ELECTROOCULOGRAPHIC GUIDANCE OF A WHEELCHAIR USING EYE MOVEMENTS CODIFICATION

Rafael Barea, Luciano Boquete, Manuel Mazo, Elena López, L.M. Bergasa.
Electronics Department. University of Alcala.
Campus Universitario s/n. 28871Alcalá de Henares. Madrid. Spain.
T: +34 91 885 65 74 Fax: +34 91 885 65 91
e-mail: barea@depeca.alcala.es http://www.depeca.alcala.es/personal/barea

Abstract: This paper presents a new method to control and guide mobile robots. In this case, to send different commands we have used electrooculography (EOG) techniques, so that, control is made by means of the ocular position (eye displacement into its orbit). A inverse eye model is developed based in electrooculography and therefore the saccadic eye movements can be detected and know where user is looking. This control technique can be useful in multiple applications, but in this work it is used to guide a autonomous robot (wheelchair) as a system to help to people with severe disabilities. The system consists of a standard electric wheelchair with an on-board computer, sensors and graphical user interface running on a computer.

Keywords: Electrooculographic potential (EOG), eye model, control system, handicapped people, wheelchair.

1 INTRODUCTION

Assistive robotics can improve the quality of life for disable people. Nowadays, there are many help systems to control and guide autonomous mobile robots. All this systems allow their users to travel more efficiently and with greater ease [SIAMO, 99]. In the last years, the applications for developing help systems to people with several disabilities are increased, and therefore the traditional systems are not valid. In this new systems, we can see: videooculography systems (VOG) or infrared oculography (IROG) based on detect the eye position using a camera [Lahoud&Cleveland]; there are several techniques based in voice recognition for detecting basic commands to control some instruments or robots; the joystick (sometimes tactil screen) is the most popular technique used to control different applications by people with limited upper body mobility but it requires fine control that the person may be have difficulty to accomplish. All this techniques can be applied to different people according to their disability degree, using always the technique or techniques more efficiently for each person.

This paper reports work in the development of a robotic wheelchair system based in electrooculography [Gips et al, 96]. Our system allows the users to tell the robot where to move in gross terms and will then carry out that navigational task using common sensical constraints, such as avoiding collision.

This wheelchair system is intented to be a general purpose navigational assistant in environments with accesible features such as ramps and doorways of sufficient width to allow a wheelchair to pass. This work is based on previous research in robot path planing and mobile robotics [Barea et al, 99]; however, a robotic wheelchair must interact with its user, making the robotic system semiautonomous rather than completely autonomous.

This paper has been divided into the following sections: section 2 describes the electrooculography technique used to register the eye movement and the eye gaze, in section 3 an eye model based on electrooculography is propused. In section 4, the visual control system and some guidance results are commented and section 5 puts forward the main conclusions and lays down the main lines of work to be followed in the future.

2 ELECTROOCULOGRAPHIC POTENTIAL (EOG)

A survey of eye movements recording methods can be seen in [Glenstup&Engell, 95] where are described the main advantages and drawbacks of each one. In this work, the goal is to sense the electrooculographic potential (EOG) because it presents a good face access, good accuracy and resolution, great range of eye displacements, works in real time and is cheap. Our discrete electrooculographic control system (DECS) is based in record the polarization potential or corneal-retinal potential (CRP) [Nicoulau et al., 95]. This potential is commonly known as an electrooculogram. The

EOG ranges from 0.05 to 3.5 mV in humans and is linearly proportional to eye displacement. The human eye is an electrical dipole with a negative pole at the fundus and a positive pole at the cornea.

This system may be used for increasing communication and/or control. The analog signal form the oculographic measurements has been turned into signal suitable for control purposes. The derivation of the EOG is achieved placing two electrodes on the outerside of the eyes to detect horizontal movement and another pair above and below the eye to detect vertical movement. A reference electrode is placed on the forehead. Figure 1 shows the electrode placement.

Figure 1. Electrodes placement.

The EOG signal changes approximately 20 microvolts for each degree of eye movement. In our system, the signal are sampled 10 times per second.

The record of EOG signal have several problems [Jacob, 96]. Firstly, this signal seldom is deterministic, even for same person in different experiments.The EOG signal is a result of a number of factors, including eyeball rotation and movement, eyelid movement, different sources of artifact such as EEG, electrodes placement, head movements, influence of the luminance, etc.

