EOG and EMG Based Virtual Keyboard: A Brain-Computer Interface

[1]Hari Singh Dhillon, [2]Rajesh Singla, [3]Navleen Singh Rekhi, [4]Rameshwar Jha
[1,3]M. Tech., [2]Lecturer, [4]Professor and Head, Department of Instrumentation and Control Engineering,
Dr. B R Ambedkar National Institute of Technology,
Jalandhar (Pb.), India
harisdhillon@gmail.com, rksingla1975@gmail.com, navleenr@yahoo.com, rjharjha@yahoo.com

Abstract- **This paper discusses a brain-computer interface through electrooculogram (EOG) and electromyogram (EMG) signals. In situations of disease or trauma, there may be inability to communicate with others through means such as speech or typing. Eye movement tends to be one of the last remaining active muscle capabilities for people with neurodegenerative disorders, such as amyotrophic lateral sclerosis (ALS) also known as Lou Gehrig's disease. Thus, there is a need for eye movement based systems to enable communication. To meet this need, we proposed a system to accept eye-gaze controlled navigation of a particular letter and EMG based click to enter the letter. Eye –gaze direction (angle) is obtained from EOG signals and EMG signal is recorded from eyebrow muscle activity. A virtual screen keyboard may be used to examine the usability of the proposed system.**

Keywords: amyotrophic lateral sclerosis (ALS); virtual keyboard; EOG; EMG; eye-gaze.

I. INTRODUCTION

Aging; it is a fate that everyone cannot avoid, and a fact that every developed country confronts at present. It is speculated that in such aging societies more machines will support our everyday life frequently and intimately.

In the European Union, it is estimated that10–15% of the total population is disabled and the population aged 60 years and older have a ratio at nearly 1 person in 10. This means that in EU there are about 80 million elderly or disabled people [1]. Besides, various reports also show that there is a strong relation between the age of the person and the handicaps suffered, the latter being commoner in persons of advanced age. Given the growth in life expectancy in the world (in the countries of the Organization for Economic Cooperation and Development (OECD) it is expected that the proportion of older persons aged 60 years and older will have reached a ratio of 1 person in 3 by the year 2030), a large part of its population will experience functional problems. Aware of the dearth of applications for this sector of the population, governments and public institutions have been promoting research in this line in the recent years. Various types of research groups at a world level have begun to set up cooperation projects, projects to aid communication and mobility of elderly and/or disabled persons with the aim of increasing their quality of life and allowing them a more autonomous and independent lifestyle and greater chances of social integration [1]. Hence, it is important to study man-machine interaction to establish better relationship with machines supporting our lives.

In particular, people suffering from Locked-in syndrome [6], spinal-cord injury [2] and amyotrophic lateral sclerosis (ALS) [14] have only control over their eye movements. As the oculomotor nuclei have some resistance to the crippling neurodegenerative effects of ALS, possibly due to the role of glutamate neurotransmitter transporters, eye movement is one of the last remaining active muscle capabilities in the latter part of the disease [14]. This is the most prominent muscle activity in their body, and hence presents electrooculogram as another possibility for use in development of brain-computer interfaces. Spinal-cord injury causes loss of independence, low quality of life and high cost of care. Therefore, we have to find easier methods to transmit user's thoughts and feelings to the machines.

Armen R et al [14] developed an EOG based system for computer control known as Telepathix. The system was created to allow users to interact with a computer only by moving their eyes. The system prompts the user to make eye movement commands to navigate the ternary keyboard shown in Fig. 1. With each successive eye movement command (*Left*, *Center*, or *Right*) the keyboard iteratively splits into thirds until a letter is chosen. The letter selection process ends when the user initiates the stop sequence by "typing" two blank spaces.

