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Infrared Non-Contact Head Sensor, for Control of Wheelchair Movements

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Abstract. This paper presents a new human-machine interface for controlling a wheelchair by head movements. The position of the head is determined by use of infrared sensors, with no parts attached to the head of the user. The placement of the infrared sensors are behind the head of the user, so that the field of view is not limited. Tests on a wheelchair have shown that the system is functioning in real life, and that the vehicle can be driven at normal speeds in a simple and natural way. The behaviour of the sensor and the generated commands are fully programable, so it can be adapted easily to other constrains or capabilities of potential users.

Keywords. Head joystick, head sensor, infrared, HMI

1. Introduction

Several electrical powered wheelchairs to assist mobility of disabled persons are available with modular architecture e.g. [1] and The SIAMO project (Integral System for Assisted Mobility) [2]. The intention of this modular architecture is that it should be easy to configure the wheelchair to suite the needs of a high variety users with different disabilities. This modular architecture also makes it easy to adapt new functionality to the wheelchair, because e.g. the human-machine interface (HMI) can be changed, and new HMI can be made, without other changes to the wheelchair system [3].

For severe disabled persons one way of controling a wheelchair is by use of head movements. There exists such devices today called head controlled joystick or head-movement interface, both mechanical, camera based [4], accelerometer based [5] and based on infrared light [6], where [5] and [6] use active components attached to the head of the user. The HMI proposed here is based on infrared light, and differs from [6] by the fact that no components are in physical contact with the head of the user.

The SIAMO wheelchair has an architecture where the HMI is independent from the rest of the system, such that the HMI can be changed without notice to the rest of the wheelchair system. This feature has been exploited to test the HMI proposed here on a real wheelchair.

2. Head Position Detection

The head movements to be detected and used for control of the wheelchair is forward–backward movement for control of driving speed and left–right tilt to control the direction

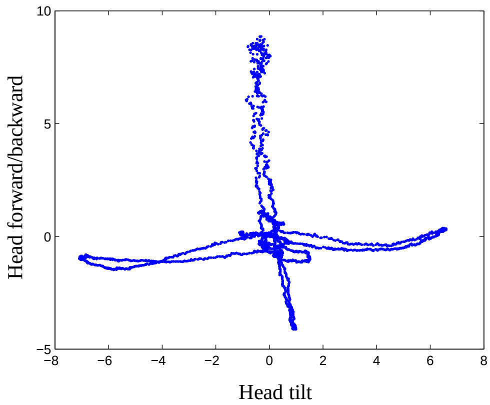

Figure 1. Head positions retrieved. Units is cm.

of driving. Head turns are not used for control of the wheelchair, leaving the user the ability to look around while driving. Codification of head movements are used to give the user the option to stop wheelchair motion immediately, as a safety precaution.

The position determination of the head is made using light sensors placed behind the head of the user. This way the users field of view is not limited by the position sensing equipment. Further more the sensors are positioned in a way, that do not extend the physical dimensions of the wheelchair. Figure 1 shows the results of a head position retrieval sequence where the head movement done is: Center – right – left – center – forward – backward – center. The head movement is clearly visible on the figure.

The measurements used here (3000 samples) are obtained with acquisition rate $200Hz$, A low pass filter averaging over 10 positions has been applied to reduce the noise on the retrieved positions.

3. Controlling an Electrical Wheelchair Using Head Movements

The head position detection has been implemented for control of an electrical wheelchair. In order to control the wheelchair the head positions have to be converted into movement orders for the wheel motors. For this purpose the area of possible head positions has been

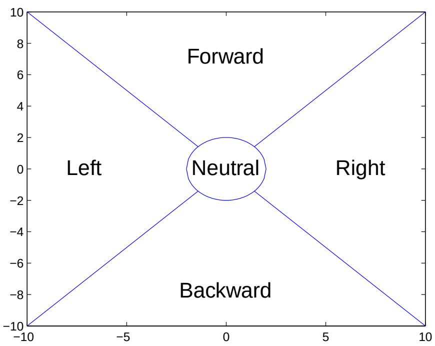

Figure 2. Area of possible head positions divided into five sectors.

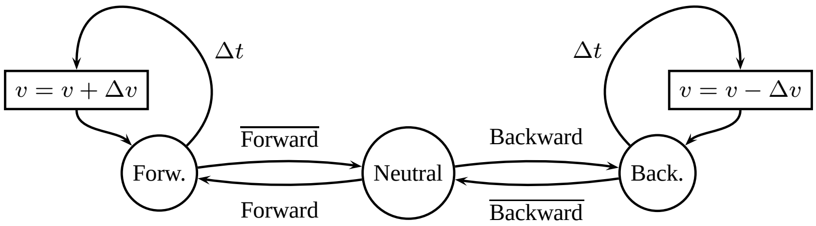

Figure 3. State machine for converting head positions to linear speed.

divided into five sectors as shown in Figure 2, and the actual head position detected is classified into one of these sectors.