For this reasons, it is neccesary to eliminate the shifting resting potential (mean value) because this value changes. To avoid this problem is necesary an ac diferential amplifier where a high pass filter with cutoff at 0.05 Hz and relatively long time constant is used. The amplifier used have programable gain ranging from 500,1000,2000 and 5000.

3 EYE MODEL BASED IN EOG (BIDIM-EOG)

Our aim is to design a system capable of obtaining the gaze direction detecting the eye movements. For this, a model of the ocular motor system based on electrooculography is proposed (figure 2) (Bidimensional dipolar model EOG, BiDiM-EOG). This model allows us to separe saccadic and smooth eye movements and calculate the eye position into its orbit with good accuracy (less than 2º). The filter eliminates the effects due to other biopotentials, just as the blinks over to the EOG signal. The security block detects when the eyes are closed and in this case, the ouput is disabled. After that, the EOG signal is clasified into saccadic or smooth eye movements by means of two detectors. If a saccadic movement is detected, a position control is used, whereas if a smooth movement is detected, a speed control is used to calculate the eye position. The final position (angle) is calculated as the sum of the saccadic and smooth movements. Besides, the model has to adapt itself to the possible variations of adquisition conditions (electrodes placement, electrode-skin contact, etc). To do this, the model parameters are adjusted in accordance with the angle detected.

A person, in a voluntary way, only can made saccadic movements unless he tries to follow an object in movement. Therefore, to control some interface it is convenient to focus the study in the detection of saccadic movements (rapid movements). This process can be done processing the derivate of the EOG signal. To avoid problems with the variability of the signal (the isoelectric line varies with time, even though the user keeps the gaze at the same position), a high pass filter with a very small cutoff frecuency (0.05 Hz) is used. The process followed can be observed in figure 3 where the results of a process in which the user made a secuence of saccadic movements of ±10º..±40º in horizontal derivation are shown. It is possible to see that the derivate of the electrooculographic signal allows us to determinate when a sudden movement is made in the eye gaze. This variation can be easily translated to angles (figure 3.d).

In the following sections, the results reached in the Electronics Department of University of Alcala at the moment are shown. It is possible to use this technique to help disabled people, because we have got an accuracy less than ±2º. Although in this paper we are going to comment the results obtained in the guidance of a wheelchair (help to the mobility), other applications have been developed to increase the facilities in people comunication (help to the comunication) [Barea et al, 00a].

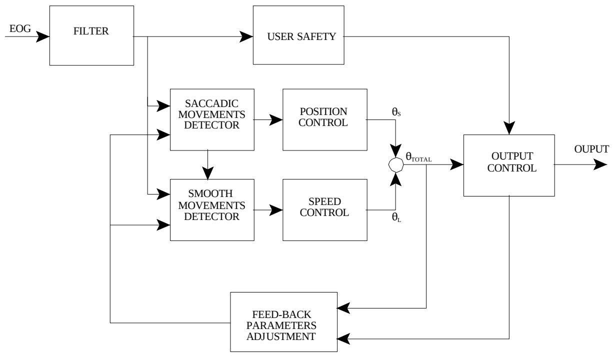

Figure 2. Bidemensional bipolar model (BiDiM-EOG).

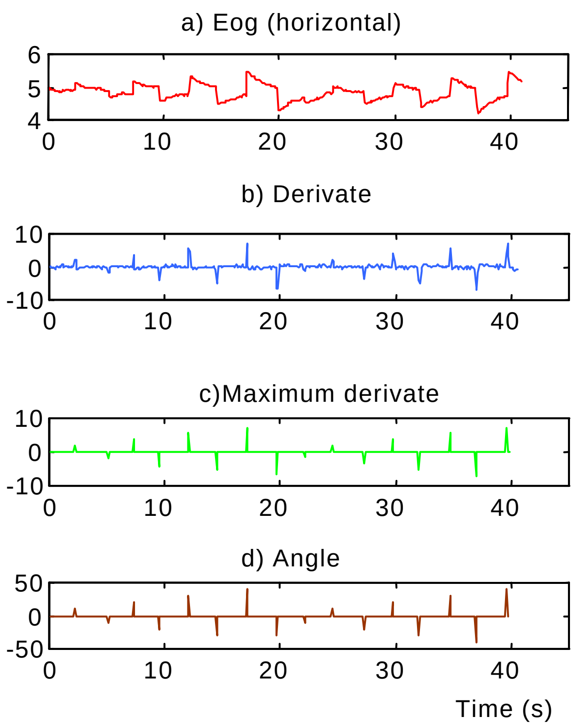

Figure 3. Process results to detect the eye gaze angle.