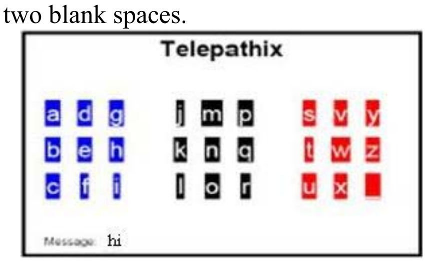

Figure 1. Ternary keyboard for electroocular spelling interface [14]

For example, if the user wants to spell "*hi*" using eye movement commands and is presented with the keyboard in Fig. 1, he or she would go through an iterative three step

978-1-4244-4520-2/09/$25.00 ©2009 IEEE

process to select each letter. Specifically in the "*hi*" case, when prompted, the user would first make a *Left* eye movement command to select the left third of the keyboard. Then the keyboard would change, only to present the nine letters of the selected third. Next, the user would make a *Right* eye movement command to select a third of the blue letters, namely, the *g*, *h*, and *i*. The interface would then orient the final three letters horizontally, and so the user would make a *Center* eye movement command to select the *h*. Thus, the user would have selected the *h*. Choosing the *i* would be a similar process. But the disadvantage of this system is that, the user has to make so many commands through eye movements to select a single letter. Thus this system is less comfortable to the patient.

Another possibility is to navigate the desired letter using eye-gaze direction and select the navigated letter using an eye blink [8]. But the blinking is a natural protection system which defends the eye from environment exposure [9], therefore, undesired blinks may cause false selection of the letters. Thus, this system can be used by those persons only who can control their eye blinks and at the same time can make blinks voluntarily.

In this paper, we proposed an EOG and EMG based virtual keyboard. In this system, the eye gaze direction is used to navigate a particular letter on the virtual screen keyboard and the EMG signal to click the navigated letter. Eye-gaze direction is obtained from EOG signal and the EMG signal recorded from the eyebrow of the user. We got this idea from [3], who developed EMG based hands-free wheelchair control with EOG attention shift detection. They used the EOG signal for speed control of the wheelchair and the EMG to select a particular direction.

II. ELECTROOCULOGRAM

Electrooculography is a method for sensing eye movement and is based on recording the standing corneal-retinal potential arising from hyperpolarizations and depolarizations existing between the cornea and the retina; this is commonly known as an electrooculogram (EOG) [1]. This potential can be considered as a steady electrical dipole with a negative pole at the fundus (retina) and a positive pole at the cornea. Therefore, a human eyeball can be assumable as a spherical battery that the centre of cornea is positive and the retina is negative [10]. It is possible to regard that the battery like this is embedded in an eye socket and rotates around the torsional centre of eye. Consequently, the micro-currents flow radially from the positive pole to the negative pole of the battery through the conductive tissue in the orbit as shown in Fig. 2. These currents generate the standing potentials around the eye. The standing potentials in the eye can thus be estimated by measuring the voltage induced across a system of electrodes placed around the eyes as the eye-gaze changes, thus obtaining the EOG (measurement of the electric signal of the ocular dipole). Sometimes, the EOG is also known as the electronystagmographic potential (ENG) [13].

