E.O.G. guidance of a wheelchair using neural networks

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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 neural network is used to identify the inverse eye model, 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.

Keyword: Electrooculographic potential (EOG), neural networks, 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 [1]. 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 [2]; 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 diferent 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 initial work in the development of a robotic wheelchair system based in electrooculography [3]. 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 [4]; 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 you can see the method used to detect saccadic eye movement using neural network (RBF). In section 4, the visual control system is described. Section 5 shows some results and section 6 puts forward the main conclusions and lays down the main lines of work to be followed in the future.

2. Electrooculographic potential (EOG)

There are several methods to sense eye movement. In this work, the goal is to sense the electrooculographic potential (EOG). Our discrete electrooculographic control system (DECS) is based in record the polarization potential or corneal-retinal potential (CRP) [5]. 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.

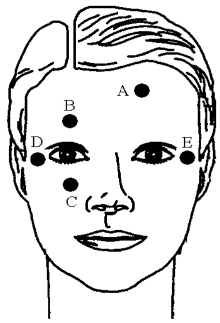

Fig 1.- Electrodes placement.

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 [6]. 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. Detection of saccadic eye movement using neural network.

Saccadic eye movements are characterized by a rapid shift of gaze from one point of fixation to another. Generally, saccades are extremely variable, with wide variations in the latent period, time to peak velocity, peak velocity, and saccade duration. To detect this movements exist different techniques mainly based in detection of the derivation of the EOG signal.

In this paper, a technique to detect saccadic movements is presented, based in neural networks. Neural networks have been designed to perform complex functions in various fields of application including identification system and classification systems. Our aim is getting an inverse eye model (Figure 2) to detect where one person is looking as a function of detected EOG.

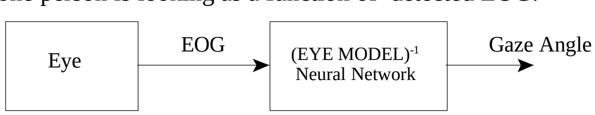

Figure 2. Eye model.

A Radial Basis Function Neural Network which only has one hidden layer is used and its ability as universal approximators of functions has been demonstrated [7].

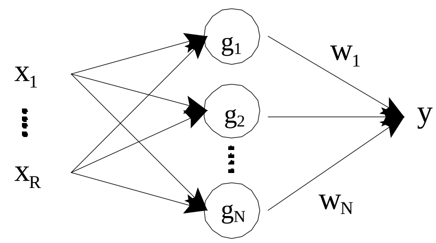

Figure 3. Model of radial basis function.

A non-lineal function g(**X**,**C**), where **X** is an R dimensional independent variable and **C** is a constant parameter of the same dimension, is said to be a radial basis function (RBF) when it depends solely on the distance between **X** and **C**: ‖**X** - **C** ‖. A function often used is an exponential one:

$$g_j(X,C_j) = e^{-\frac{(x_1-c_j)^2+(x_2-c_j)^2+..+(x_R-c_j)^2}{s^2}} \qquad (1)$$

If we consider a network of R inputs and one output (y) and defining the error to be minimized as:

$$E(k) = \frac{1}{2}\cdot[y(k) - y_d(k)]^2 = \frac{1}{2}\cdot[e(k)]^2 \qquad (2)$$

The neural network output being:

$$y(k) = \sum_{j=1}^{N} w_j \cdot g_j(k) \qquad (3)$$

and $y_d(k)$ the desired output at the moment k.

The equation for the adjustment of the weights is:

$$w_j(k+1) = w_j(k) - a\cdot e(k)\cdot g_j(k) \qquad (4)$$

Figure 4 shows the real EOG and the gaze angle desired for eye displacement between -40º and 40º with 10º increments during 5-second intervals with AC amplifier. The EOG signal is sampled each 0.2 s.

The network inputs are the present EOG signal and the last nine delayed because a RBF tapped delay network is used and the network output is the angle of the gaze desired. In our case, R=10 and N=20. To training the network is used MATLAB.

In figure 5, the result of the training is shown. It can be see that it is possible to detect de gaze angle detecting the saccadic movements using RBF neural network. Therefore, this inverse eye model allows us to know where a person is looking using EOG signal.

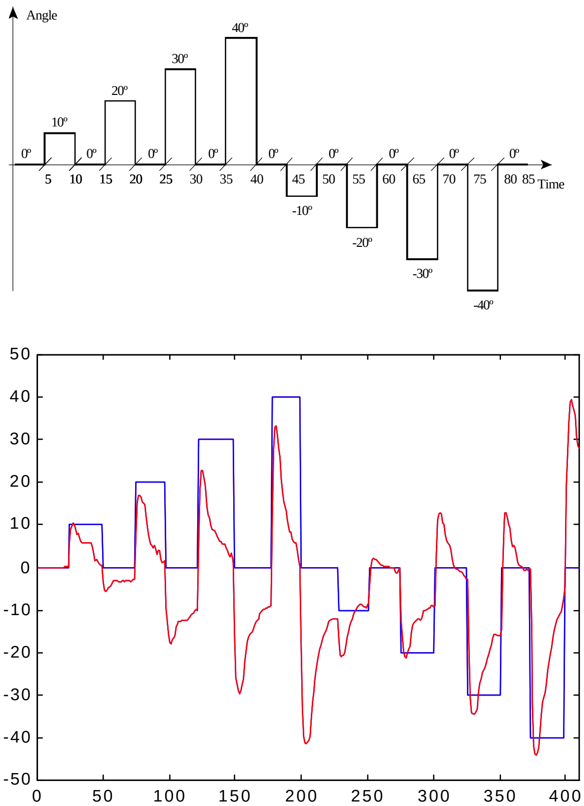

Figure 4. Eog signal and gaze angle desired.

