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

Rafael Barea, Luciano Boquete, Manuel Mazo, Elena López, L.M. Bergasa.
Electronics Department.
University of Alcala.
Alcalá de Henares. Madrid. SPAIN.
e-mail:barea@depeca.alcala.es http://www.depeca.alcala.es

**Abstract.** In this paper we present a new architecture of spiking neural networks (SNNs) to control the movements of a wheelchair. 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). Spatio-temporal coding that combines spatial constraints with temporal sequencing is of great interest to visual-like circuit model. Therefore, a neural network (SNN) is used to identify the eye model, therefore the saccadic eye movements can be detected and know where user is looking at. The system consists of a standard electric wheelchair with an on-board computer, sensors and graphical user interface running on a computer.

## 1. Introduction

Artificial neural networks (ANNs), whose functioning is inspired by some fundamental principles of real biological neural networks, have proven to be a powerful computing paradigm. Real biological neurons communicate through short pulses, called "spikes", which are omitted at varing rates. This firing rate which has been considered for a long time as the relevant information being exchanged between neurons. It seems very promising to extend the computational possibilities of ANNs by considering spiking neural networks, which allow to take the timing of single spikes. So far there is not much known about possible computational mechanisms on the basis of the timing of single spikes. Some results have been provided recently by Maass: he defined the spiking neurons theory [1] and characterized the computational power of SNNs [2].
On the other hand, 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 [3]. 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 [4]; 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 initial work in the development of a robotic wheelchair system based in electrooculography [5]. 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 work is based on previous research in robot path planing and mobile robotics [6]; 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 sections 3 and 4 you can see the SNN used to detect saccadic eye movement using neural network (SNN). In section 5, the visual control system is described 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) [7]. 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.

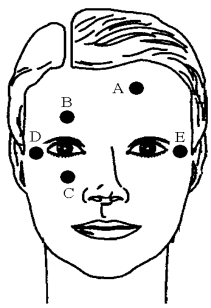


Figure 1. Electrodes placement.

## 3. Spiking Neural Network Architecture

There exist various formal models for spiking neurons. The leaky integrate-and-fire neuron captures only some elementary features of biological neurons, but it is still able to reproduce a vast variety of propierties of biological neural networks. We are going to use the following definition of an spiking neuron network [1]:

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- A finite directed graph <V,E> (V neurons and E synapsis).
- A subset $V_{in} \subseteq V$ of input neurons.
- A subset $V_{out} \subseteq V$ of output neurons.
- For each neuron $v \in V - V_{in}$ a threshold function $\Theta_V : R^+ \longrightarrow R \cup \{\infty\}$ where $R^+ = \{x \in R \quad x \geq 0\}$ .
- For each synapse <U,V> $\in$ E a response function $\varepsilon_{UV} : R^+ \longrightarrow R$ and a weight $W_{U,V} \in R^+$.

We assume that the firing of the input neurons $v \in V_{in}$ is determined from outside of N, i.e. the sets $F_V \subseteq R^+$ of firing times ("spikes train") for the neurons $v \in V_{in}$ are given as the input of N. For a neuron $v \in V - V_{in}$ one defines its set $F_V$ of firing times recursively. The first element of $F_V$ is $\inf\{t \in R^+ : \quad P_V(t) \geq \Theta_V(t-s)\}$ , and for any $s \in F_V$ the next larger element of $F_V$ is $\inf\{t \in R^+ : t > s \quad and \quad P_V(t) \geq \Theta_V(t-s)\}$ , where the potential function $P_V(t) : R^+ \rightarrow R$ is defined by:

$$P_V(t) = 0 + \sum_{U:<U,V>\in E} \; \sum_{s \in F_U : s<t} W_{UV} \cdot \varepsilon_{UV}(t-s)$$

The functioning of this neurons is: for a synapse <U,V>, the response function $\varepsilon_{UV}$ describes the shape of the postsynaptic potential (PSP) caused by an incoming spike to this synapse from neuron U. In the following we will asume that $\varepsilon_{UV}(t) = 0$ for $t \in [0, d_{U,V}]$, where $d_{U,V}$ models the delay between the generation of the action potential at the axon of neuron U and the time when the resulting PSP starts influence ten soma of neuron V. Figures 2 and 3 show the shape of the threshold function and the response functions used.

