**AI Support for a Gaze Controlled Wheelchair**

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**Introduction**

Currently, one can distinguish two basic modes used for control of a wheelchair:

- In the direct mode, the wheelchair is driven in the same way as a car. The user indicates direction of the wheelchair movement using a steering wheel or a joystick and similar approach is applied for changing the speed.

- In the indirect mode, the user communicates with the wheelchair using a control panel reviewing the available predefined commands, e.g. “go 0.5 m forward”, “turn 30 degrees right”, … The control panel consists either of a set of different buttons suited for the particular user (HW solution) or it is represented by a GUI of a computer screen (SW solution).

The I4Control® system is a wearable system for gaze-computer interaction that is able to simulate the function of a joystick or to select from a grid-like structure using an appropriate GUI (Fejtová et al., 2006). Consequently, it can serve as a single input device for control of a wheelchair in both upper mentioned modes. This is certainly true from purely technical point of view. But this is not enough because safety of the resulting system has to be ensured! That is why special attention has to be given to the questions concerning reliability of the acquired signal and various ways it can be influenced or obscured. The fundamental danger related to gaze-based control comes from physiological reactions to certain stimuli that we have “build-in” to protect our eyes and even ourselves: we close eyes when a strong light flashes, we look into the direction of a loud sound, etc. It is a question how these immediate reactions can be distinguished from the intentional control signals the user wants to mediate to the controlled system. Moreover, the quality of the gaze control is significantly influenced by any change of light conditions for which the human eye has to adapt itself. Even if we use the best algorithms to evaluate point of gaze we can lose the control of the system for the time interval the human eye needs for adaptation to changed conditions. And this is not acceptable.

To make up for limitations of gaze control we have conducted several experiments with a wheelchair complemented by several AI features that have been developed in the field of intelligent mobile robotics. The resulting system is described in the section on an environment sensing system. Its functionalities seem to be useful not only for gaze-based wheelchair control but in a more general context. That is why we reconsider the indirect mode of wheelchair control and suggest its further refinement in the next section. In the conclusions there are mentioned some ideas for our future work towards construction of a smart wheelchair.
Environment Sensing System

To ensure safety of the wheelchair user and to support autonomy, the wheelchair has been equipped with a sensory system consisting of sonar and laser rangefinders, color camera and a notebook that conducts all necessary sensor data processing. The forward-looking color camera acquires images at 15 frames per second. The laser rangefinder is aimed to the front and provides a planar scan with 230° field of view and range of 4 m. Sonars are located at the back of the chair and are used to detect obstacles during backward movement. The wheelchair has been also equipped with a prototype odometric system previously developed for another project.

The safety is enforced by limiting the maximal speed of the wheelchair whenever nearby obstacles are detected by any of the aforementioned sensors. When moving forwards, the rangefinder scan is searched for objects closer than 1 m. If such objects are detected, the maximal speed is decreased and when such distance is 0.2 m, the wheelchair forward movement is turned off. Similar rules are introduced for backward movement and for sonar sensors. We plan to implement algorithm similar to insect-like navigation, where obstacle detection is based on optical flow computed from image sequence acquired by the camera mounted to the wheelchair.

The sensors are not used only for obstacle detection – their input is essential for construction of autonomous modes of navigation. So far, we have tested two algorithms based on data from color camera and one laser rangefinder based algorithm.

- First vision based algorithm (Kosnar et al., 2008) recognizes pathways in front of the wheelchair. The user first specifies, which parts of current image represent obstacles and what color has the path. The algorithm indicates, what trajectory will be followed. After the user confirms the trajectory, the wheelchair starts to move. While moving, estimated future trajectory is shown enabling the user to redefine obstacle and path colors on demand. Moreover, this algorithm can be used to create a graph like map of the environment. With this map, the driver can just specify required destination.