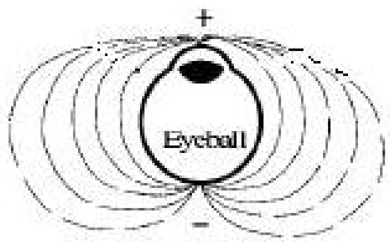

Figure 2. Flow of micro-currents from the positive pole to the negative pole

III. EOG RECORDING

The EOG is captured by five electrodes placed around the eye as shown in Fig. 3. The EOG signals are obtained by placing two electrodes to the right and left of the outer canthi (D-E) to detect horizontal movement and another pair above and below the eye (B-C) to detect vertical movement [1]. A reference electrode is placed on the forehead (A). The EOG changes approximately 20 microvolts for each degree of eye movement [1]. 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, electrode placement, head movements etc. It is therefore necessary to eliminate the shifting resting potential (mean value) because this value changes. To avid this problem an ac high-gain differential amplifier (1000-5000) is used, together with a high pass filter with cutoff frequency at 0.05 Hz and a low pass filter with cutoff frequency at 35 Hz. Fig. 4 shows schematic for EOG recording for one channel and figure 5 indicates simultaneous recording of vertical and horizontal eye movements. Simple Ag-AgCl electrodes are used in this recording. Silicon-rubber electrodes of impedance below 10 KΩ can also be used for measurement of EOG [6]. Due to the low impedance range starting from 40 -200 Ω, the silicon-rubber conducting electrode is more suitable to sense the very low amplitude bio- signals as compared to other types of electrodes such as Ag-AgCl electrodes. Additionally, an electrolytic gel based on sodium chloride is applied to the skin since the upper layers of the skin are poor conductors of electricity. A gel concentration in the order of 0.1 M (molar concentration) results in a good conductivity and low junction potential without causing skin irritation [11].

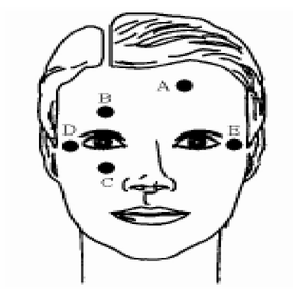

Figure 3. Placement of electrodes for EOG recording [6]

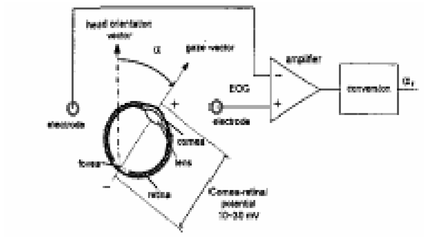

Figure 4. EOG recording

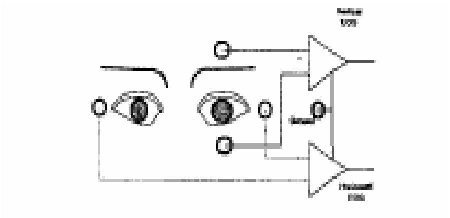

Figure 5. Simultaneous recording of horizontal and vertical eye movements

When the gaze vector is within the angular range of ±50° horizontally and ±30° vertically, the recorded EOG signals are almost proportional to the eye gaze displacement [1] as shown in Fig. 6. To get this waveform, the user stared sequentially at targets located at 10° incremental azimuthal angles, interleaved with gazes retuning nominal zero angle as shown in Fig. 7. The obtained EOG is used for the calibration of the system.

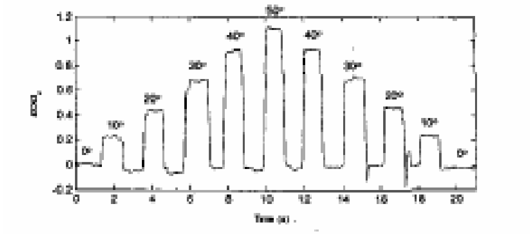

Figure 6. Recorded EOG signal in a linearity measurement experiment [2]

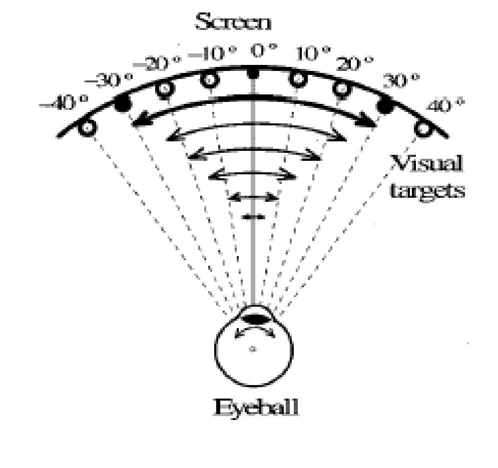

Figure 7. Eye movement modes [16]

IV. EMG RECORDING

EMG is recorded by using a small wearable device that acquires signals from the sensors on a headband. Fig. 8 shows headband device and how a user wears it. Sensors are used to read and process EMG signals. It is responsive to facial muscle activity. EMG is detected between 70-1000Hz [3]. The EOG signal lies in amplitude range of 10 -100 µvotls [7] and the frequency range of DC-100Hz [9] but the useful frequency component is DC to 10 Hz [11]. Therefore, EMG signals can be easily separated from the EOG signals using a band pass filter.