4 GUIDANCE OF A WHEELCHAIR USING COMMANDS GENERATED BY EYE MOVEMENTS DETECTED USING ELECTROOCULOGRAPHY.

The aim of this control system is to guide an autonomous mobile robot using the positioning of the eye into its orbit by means of EOG signal. In this case, the autonomous vehicle is a wheelchair for disable people. Figure 4 shows the wheelchair used.

Figure 5 shows a diagram of the control system. The EOG signal is recorded using Ag-AgCl electrodes and this data, by means of an adquisition system are sent to a PC, in which they are processed to calculate the eye gaze direction. Then, in accordance with the guidance control strategy, the control commands of the wheelchair are sent. The command sent to the wheelchair are the separate linear speed for each wheel. It is possible to see that exists a visual feedback in the system by means of a tactile screen that the user has in front of him. Figure 6 shows the user interface where the commands that the user can generate are: Forward, Backwards, Left, Right and Stop.

Figure 4. Wheelchair.

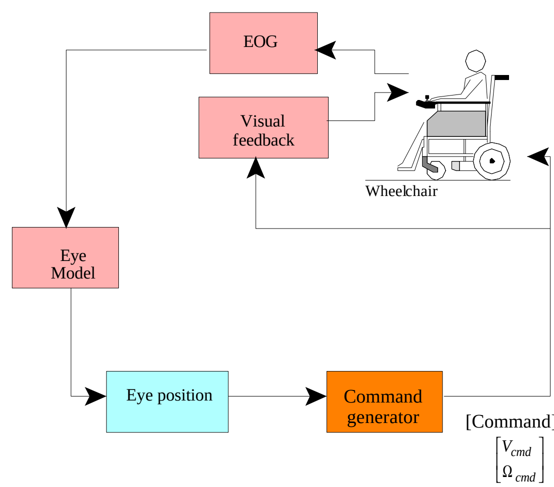

Figure 5. Guidance system.

Figure 6. User interface

To control the robot movements there are multiple options: direct access guidance, semiautomatic and automatic sweep (scan) or interpretation of different commands generated by means of eye movements.

In former works, we studied the direct access guidance [Barea et al, 99] and automatic and semiautomatic "scan" [Barea et al, 00b]. In direct access guidance, the user can see the different guidance commands in a screen (laptop) and select them directly. In this way, when the user looks at somewhere, the cursor is positioned where he is looking, then, the users can select the action to control the wheelchair movements. The actions are validated by time, this is, when a command is selected, it is necessary to stay looking at it for a period of time to validate the action. In "scan" guidance, it is necessary to do an eye movement (a "tick") to select among the different commands presented in the screen. The actions are validated by time, this is, when a command is selected, if other "tick" is not generated during a time interval, the command is validated and the guidance action is executed.

For this reason, we are going to focus our work in the interpretation of different ocular commands because it allows us to generate simple code for controlling the wheelchair. Figure 7 shows the user interface of the wheelchair.

Figure 7. User-wheelchair interface.

The guidance based on ocular commands has different options, such as continuous guidance, on-off activation commands and tracking of the direction of the eye gaze. In this paper, we are going to study the continuous control technique.

This control attempts to emulate the intuitive control that a non-handicapped person makes when he drives a mobile. This system controls the linear speed as the car accelerator and the angular speed as the steering wheel of a car. For this, we have implemented the following movement commands:

UP: Linear speed increase (V++).
DOWN: Linear speed decrease (V–).
RIGHT: Angular speed increase (W++).
LEFT: Angular speed decrease (W--).

Commands generation is coded using a state machine that establishes the state (command) where the system is working (figure 8).