- Second vision based algorithm (Krajnik and Preucil, 2008) detects significant objects in the image, measures their positions and creates a simple description of the path the wheelchair follows. The description of the recorded path can then be stored in a corresponding database and later used to ensure autonomous traversal of the path by the wheelchair.

- Third algorithm incorporates laser rangefinder measurements into a two-dimensional map of indoor environment. After a reliable map is created, the path between any two reachable points on the map can be planned through dedicated AI algorithms. The wheelchair can safely follow the designed path provided upper mentioned obstacle detection is applied.

The refinements of indirect mode for wheelchair control

Let us consider the indirect mode ensured by a computer GUI. In this case the input is not limited to direct physical contact based on touch but it can be mediated by number of alternative interfaces including e.g. those applying gaze, voice or blow (Felzer and Nordmann, 2007).

The simplest approach offers the user to compose his/her journey from many elementary steps. GUI interface offers several buttons with corresponding labels for example: 1m forward, 2m forward, left 10 degree, right 20 degree. User selects appropriate button and the wheelchair performs requested action. In a more sophisticated setting the user can first design a sequence of elementary steps and finally give a command to perform them in one run. Here, the user must be able to interrupt movement of the wheelchair in any moment. This can be achieved either by using an independent input channel dedicated to this purpose or by specifying a special combination of the main control signals. This combination has to be such that it is highly improbable that the user executes it without specific intention. This type of wheelchair control is rather demanding and the movement takes a lot of time.
The following options rely on incorporation of various AI features (Mandel et al., 2005) based on self-orientation and localization of wheelchair in world as well as on some methods of artificial intelligence (image detection, creating of map, smart localization, …). Those features we are currently applying have been briefly described in the former section. The first option the image from camera of the control system is displayed on user’s screen. Control system detects (recognizes) some routes (footpath, road, …) and the user can select one of the offered possibilities. When selection is confirmed, the wheelchair starts to follow the requested path. Movement of wheelchair stops automatically whenever the control system detects some obstacle it cannot cope with itself.

Further improvement is represented by the second option which incorporates learning. Suppose, the wheelchair has built-in a map of the environment it moves in and it offers a list of pre-created or learned paths. As soon as the wheelchair can identify its location, it is enough if the user selects his/her target position (for example: kitchen, bathroom, bedroom, …) and wheelchair can plan its journey to requested position itself by composing it from the parts listed among its ready-made paths. The obstacle detection subsystem ensures that users' reactions to surprising stimuli do not negatively affect function and safety of the resulting system because wheelchair movement is automatically halted whenever the control system detects any serious problem (for example big obstacle).

Universal GUI for wheelchair control

Of course, the control system of wheelchair does not have to be restricted to a single option just described. User can make choice from the appropriate options according his/her actual location. In the home environment, it is possible to rely on pre-created paths and select target position, only. In structured outdoor environment (parks, pathways) it seems useful to use simple path recognition methods and in unstructured or otherwise complicated environment it is possible to use direct control of movement.

Moreover, the user can wish to switch among several input devices (buttons, eye movement recognition, …). To support freedom of choice while ensuring safety, the control system is divided into two parts. The first part includes mainly interface for input device and GUI interface (dialog with buttons) to select appropriate options / actions. This part also controls high level commands such as: go to target position. Second part takes care of autonomous movement of the wheelchair and ensures safety during the journey. This part performs movement commands (go, turn left, stop) and it checks permanently that the movement in intended direction is safe.
Figure 2. Block diagram of wheelchair system.

Conclusions

There are a number of AI algorithms that can improve wheelchair user’s comfort and safety (Mandel et al., 2005). When considering them one has to take into account their time and memory requirements so that they fit the needs of the requested tasks and can be conducted by the HW available on the wheelchair (notebook in our case). As a next step, we are planning to implement a simple tracking program, which will simplify creation of the pre-defined paths: the user will be able to specify an object and the wheelchair will follow it, track its path and remember it. This approach will be used to support the learning based option mentioned as a refinement of the indirect mode of wheelchair control.

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