The control scheme for the wheelchair is basically that the way the head is moved that way should the wheelchair move, i.e. bending the head forward increases the speed, and tilting the head to the left make the wheelchair turn left. A state machine is used to change the linear speed (forward/backward speed) of the wheelchair, based on the sector in which the head currently is. Figure 3 shows the state machine for the normal increase/decrease of the velocity and turning. The variables in the state machine are linear speed v, linear speed increment/decrement Δv, and time step Δt.

The angular speed (turning speed) is not controlled by the state machine. The angular speed is controlled directiy by the user by degree of head tilt. Little tilt of the head results in low truning speed, and more tilt of the head raises the turning speed. A dead zone for angular speed in the center position makes i easy to drive straight ahead.

To stop forward/backward motion instantaneously codification is used, so that a movement by the head in the opposite direction and quickly back to neutral will stop the wheelchair. If the head is not moved back to neutral position quickly then normal increase/decrease of the velocity according to head movement will be done. Figure 4 shows the state machine part that takes care of the codificated stopping commands. F and B in the figure references to Forward and Backward respectively.

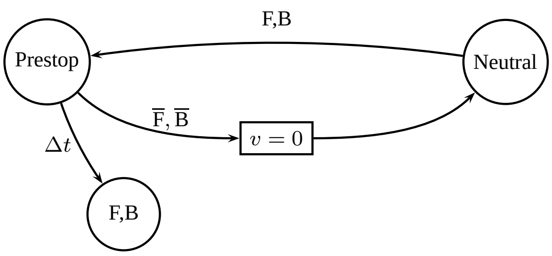

Figure 4. State machine part for codificated stop commands.

The time for a quick move is set to $\Delta t = 0.3$ sec. and normal increase/decrease of linear speed will be in steps of $\Delta v = 0.05$ m/s with the first increment/decrement after $\Delta t = 0.3$ sec. to lower the respond time. These values are subject to change to fit the needs and abilities for the individual user. The angular speed i found by multiplying a scalar to the actual head tilt. By changing this scalar it is possible to control the degree of head tilt that will result in maximum turning speed.

To test the command system and state machine generating driving commands, a simple "wheelchair simulator" was made. The simulator moves a spot on the computer screen, according to linear velocity v and angular velocity ω. With the simulator the control of the wheelchair with head commands seems natural, and fairly easy, and it can be used as a first training of the wheelchair user when introduced to the system.

4. Implementation on the SIAMO Wheelchair

The SIAMO project is an integral system for assisted mobility in the field of electronic systems for the guidance of wheelchairs for the disabled and/or the elderly [1]. Their electronic systems have been designed to meet a wide range of needs experienced by the users of this type of wheelchairs.

One of the most important feature is their modularity, making them easily adapted to the particular needs of each user according to the type and degree of handicap involved. The overall system includes a complete user-machine interface, motor control modules, and safety and autonomous guidance systems. Also the computing architecture is open enough, so new interfaces and sensorial modules can be added to the system in order to improve adaptability [7].

Figure 5. The sensors attached to the head rest piece of the SIAMO wheelchair.

Figure 5 shows the head rest piece of the SIAMO wheelchair with the prototype of the new HMI attached to it. The computer that controls the sensors and does the necessary processing of the measurements are placed behind the seat on the prototype, but the size of the computer opens for the possibility to place it under the seat.

The SIAMO wheelchair uses a network of micro-controllers linked by a serial communications channel, where commands and status are exchanged via messages. Then, the speed commands from the computer to the wheelchair are passed to the SIAMO control system, through the computers parallel port.

5. Conclusion

A new infrared non-contact head sensor has been proposed for HMI to wheelchair control. The HMI has been tested in the laboratory. A wheelchair simulator has also been implemented, and tests using this simulator have shown that the HMI has robust performance, both to variations in the sensors and to the changing hair color of different users.

The proposed HMI have been implemented on the SIAMO wheelchair as a new input device module. The SIAMO modular architecture makes it easy to do this kind of upgrade. Test drives with the wheelchair have shown that proposed HMI is usefull for controlling the wheelchair, and that the control of the wheelchair feels natural and comfortable.

Also, the commands and behaviour of the sensor can be easily reprogramed, adapting it to other ways of driving or specific constrains of some kind of potential users.

6. Acknowledgments

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