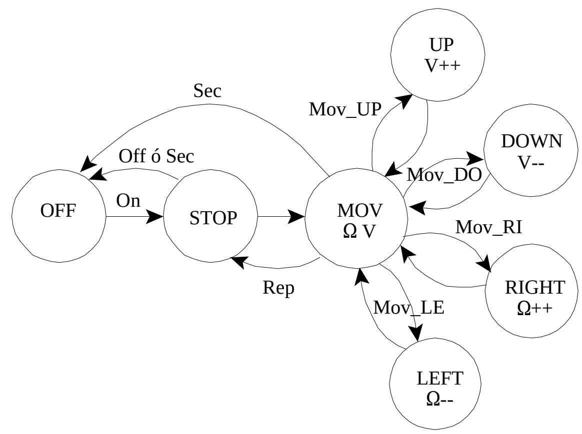

Figure 8. State machine

Now, some examples of guidance are shown. Figure 9 shows the trajectory obtained using total ocular control. Figure 10 shows EOG horizontal and vertical derivations and figure 11 and 12 show the generation of commands in function of EOG signal detected.

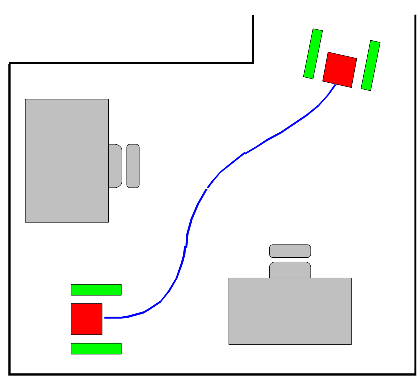

Figure 9. Trajectory generated.

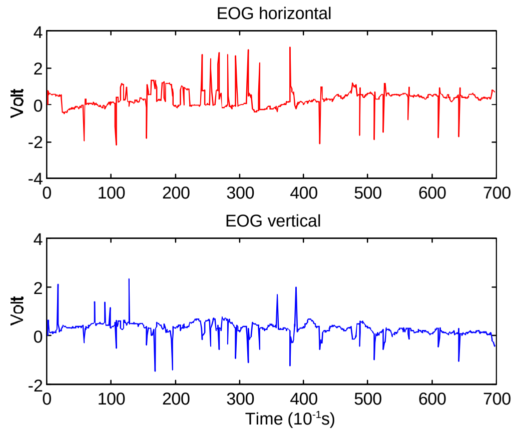

Figure 10. EOG signal

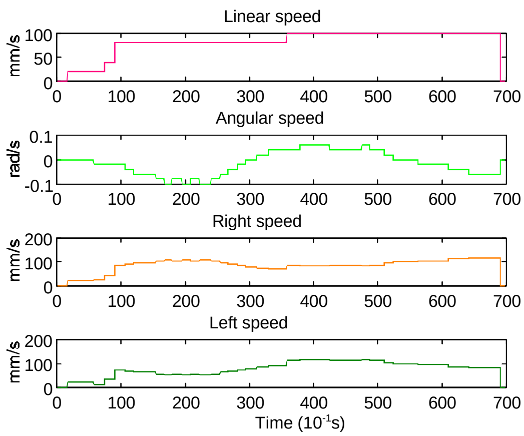

Figure 11. Guidance speed

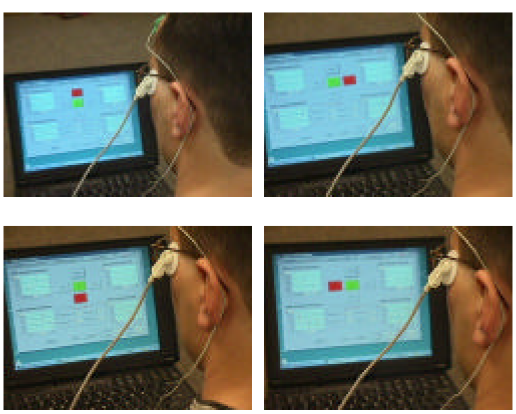

Figure 12. Visual Interface

Another example of guidance is shown in figure 13 where the trajectory followed by the wheelchair and different images of the guidance are shown.