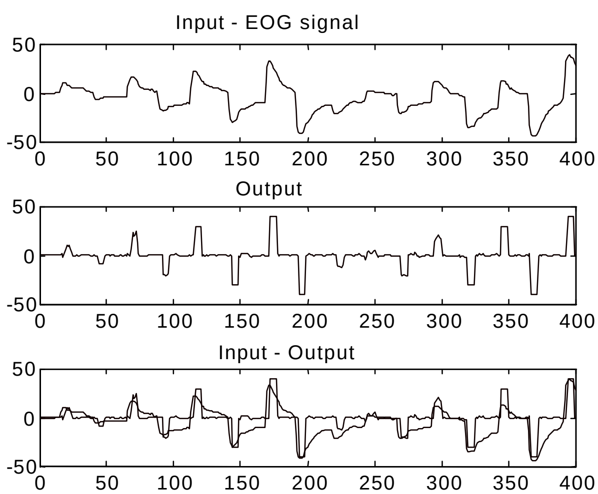

Figure 5.- Result using R.B.F.

4. Visual control system 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 6 shows the scheme of the system.

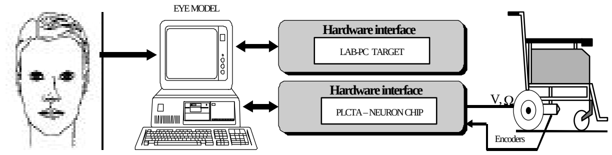

Figure 6. Wheelchair control system.

The EOG signal are processed in the computer and send the control command to the wheelchair. The command sent to the wheelchair are the separate linear speed for each wheel.

To control the robots movements multiple options can be used: interpretation of different commands generated by means of eye movements, generation of differents trajectories in functions of gaze points, etc. We are going to use the first option because it allows us to generate simple code for controlling the wheelchair using the eye position.

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.

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 [1].

Figure 7 shows the user interface of the wheelchair.

Figure 7. User-wheelchair interface.

5. Results

In this section, several results for the wheelchair guidance are shown.

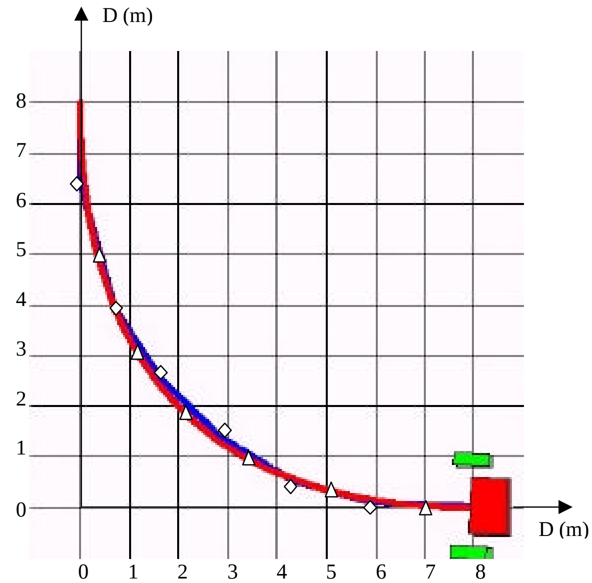

Fig 8.- Wheelchair guidance I.

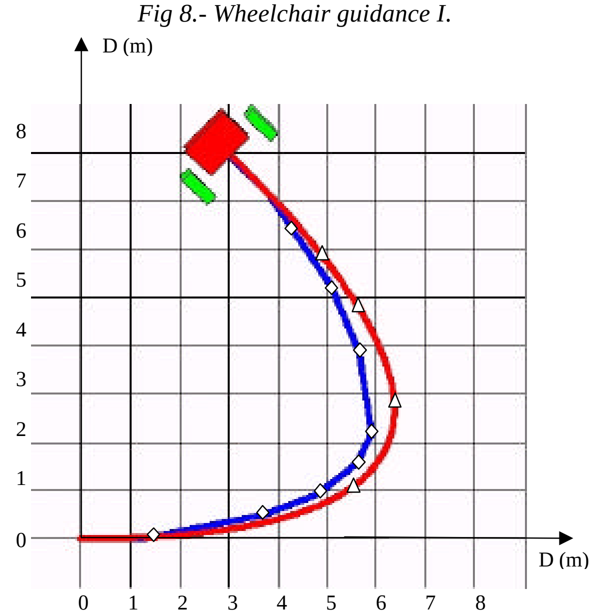

Fig 9.- Wheelchair guidance II.

In figures 8 and 9, the red line Δ represents a “3-spline curve-line” that we want to follow. This trajectory is obtained using a trajectory spline generator developed in SIAMO project. On the other hand, the blue line ◊ represents the trajectory obtained when the wheelchair is guided using EOG. Is possible to apreciate that the desired trajectory is followed with a small lateral error.

Nowadays, we are not try this control with persons with disabilities but we considerated that 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 [3].

6. Conclusions

This research project is aimed towards developed a usable, low-cost assistive robotic wheelchair system for disabled people. In this work, we presented a system that can be used as a means of control allowing the handicapped, especially those with only eye-motor coordination, to live more independient 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.

7. Acknowledgments

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