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Assistive robot application based on an RFID control architecture and a wireless EOG interface

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ABSTRACT

This paper describes an assistive robot application that combines a portable wireless interface based on electrooculography (EOG) and Radiofrequency Identification (RFID) technology. This assistive application is aimed at handicapped users who suffer from a severe motor disability. To that end, a realistic application has been designed. It consists of an environment in which users can bring a glass and a water bottle closer with only the help of their eye movement using a real robot arm. RFID will be used as a support to the EOG interface in a shared control architecture by storing information of the objects in tags placed on the scene. Five volunteers tested the assistive robot application. The results obtained show that all of them were able to finish the tests in a suitable time and the results improved with practice and training. This proves that the assistive robot application can be a feasible way to help handicapped users.

1. Introduction

Nowadays, there is an increasing interest in the improvement of the quality of life of handicapped people. There are a lot of works centered in solving accessibility issues using rehabilitation robotics [1–3] or developing alternative communication methods with the environment [4–6].

Human–machine interfaces are used to interact with external devices. Some of them are aimed at helping handicapped people. There are several ways to obtain human orders without using arms or hands, e.g., from the voice [7,8], ocular movements [9] or brain signals [10]. For example, in Brain–Computer Interfaces electroencephalographic signals are used to control external devices [11,12].

Ocular movements can be used to generate commands to control external devices. There are several methods to obtain eye movement like Videooculography (VOG), which records the image of the eye and through image analysis obtains the direction of the eye [13]; or Infrared Oculography (IROG), which measures the eye gazing by using an infrared light that reflects on the retina [14–16]. In this work, electrooculography (EOG) is going to be used. The EOG technique allows detecting the movement of the eyes by measuring the potential between the cornea and the retina. The advantage of EOG in terms of accuracy and complexity is quite important so it is one of the most commonly used methods to detect eye movement. There are several works where EOG has been used as an assistive technology for physically impaired users, for example to control wheelchairs [17,18] or to prevent car accidents [19].

In this paper a portable and wireless interface based on EOG [20] has been used to control a robot arm. The interface is a cheap and small sized device with USB compatibility. A processing algorithm for the EOG signals has been developed in order to detect eye movement and blink. The use of dry electrodes improves the comfortability for the user. Nevertheless, the use of an EOG interface is still far from being capable of performing tasks which require generating complex control commands to optimally guide an external device or application. The use of a shared control approach can solve these limitations.

Shared control has a wide range of applications. In robotics, it is usually used with multi-agent systems on cooperative tasks [21,22]. One of the most important goals of shared control is improving the control of the device by the user in tasks related to teleoperation and telemanipulation [23–25]. There are some works of shared control for disabled people, e.g., to aid blind people [26] and to improve mobility [27].

In this work, the combination of an EOG interface with RFID technology in a shared control architecture is used. Radiofrequency devices are very useful in all sorts of scientific and industrial environments. The applications of RFID are usually aimed at tracking and identification of objects. RFID has been used in robot localization using tags as landmarks [28,29]. There are also works on navigation [30] and indoor navigation for visually impaired users [31]. The classification of objects is another goal

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of RFID architectures [32]. However, the combination of RFID with electrooculography has not been used in other works.

The main goal of the assistive application presented in this paper is to perform pick and place operations with a robot arm. To this purpose, a realistic application in a domestic context has been designed. It consists of bringing a water bottle and a glass close to the user. The use of a shared control architecture increases the number of commands that can be generated by the EOG interface alone. This can be very useful for people with a severe motor disability increasing their autonomy as they can perform complex tasks that could be very difficult or slow with other systems. To test the assistive application, five healthy volunteers did several repetitions of the same sequence of movements and actions. In our previous work [20], the EOG electronics was developed and tested successfully. With the results obtained in this novel work, we have proved that the device can be useful in a realistic assistive application with daily objects combining RFID in a shared control architecture. The EOG processing algorithm was also improved from our previous work, including the detection of the blink that allows interacting with objects.

The remainder of this paper is organized as follows. Section 2 describes the EOG interface by explaining the electronics and the EOG processing algorithm. Moreover, the shared control architecture based on the combination of RFID technology with the EOG interface is explained. The experimental application designed and the results obtained are shown and discussed in Section 3. Finally, Section 4 contains the conclusions.

2. Material and methods

In this section, the electrooculography (EOG) theory is going to be explained as well as the acquisition hardware used to register the EOG signals and the processing algorithm to obtain the direction of the eye movement and the blink. In addition, a shared control architecture that combines the EOG interface with the RFID technology is described. This architecture will be used to control a robot arm.

