIEND, EASY, Rolland, VICTORIA, OMNI, TAO, SIAMO, CALL, NavChair, TinMan being examples thereof [11-14].

MOVEMENT addresses the needs of persons that do not need or want to use a wheelchair all the time but just intent to use it occasionally for managing their way from room to room. Persons normally not able to control a wheelchair (e.g. in case of spasm or athetosis) will also profit from the system developed within the MOVEMENT project. It, therefore, will be possible to drive the MOVEMENT system in a manual, an assisted or an autonomous mode.

Figure 1: Typical combinations of MOVEMENT-modules for moving people and objects

To support the project intentions, the User Interface for MOVEMENT will consist of a modular combination of traditional input/output with additional input channels and feedback, adaptive behaviour, prediction of user intention in combination with shared control, autonomous navigation and collision avoidance.

In addition to a joystick (also head, chin, mouth or suck/puff operated versions) for conventional manual steering, assisted driving will be possible via alternative channels like touch screen, spoken commands and gesture recognition.

Feedback to the user will be possible via a force feedback channel (joystick), vibration (e.g. to signal critical distance to obstacles) or speech output. All input and output channels are integrated into the common user interface front-end module which permits the system to have input and output mapped to a format best suited to the user needs.

In case of a multi-modal User Interface the user has the choice of using any of the available input devices or input methods, even more than one in parallel [9][10]. At the same time, the system has the choice of several

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output modalities to convey to the user the current status and the available options to choose from. If the User Interface shall serve users with diverse abilities, the set of input and output modalities does not primarily aim at the increase of speed by combination of several channels but mainly on providing the user with at least one modality that she or he can use. A multi-modal modular User Interface not only offers the choice of the input or output channels at the time of adaptation to a specific user so that the preferred devices can be mounted and configured for later use, but also the choice to shift the focus of use during actual use.

The User Interface front-end is able to deliver both, direct drive signals (v, ω) that are processed by the shared control unit before being fed into the motor controller, and a high level target definition used for autonomous driving to a pre-defined location.

For all operating modes the User Interface will adapt to the user characteristics and specific habits so that the initial setup will be improved over time.

System Overview

Figure 2 shows how the User Interface module interacts with other components of the MOVEMENT system. After the pre-processing stage, the user input is received by the Shared Control Unit (SCU). This logical module enhances user input particularly in the case of low-level velocity input by a continuous joystick-like device or a discrete interface. In order to perform its task, the SCU not only processes user signals but also takes the context information into account. The context refers to environmental sensor information (Sensor database) as well as to internal information of the platform like the localization (Localization) or battery status (Status database).

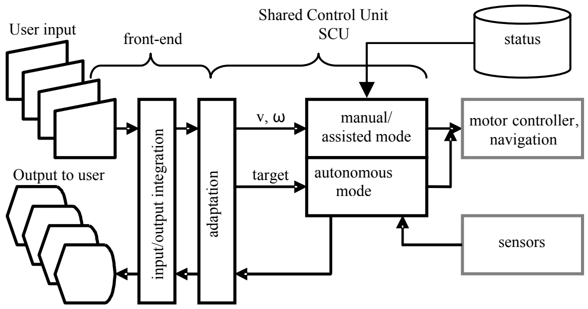

Figure 2: User Interface interaction block diagram

In order to overcome traditional restrictions in user interface design the concepts must be extended to include input not explicitly entered into the User Interface. Contrary to the usual approach to define the input-output relation via a deterministic black box it is necessary to make input and output meaning depend on what is called "context".

Contexts can be:

- Time
- Place, environment, obstacles
- State, actual status of user and system
- History, what the user has done
- Preferences, what does the user like
- Knowledge, what does the user know
- Abilities, what is the user able to do
- Possibilities, properties of what is controlled

The SCU also interacts with a planner that forms part of the MOVEMENT base platform. The planner is a source of information for the SCU when estimating the intent of the user. As it is explained in the next section, a probabilistic model of the user is maintained in order to estimate his or her intention. The most feasible intention according to a specific metric is selected as the most probable user intention. The SCU plans paths to possible intentions and compares which of the planned paths resembles more the input of the user, given the current sensory information.

On the one hand, the system has to create a model of the user and the current situation in order to be able to predict what suits best the needs of the real user in this specific moment and situation. On the other hand, the user also is creating a model of what the system looks like or can do in which way. Despite all adaptability, the user still must have the feeling of being in control of a reliable and predictable system.

Shared Control and Autonomy

Potential users of the MOVEMENT system might not always be able to command a standard power wheelchair. Due to their impairment, they might not possess sufficient driving skills to steer a power wheelchair safely. It can also be very tiring for them to control the system during extended periods of time or when driving in narrow passages or in a crammed environment. A possible solution for this problem could be a fully autonomous wheelchair where the user has little or nearly no control over the driving behaviour. Previous experience and research on user requirements gained in the course of a project (*Sensor-assisted wheelchairs featuring shared autonomy*) clearly shows that users tend to dislike systems over which they have not sufficient control [4].