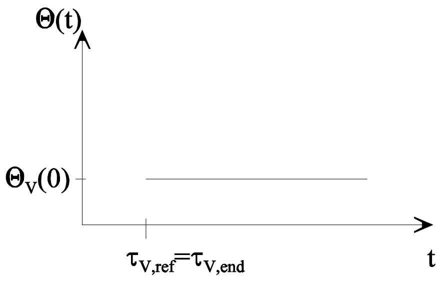


Figure 2. Constant threshold function.

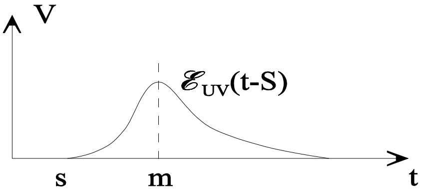


Figure 3. Response function.

At t=0 the neuron V generated an action potential. The architecture model can be observed in figure 4. The network inputs are the angle of the gaze desired and the last

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nine delayed because a spiking tapped delay network is used and the network output is the EOG signal present.

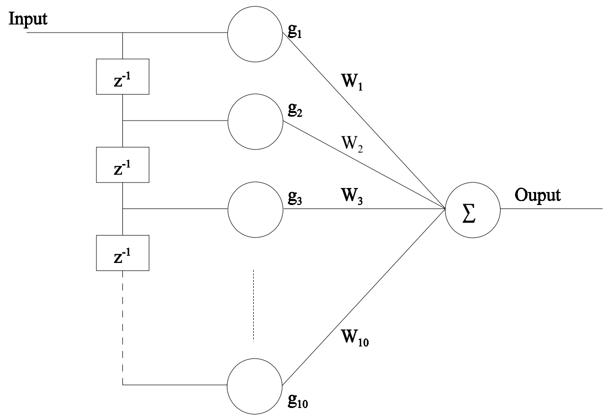


Figure 4 . Spiking network architecture.

The ouput of the network is: $$y = \sum_{i=1}^{M} g_i(t) \cdot W_i(t)$$

Where Wi represents the strength (weight) of the synapse between neurons i and j. Learning is done by ajusting Wi, minimizing the global error.

## 4. Detection of saccadic eye movement using spiking 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 perfom complex functions in various fields of application including identification system and classification systems. Our aim is getting an eye model (Figure 5) to detect where one person is looking at as a function of detected EOG.
A Spiking neural network with only one hidden layer is used (Figure 4). Figure 6 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 to avoid problems [8].The data are normalized to ±1. The EOG signal is sampled each 0.2 seg. The network inputs are the EOG signal present and the last nine delayed because a SNN tapped delay network is used and the network output is the angle of the gaze desired. In our case, we can vary the delay, mean and duration of the PSP for each neuron. In figure 6, the result of the training is shown. It can be see that the network identify the system in few cycles

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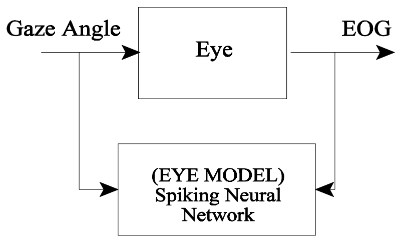
and therefore, it is possible to detect the angle of the gaze detecting the saccadic movements using SNN neural network. Therefore, this eye model allows us to know where a person is looking at, using EOG signal.



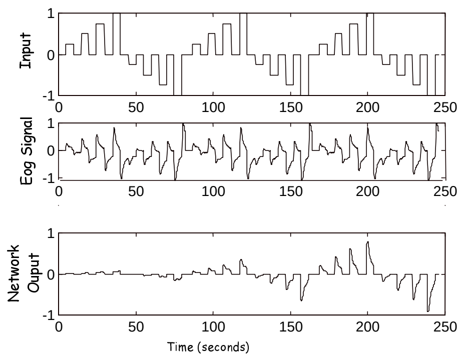




Figure 5. Eye model. Figure 6.- Result using SNN.

## 5. 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 disabled people.The EOG signal are procesed 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 robot 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. 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 [3]. Figure 7 shows the user interface of the wheelchair.

Figure 7.
User-wheelchair interface.

## 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 decrease 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 technic should not be limited by the device intended to assist them if the environment have accessible features. We have seen that SNNs are computationally very powerful and fast neural networks, whose consideration and analysis are important both from the biological as well as from the computational point of view. Therefore this type of neural network (SNN) is valid to identify the eye model where saccadic eye movements are characterized by a rapid and accurate shift of gaze.

## Acknowledgments

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