2.1. EOG interface

EOG is based on the fact that the eye acts as an electrical dipole between the cornea (positive potential) and the retina (negative potential). The potential between both parts is usually negative, so any rotation of the eye causes a change in the direction of the vector corresponding to the dipole that can be measured (see Fig. 1).

The EOG signals are usually between 50 and 3500 μV with a frequency range of about 100 Hz between the Bruch membrane and the cornea [17]. It has a practically linear behavior for gaze angles between ±50° for horizontal movement and ±30° for vertical movement [33].

To obtain the EOG biosignals from the user, four dry electrodes are used. There is a fifth electrode used as reference. The electrodes work with horizontal and vertical movement of the eyes so their positions are commonly distributed as can be seen in Fig. 2. The four input and reference electrodes used are the model E273 from Easycap, which are flat electrodes of 12 mm diameter with a light-duty cable and 1.5 mm-touchproof safety sockets. The advantage of this type of electrodes is that they do not require conductive gel to operate, so there is only need of some cleaning abrasive gel on the skin before placing them, what makes the placing of the electrodes on the user easier and faster.

2.1.1. EOG-based device

To register the EOG signals the electronics designed in [20] has been used. These electronics are portable and do not need an electrical supply from a network, as they work with batteries (AA). Moreover, the communication is wireless, so the user has more mobility. The device sends the registered EOG signals through USB with a frequency sample of 30 Hz. The device is shown in Fig. 2. All these characteristics, together with the dry flat electrodes used, make possible a comfortable and ergonomic use of the ocular interface.

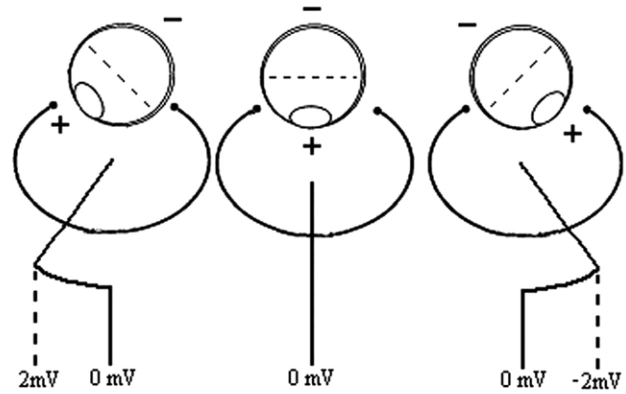

Fig. 1. Ocular dipole.

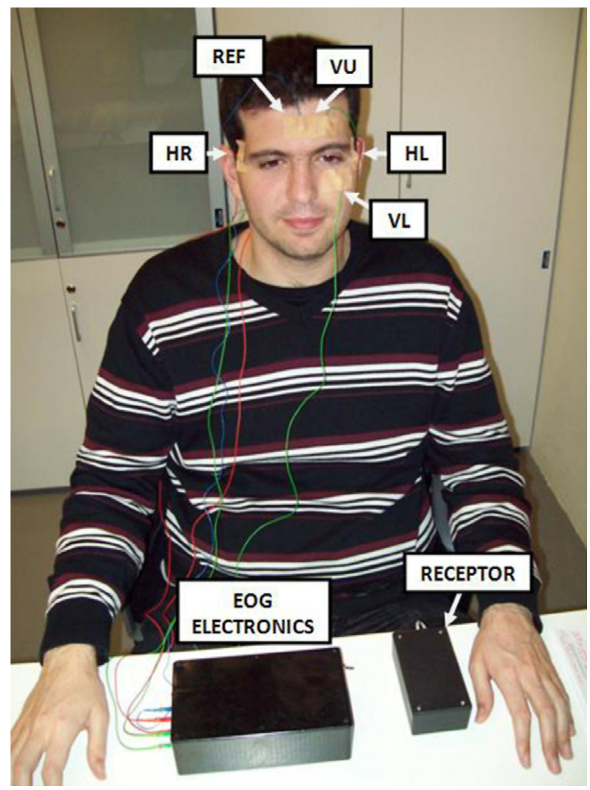

Fig. 2. Wireless electronic EOG device. Electrodes location: HR — Horizontal Right; HL — Horizontal Left; VU — Vertical Up; VL — Vertical Low; and REF — Reference.

2.1.2. Processing algorithm

To obtain the direction of the eye movement and blink it is necessary to process the EOG signals with a suitable algorithm. To generate an ocular command, the user must perform a fast eye movement in the desired direction and then return to the center position. The algorithm is capable of detecting four directions of movement (left, right, up and down) as well as blinks performed by the user. The signal is processed in windows of one second. As the sample frequency chosen is 30 Hz, the trial processed each second will consist of 30 samples. Several thresholds will be selected