What you see is where you go: Testing a gaze-driven power wheelchair for individuals with severe multiple disabilities

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What You See is Where You Go: Testing a Gaze-Driven Power Wheelchair for Individuals with Severe Multiple Disabilities

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Abstract

Individuals with severe multiple disabilities have little or no opportunity to express their own wishes, make choices and move independently. Because of this, the objective of this work has been to develop a prototype for a gaze-driven device to manoeuvre powered wheelchairs or other moving platforms.

The prototype has the same capabilities as a normal powered wheelchair, with two exceptions. Firstly, the prototype is controlled by eye movements instead of by a normal joystick. Secondly, the prototype is equipped with a sensor that stops all motion when the machine approaches an obstacle.

The prototype has been evaluated in a preliminary clinical test with two users. Both users clearly communicated that they appreciated and had mastered the ability to control a powered wheelchair with their eye movements.

CR Categories: H.5.2 [User Interfaces]: Input devices and strategies (e.g., mouse, touchscreen); J.3 [Life and Medical Sciences]: Health

Keywords: eyes-only interaction, smart wheelchair

1 Introduction

Individuals with severe multiple disabilities (physical, cognitive, communicative and perceptual impairments) have little or no opportunity to express their own wishes, make choices or move independently. This applies to individuals with severe developmental disabilities as well as those with severe acquired brain injuries and other neurological impairments. Furthermore, it is usually quite difficult to adequately evaluate the cognitive capacity of individuals who have extremely limited voluntarily control of their own movement and communication.

Clinical experience with existing systems has shown that using systems with simple on-off functionality in order to move freely and safely in a secure environment leads to many positive developments [Nilsson & Nyberg 2003]. This occurs in several different areas, such as body and environment awareness, social interaction, communication and concentration. The ability to move and explore independently is motivating and also facilitates learning.

Individuals with severe cognitive impairments who use such systems often slowly develop an awareness of their own ability to explore their surroundings and, as a result, their ability to communicate with people around them. Many individuals develop the skills necessary to accomplish increasingly complex tasks, such as an understanding and ability to control the direction of a wheelchair with greater degrees of independence. Last but not least, the individual's behaviour during interaction with the system enables family and staff to gather invaluable information about the individual's skills, interests and personality.

In the absence of any such system for the intended user group, the objective of this work has been to develop a prototype for a gaze-driven device to manoeuvre powered wheelchairs or other moving platforms. Powered wheelchairs are expensive, so the intention is to create a system that can be adapted and fitted to the user's current equipment. When fully developed, the system will function like an intelligent robot that can be adapted for different levels of support according to the cognitive level, motor control and perceptual skills and difficulties of the intended user. Individuals with severe multiple disabilities will be able to use the built-in robot function to safely steer an electric wheelchair in a controlled indoor environment with their eye movements only. This will enable them to move independently and use their actions to make and display their own wishes and choices.

According to [Simpson 2008], there is a large and growing potential group that could benefit from a smart wheelchair. Our work is initially directed towards the smaller group of individuals that have severe combined disabilities based on the personal experience of the group's needs and its potential for development. If a safe, robust system can be developed for this group it could then be adapted for a larger user group.

2 Related Work

A *powered wheelchair* is one that is equipped with an electric motor. The wheelchair is usually controlled with a joystick, but other input devices can be used if the user lacks either coordination or the use of their hands or fingers. A number of devices are discussed in [Tuisku et al. 2008], including button control, head control, breath control and speech control. While a powered wheelchair eliminates many of the manual strength problems inherent in an unpowered wheelchair, the steering mechanism still requires an upright posture and some upper-body mobility and strength [Simpson 2005].

Individuals with severe multiple disabilities, the target group, are not able to move independently with a traditional powered wheelchair. This work has proposed a gaze-driven approach to control the wheelchair. Eye tracking, or gaze-driven control, has been applied in many research studies. For example, [Peters and Itti 2006] evaluated new methods for predicting the gaze direction of individuals playing computer games. Several researchers, such as [Li et al. 2006] and [Topal et al. 2008], have focused on the technology behind the eye tracking devices but only a few have focused on eye tracking for wheelchair manoeuvring. [Barea et al. 2003] has shown that electro-oculography can be used to determine where a user is looking by attaching a number of electrodes to the face in order to measure the eye lobe orientation. It has also been shown that outdoor tracking poses a special problem as direct sunlight makes tracking more difficult [Canzler & Kraiss]. [Tall et al. 2009] describes three design approaches for gaze control were the user controls the wheelchair by: 1) gazing directly at the physical target point, 2) gazing at on-screen buttons which activates the controls of the chair, and 3) by gazing at target points on an image of the front view.