Giving users the opportunity to perform tasks normally out of their reach considerably increases their self-esteem and autonomy. Bearing in mind this fundamental requirement and considering that the user should still have the feeling of being in control, an intelligent power wheelchair is going to be devised in the course of the MOVEMENT project. The User Interface plays a significant role since it is the point of interaction with the system.

Autonomous robots differ from intelligent wheelchairs in a fundamental aspect. In the first case, a robot has full control over itself. Conversely, two controllers are identified for an intelligent wheelchair, namely the human user and machine intelligence. Both share the control of the system with the purpose of enhancing strengths and removing weaknesses of each other. Humans have excellent skills for global planning and coarse control. Precise local execution of a particular plan is better done by the robot. In a shared control situation, the intelligent controller relieves the human from low level tasks without sacrificing the cognitive superiority and ability of human beings who are capable of acting in unforeseen situations.

A problem in shared control for wheelchairs is to automatically determine how much assistance is required. If the level of shared control is not adapted to the user, he/she might get frustrated as the wheelchair does not behave as expected. Therefore, before assisting the user, the controller estimates what might be the true intent of the human user.

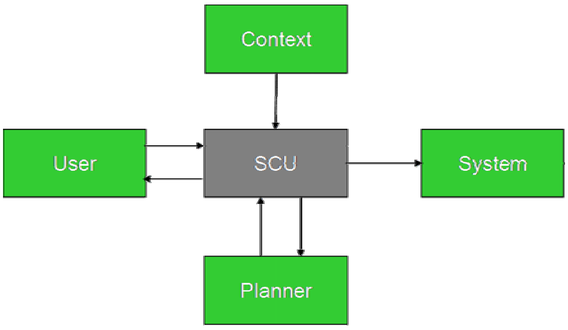

Figure 3: Interfaces of the SCU to the rest of the MOVEMENT system

The proposed shared controller estimates the intent of the user out of low quality input signals by integrating environmental information into the explicit model it maintains of the user. This process is not always straightforward and consequently a challenging research topic. If the user is e.g. in front of an obstacle and his/her inputs are unclear, the possible intentions could be to avoid the obstacle or to dock at it. In this case it is not an easy task to deduce the correct intention solely out of the user's corrupted commands and environmental data provided by sensors.

In the intelligent shared controller that will be developed within the MOVEMENT project the users intentions are represented in terms of end poses (target coordinates and orientation) and end velocities (linear, rotational). The idea is to keep an explicit probabilistic model of the user [5 -8]. This model is tailored to a particular user and his/her impairment (adaptation). The framework calculates a probability distribution over possible intentions. Probabilities get updated with Bayes' rule each time new user signals are available.

In the MOVEMENT system the User Interface is closely related to different modes of assistance that is given to the user. This can best be shown for the modes for driving tasks:

- Manual mode

Here only basic safety measures (collision avoidance) overlay the signals of the user while manually controlling the system. This behaviour is implemented by a safety layer and active in all modes.

- Assisted mode

This mode interprets the input from the user in the following ways: it takes the input as indication for the user's intent and produces a smooth trajectory defined via the average speed and direction given by the user and it also includes the environmental situation. The user can at any time change the direction and speed of movement by giving new input, the system, however, is influencing how the final movement is done and is providing smooth transitions.

- Autonomous mode

Here the user pre-selects a target location; the system autonomously plans a path and performs the driving. The user stays in control of the process because for the user it is still possible to interrupt the process or influence the driving speed by overlaid input. In this mode it is the user that influences the automatic driving done by the system. The navigation is mainly based on data received via a stereo vision system.

An example (see Figure 4) can show the various possibilities that arise when the user decides to drive to another place.

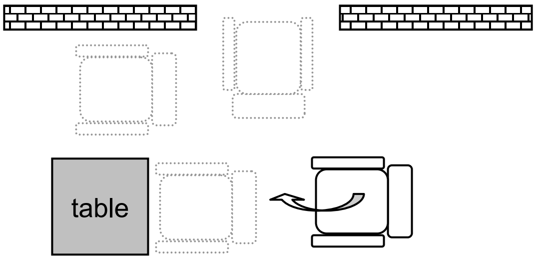

Figure 4: User intention estimation and assistance

The user, when initiating the driving process, might want to do several things: drive close to the table, drive through the door, bypass the table but most likely not drive against the wall, the table or other obstacles. The system, therefore, as a basic step of context, needs to be aware of the positions of "attracting" objects like table or door but also of the obstacles like table or walls. It can be seen that in this example the table can play a double role depending on what the user wants to do.