Figure 8. A subject is wearing the head band (left), dada acquisition box and headband (right) [3]

V. VIRTUAL KEYBOARD

Fig. 9 shows the whole process of selection of a letter from a virtual screen keyboard. First of all EOG signal is measured using the method discussed in section III. The eye-gaze angle is calculated from the EOG signal using an algorithm described in [2], [10]. When the curser reaches the required letter, EMG signal is used to make a click on the selected letter. The movement of the curser on the computer screen using eye-gaze angle is described in [1]. The point where the eyes are focusing on can be extracted from the velocity profile of the EOG signal [12]. The curser on the letter boxes moves according to subject's intention. EMG signal is used to make a click because its accuracy and clearance. This is because users can produce fast and frequent EMG click signals by quickly tensing and relaxing eyebrows to generate bursts of increased EMG signal in time domain. This is referred as "EMG-click" [3].

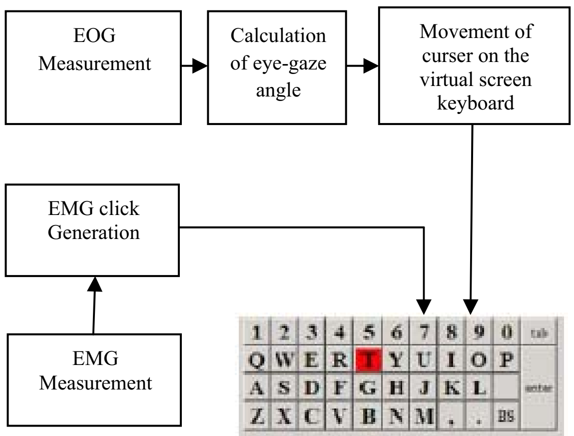

Figure 9. Block diagram of brain-computer interface using EOG and EMG signals

VI. DISCUSSION

Our purpose is to develop a human-friendly communication tool between a man and a computer. A virtual keyboard based on EOG and EMG signals is described in this paper. Electrooculography (EOG) is used to detect eye movements and calculate eye-gaze angle. Other methods to detect eye movements are videooculography (VOG), infraredoculography (IROG), sclera coil (SC) etc [1]. The VOG to detect eye movements from pictorial images of the eyeball is expensive because it requires a video camera to film eye movement in real time [5]. Eye movement detection using IROG is difficult to use over a long period because the eyes tend to become dry and fatigued [5]. Therefore, we decided to use EOG method for measurements of eye movements because it presents a good face access, good accuracy and resolution, great range of displacements, work in real time and is cheap. In the proposed system, EMG signal obtained from eyebrow, is used to make click on the selected letter.

VII. CONCLUSIONS

This proposed system is aimed towards development of a usable and low cost brain-computer interface for disabled and aged persons. It 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 increases the response time and rate of information flow. Further study is required to remove the problems encountered in measurement of EOG. For example, to make the EOG comfortable, surgically implanted electrodes could be used which provide equivalent signals without cosmetic penalty.

REFERENCES

[1] Rafael Barea, Luciano Boquete, Manuel Mazo (Member IEEE), and Elena Lopez, "System for Assisted Mobility using Eye Movements Based on Electrooculography", IEEE Transactions on Neural Systems and Rehabilitation Engineering, VOL. 10, No. 4, pp 209 – 218, December 2002.

[2] Yingxi Chen, and Wyatt S Newman, "A Human-Robot Interface Based on Electrooculography", Proceedings of the 2004 IEEE International Conference on Robotics and Automation, New Orleans, LA – April 2004, pp 243-248.