A *smart wheelchair* is a powered wheelchair that has additional functionality [Simpson 2004]. Examples of such functions include obstacle detection, line following, wall following, docking and door passage. Although a few commercially available systems have a line following function for powered wheelchairs, most have both technical and practical limitations. They are often designed for a specific manufacturer, which limits the variety of wheelchairs and adaptations that are possible. Furthermore, current research on smart wheelchairs typically takes place in a university-affiliated robotics lab with a focus on intelligent robotics (see for example [Demeester et al. 2003], [Uchiyama et al. 2005], or [Uchiyama et al. 2008]). As a result, it is important to note that the foundation of this project is the work to habilitate the intended target group that is carried out by one of the authors on a daily basis.

3 Technical Description

A first phase prototype for a gaze-driven smart wheelchair has been developed. The following requirements were identified in order to meet the needs of the target group:

- The system can be used with a standard powered wheelchair or other moving platform
- The user can steer the powered chair solely by looking at the monitor
- The system stops the powered wheelchair when it approaches an obstacle
- The system is easy for an attendant to understand and control
- The system can be controlled directly by an attendant.

3.1 Components

The system contains the following components: a graphical user interface (GUI) which runs on an eye-tracking enabled computer, a mobile platform, a web camera and sonar.

The computer system chosen for users to control the electric wheelchair in the user tests presented here is the MyTobii P10. The MyTobii P10 is an eye-controlled communication device with a screen, an eye-control device and a computer integrated in one unit that can be easily mounted on a powered wheelchair. The An earlier pilot test was conducted, with the assistance of two university students, which showed that this eye tracking system works well with individuals with severe multiple disabilities. In order to be able to steer and control the powered wheelchair with eye movements, an image of the room is shown on the computer screen. This image is provided by a small web camera. In essence, therefore, the GUI comprises a live image of the surroundings in front of the chair, upon which steering arrows are superimposed. When the user focuses on one of the arrows, a signal that corresponds to a joystick command is sent to the powered wheelchair. The superimposed image with directional arrows provides an intuitive and easily understandable means of steering the wheelchair or platform. It should also be noted that the amount of details in the GUI (and thus options to control the chair) can be adapted to the needs and capabilities of the user. The GUI is shown in Figure 1. In comparison to the three design approaches proposed by [Tall et al. 2009] we have added a fourth approach by combining approach two and three i.e. on-screen buttons superimposed on a front view image.

The software associated with the steering user interface also collects and interprets range data from the sonar and moderates the signal sent to the wheelchair. In order to create a safe product with redundant capacity, these functions should probably be separated in the future.

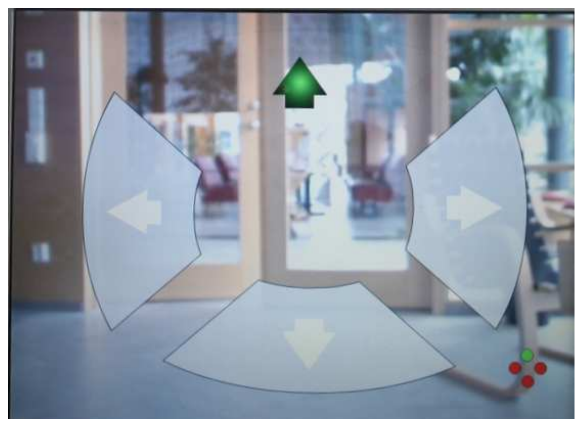

Figure 1. *The GUI in its forward state*

According to the first requirement specification, the system should be integrated with a normal powered wheelchair or moving platform. Because joystick contacts are common on standard powered wheelchairs and platforms, they were utilised as the contact between the computer system and the moving platform. For both practical and safety reasons, it must also be possible for the wheelchair to be easily controlled by an attendant, which is why an additional manual joystick is integrated into the system. A switch is used to alternate between eye-movement control and joystick control.

The prototype was tested with a Permobil C500, which is a robust and modern powered wheelchair, and an AKKA-platta, which is a simpler platform for indoor use upon which the user's manual wheelchair is placed. The MyTobii P10 was connected to the joy-stick ports of the Permobil and AKKA-platta via a relay box and in essence our software mimicked the functionality of very basic joy-sticks.