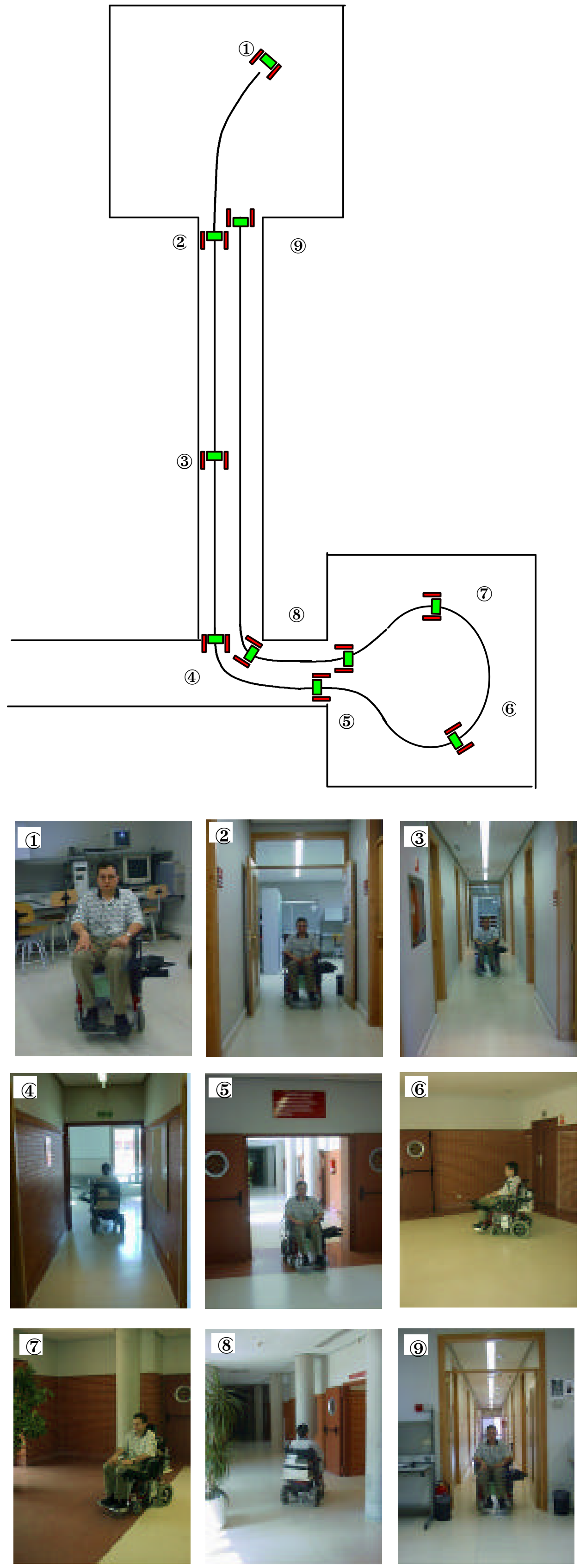

Figure 13 . Trajectory and example of guidance

Nowadays, we are not trying this control with persons with disabilities but we consider that it is not difficult to learn the control commands. Learning to use this system must be done in an acquired skill. Some studies have shown that disable persons usually requires about 15 minutes to learn to use this kind of systems [Gips et al., 96].

Besides, we need several alarm and stop commands for dangerous situations. This codes can be generated by means of the blink and alpha waves in EEG to detect when the eyelids are closed. On the other hand, the robotic wheelchair system must be able to navigate indoor and outdoor environments and should switch automatically between navigations modes for these environment. Therefore, all this system can be apply different navigations modes in function of their disability degree, using always the techniques more efficiently for each people. It is necessary to use different support system to avoid collisions and the robotic system can switch automatically for controlling the system in an autonomous form. For example, if the user lost the control and the system is unstable, the wheelchair should switch and obtain the control system.

This work is included in a general purpose navigational assistant in environments with accesible features to allow a wheelchair to pass. This project is known as SIAMO project [SIAMO, 99]. A complete sensory system has been designed made up of ultrasonic, infrared sensors and cameras in order to allow the detection of obstacles, dangerous situations and generated a map of the environment. Then, the control and navigation module has to guarantee a comfortable path tracking and can switch for controlling automatically the wheelchair and made the trajectory o command defined by the user.

5 Conclusions

This research project is aimed towards developed a usable, low-cost assistive robotic wheelchair system for disabled people. In this work, we present a system that can be used as a means of control allowing the handicapped, especially those with only eye-motor coordination, to live more independent lives. Eye movements require minimum effort and allow direct selection techniques, and this increase the response time and the rate of information flow. Some of the previous wheelchair robotics research are restricted a particular location and in many areas of robotics, environmental assumptions can be made that simplify the navigation problem. However, a person using a wheelchair and EOG technique should not be limited by the device intended to assist them if the environment have accessible features. The total command control based on EOG permits to wheelchair users to guide it with a enough degree of comfortability.

6 Acknowledgments

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