[3] Chun Sing Louis Tsui, Pei Jia, John Q Gan, Huosheng Hu, and Kui Yuan, "EMG-Based Hand-Free Wheelchair Control with EOG Attention Shift Detection", Proceedings of the 2007 IEEE International Conference on Robotics and Biomimerics, December 15-18, 2007, Sanya, China, pp 1266-1271.

[4] Jonathon B Hiley, Andrew H Redekopp, and Reza Fazel (Senior Member, IEEE), "A Low Cost Human Computer Interface Based on Eye Tracking", Proceedings of the 28th IEEE EMBS Annual International Conference, New York City, USA, August 30 – September 3, 2006, pp 3226-3229.

[5] Kenji Yamagishi, Junichi Hori (Senior Member, IEEE), and Michio Miyakawa (Member IEEE),"Development of EOG-Based Communication System Controlled by Eight Directional Eye Movements", Proceedings of the 28th IEEE EMBS Annual International Conference, New York City, USA, August 30 – September 3, 2006, pp 2574-2577.

[6] M Trikha (Student Member, IEEE), A Bhandari (Student Member, IEEE), and T Gandhi, "Automatic Electrooculogram Classification for Microcontroller Based Interface Design", Systems and Information Engineering Design Symposium (SIEDS) 2007, IEEE, Charlottesville, VA, 27th April, 2007, pp 1 – 6.

[7] Yoshiaki Kuno, Tohru Yagi, and Yoshiki Uchikawa, "Biological Interaction between Man and Machine", Proceedings of the 1997 IEEE/RSJ International Conference on Intelligent Robotics and Systems, 7 – 11 September, 1997, pp 318-323.

[8] Batu Akam, and Ali Ozgur Argunsah, "A Human-Computer Interface (HCI) based on Electrooculogram (EOG) for Handicapped", IEEE 15th International Conference on Signal Processing and Communication Applications (SIU 2007), 11-13 June, 2007, Eskisehir, pp 1-3.

[9] Tomasz Pander, Tomasz Przybyla, and Robert Czabanski, "An Application of Detection Function for the Blinking Detection", Proceedings of the International Conference on Human System Interactions (HIS 2008), Krakow, Poland, 25 – 27 May, 2008, pp 287-291.

[10] Nobuyuki Itsuki, Masashi Yamada, Masanori Kubo, and Kayo Shinomiya, "Improved Method for Measuring Electrooculogram and its Evaluation", 8th International Conference on Control, Automation, Robotics and Vision, Kunming, China, 6 – 9th December, 2004, pp 947-952.

[11] S Venkataramanan, Pranay Prabhat, Shubhodeep Roy Choudhury, Harshal B Nemade, and J S Sahambi, "Biomedical Instrumentation based on Electrooculogram (EOG) Signal Processing and Application to a Hospital Alarm System", Proceedings of ICISIP 2005, pp 535-540.

[12] Yonugmin Kim, Nakju Doh, Youngil Youm, and Wan Kyun Chung, "Development of Human-mobile Communication System using Electrooculogram Signals", Proceedings of the 2001 IEEE/RSJ International Conference on Intelligent Robotics and Systems, Maui, Hawaii, USA, October 29 – November 03, 2001, pp 2160-2165.

[13] Rafael Barea, Luciana Boquete, Elena Lopez, and Manuel Mazo, "Guidance of a Wheelchair using Electrooculography", Proceedings of the 3rd IMACS International Conference on Circuits, Systems, Communication and Computers (CSCC'99), July 1999.

[14] Armen R Kherlopian, Joseph P Gerrein, Minerva Yue, and Kristina E Kim, "Electrooculogram based System for Computer Control using A Multiple Feature Classification Model", Proceedings of the 28th IEEE EMBS Annual International Conference, New York City, USA, August 30 – September 03, 2006, pp 1295-1298.