4 Evaluation

The first phase prototype was tested with two individuals, both of whom have severe multiple impairments and are totally dependent on others for assistance with all position changes and mobility. One of the individuals has a traumatic brain injury that she acquired in adulthood, while the other has had cerebral palsy since birth. The individuals' control of voluntary movement is extremely limited, energy demanding and non-functional with the exception of differing degrees of control of head movements. Both participants have limited communication skills but were able to understand instructions and willingly agreed to participate (formal acceptance was given by their legal guardians).

The objective of the two user tests was to evaluate gaze-controlled steering and obstacle detection. During both tests the tested system comprised of the prototype (software, sonar and camera), and the MyTobii P10 system. In user test 1, the Permobil C500 was used and during user test 2 the AKKA-platta (moving platform) and the participant's personal manual wheelchair was used.

4.1 User test 1

J, a woman with a severe acquired brain injury, clearly understood and mastered the calibration necessary for eye tracking and control of the wheelchair. J has not been able to change position or move independently since her injury three years ago. Nevertheless, she is dependent on frequent position changes to avoid pain and increased spasticity.

Figure 2. *J driving the Permobil C500*

J clearly chose not to follow instructions during the test but instead drove the chair where she wished. This possibility was both very amusing and rewarding for her. The test also illustrated the need for improvements in several functions of the prototype. One example was that J's limited head control made it necessary to adapt the size of the user interface (superimposed control arrows). Another example is the independent control of her seating position.

4.2 User test 2

M, a woman with cerebral palsy and learning disabilities, was motivated and able to control and drive short distances in all directions. The strong influence of involuntary movements and reflex activity meant that more adaptations were needed for the calibration for eye tracking. This case also showed the need for further adaptations of the user interface. M's gaze often wandered, which activated the P10's inherent menu options and this proved distracting and tiring. M had previously tested two systems for independent mobility, neither of which were motivating for her. A simple line following system proved too limited in terms of freedom of movement and became boring. Despite the different adaptations, joystick control required too much energy and concentration to be functional.

Figure 3. *M sitting in her personal manual wheelchair, positioned on the mobile platform 'AKKA-plattan'*

5 Results

The first test was promising with both participants clearly communicating that they had understood and mastered control of a powered wheelchair or platform with their eye movements. The system's functionality has therefore been validated with the target group. The user tests offered valuable feedback from the users for improvements to the system. In addition to the fact that the system must be more robust, the following needs for improvement have been identified:

- The wheelchair should react immediately when one of the user interface arrows is activated

- It must be possible to adjust the wheelchair's acceleration and speed more exactly
- More variations of the graphical user interface must be developed for more flexible adaptations to varying individual needs
- It must be possible to hide and lock the computer system menus during end user activities
- The system should include the functionality to control all powered wheelchair functions (backrest, foot rest, chair-lift, etc.) through eye movements.

6 Conclusions and Future Work

This paper has shown that gaze-driven powered wheelchairs enable the target group of individuals to move independently. A first phase prototype has been constructed and clinically tested and evaluated by two individuals. Both tests were performed indoors, neglecting issues such as sunlight and bumpy terrain.

The results of the user tests show that a user interface combining on-screen buttons with a front view image was clearly understood by our test users. The superimposed controls presumes to provide a clearer, stronger functional signal to the intended user group with cognitive and perceptual impairments It should be noted that we have not tested if this approach is easier to understand then utilising the whole screen for direct gaze mapping. However, given the proximity of the screen to the users and their limited possibility of voluntary head movement it might be difficult for the users to avert the gaze from the screen in order to stop the chair from moving.

Future work will further develop the prototype. The system must execute all of its tasks more robustly and safely but further developments of additional functions are also planned. A robust prototype with additional functionality in the form of wall following and obstacle avoidance will be used in more comprehensive clinical tests in order to validate the system.

Long-term goals include the integration of intelligent navigation. For example, a user can choose a specific place to which he or she wishes to move to by focusing on a picture of the actual room and the system will automatically navigate the wheelchair to the destination. In this case the system must be able to recognise the wheelchair's position in a given environment. This functionality will make it possible to adapt the system to the user's needs according to their cognitive skills in order to achieve optimal independence and mobility.

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