In the manual mode the system would simply avoid that the user crashes into any obstacle by reducing the momentary speed to a safe level. In the assisted mode the input of the user would be processed such that the likely goals are more attractive and such easier to reach without much intervention from the user, whereas the obstacles would produce virtual resistance and the user can only approach them with putting more emphasis into their direction. In the autonomous mode the user pre-selects the target (table, other room) but still can influence the driving speed by overlaying input. In any of the non-manual modes the context processing could take into consideration additional information like time of day (it could be more likely to go to the kitchen at lunch time) and history on similar commands.

The User Interface is planned to be implemented in form of an intelligent agent, the intelligence of the user and that of the system collaborating to perform a task. This approach is very robust, as the agent can compensate for lack of skills, abilities, memory or attention of the user and the user can compensate for any incompleteness in the agent's ability to solve the task or decide what information is relevant. The User Interface as such plays a role like a butler or assistant but can also act as instructor or teacher. As a teacher, the User Interface can successively take over to perform the work for the user, always keeping the user informed about the ongoing task and the situational options to react and avoiding abrupt changes in responsibilities and unclear situations for the user.

Conclusions

The main goal of the presented User Interface concept is to release the user from navigation burdens while allowing him or her to stay in complete control. The User Interface also provides alternative input and output appropriate for the user and adapted to his or her needs. It therefore comprises of a multi-modal and modular front-end for input and output and a shared control unit assisting the user. Within the MOVEMENT project the presented User Interface will be implemented in the prototypes that will be tested in 2006.

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References

[1] MOVEMENT project homepage http://www.fortec.tuwien.ac.at/movement

[2] http://www.curtisinst.com/index.cfm

[3] http://www.dynamic-controls.co.nz/

[4] *"STWW: Sensor-assisted wheelchairs featuring shared autonomy"*, http://www.mech.kuleuven.be/pma/project/stww http://www.mech.kuleuven.be/mlr/

[5] E. DEMEESTER, M. NUTTIN, D. VANHOOYDONCK, AND H. VAN BRUSSEL (2003): *"A Model-based, Probabilistic Framework for Plan Recognition in Shared Wheelchair Control: Experiments and Evaluation"*, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) 2003, pp. 1456-1461.

[6] E. DEMEESTER, M. NUTTIN, D. VANHOOYDONCK, AND H. VAN BRUSSEL (2003): *"Fine Motion Planning for Shared Wheelchair Control: Requirements and Preliminary Experiments"*, 11th International Conference on Advanced Robotics (ICAR) 2003, pp. 1278-1283

[7] M. NUTTIN, D. VANHOOYDONCK, E. DEMEESTER, AND H. VAN BRUSSEL (2002): *"Selection of suitable human-robot interaction techniques for intelligent wheelchairs"*, in 11th IEEE Int. Workshop on Robot and Human Interactive Communication ROMAN 2002, pp. 146–151

[8] E. DEMEESTER, M. NUTTIN, D. VANHOOYDONCK, G. VANACKER, AND H. VAN BRUSSEL (2005): *"Global Dynamic Window Approach for Holonomic and Non-holonomic Mobile Robots with Arbitrary Cross-section"* 2005 IEEE/RSJ International Conference on Intelligent Robots and Systems, IROS-2005, pp. 2694-2699

[9] EMBASSI project, http://www.embassi.de/estart.html

[10] PAUL D. NISBET (2002): *"Who's intelligent? Wheelchair, driver or both?"*, Proc. 2002 IEEE Conference on Control Applications

[11] FLORIAN BLEY ET AL. (2004): *"Supervised Navigation and Manipulation for Impaired Wheelchair Users"*, Proc. IEEE 2004 Conference on Systems, Man and Cybernetics. Impacts of Emerging Cybernetics and Human-Machine Systems

[12] GOMI, T. AND GRIFFITH, A. (1998):, *"Developing Intelligent Wheelchairs for the Handicapped"* in Assistive Technology and Artificial Intelligence: Applications in Robotics, User Interfaces, and Natural Language Processing, 1988, pp 150

[13] R.C. SIMPSON ET AL (1998): *"Navchair: An assistive wheelchair navigation system with automatic adaptation"* in Assistive Technology and Artificial Intelligence: Applications in Robotics, User Interfaces, and Natural Language Processing 1998, pp 235.

[14] HOYER, H. ET AL. (1999): *"The OMNI-Wheelchair – State of the Art.*

[15] HOYER, H. ET AL. (1999): *"The OMNI-Wheelchair – State of the Art"* in Proc. of the 14th Annual Int. Conf. On Technology and Persons with Disabilities. Los Angeles, 1999