EOG based Virtual Keyboard

S. Sai Surya Teja*, Sharat S. Embrandiri*, Nitin Chandrachoodan† and Ramasubba Reddy M.*
*Bio-Medical Engineering Group, Dept. of Applied Mechanics, IIT Madras, India
†Dept. of Electrical Engineering, IIT Madras, India

***Abstract*—In this paper, an EOG based assistive system for typing text using a virtual keyboard is presented. An indigenously developed acquisition system based on arduino interfaced ADS1299 with a wearable dry electrode mask is used to record and process EOG signals. An accuracy of 100% and an average speed of 1 char/12 sec was achieved by an untrained person in online implementation of this system. This can be further improvised by word prediction algorithms.**

I. Introduction

Electrooculograms (EOGs) are strong bio-potentials induced by eye movements. The metabolically active retinal epithelium generates the Corneal Retinal Potential (CRP), which imparts the eyeball it's dipole characteristics [1]. Using bi-channel acquisition with electrodes aligned along the horizontal and vertical axes, signals pertaining to the eyeball movement can be acquired. Useful EOG features are generally observed in the 10-100 μV magnitude range and 0- 10 Hz frequency range [1]. EOGs being essentially eye movement dependent can be manipulated by a human, which offers a way for an effective human-computer interaction. Potential applications of EOG include context recognition systems [2] and assistive technology such as wheelchairs [3], alarm systems [1] etc. In this work, an EOG based virtual keyboard, a potential assistive device to aid communication for paralyzed and disabled patients with intact and functional ocular system is proposed and implemented. Despite it's relatively high magnitudes, EOG signals are still susceptible to nondeterministic variations since they are governed by numerous parameters such as eye blinks, electrode placement, head movement, luminance etc., which need not be constant across subjects and sessions. To overcome these constraints, we use a simple multi-thresholding algorithm for EOG detection and classification. Prior to device use each time, threshold values are derived from a calibration session for individual subjects. After verifying the offline accuracy, the algorithm is ported to an asynchronous mode EOG based virtual keyboard. The asynchronous mode accuracy and speed is estimated to determine the efficacy of the designed system

II. Acquisition System

EOG is acquired by an indigenously developed acquisition system from particular positions on the face as shown in Figure 1(a). Differential voltage between Vpos and Vneg corresponds to the vertical channel, which yields information about blink and vertical movement of the eyeball. Similarly, the differential voltage between Hpos and Hneg corresponds to the horizontal channel, which gives information about horizontal movement of the eyeball. A wearable mask with thin copper plates (dry electrodes) attached at specific positions as shown in figure 1(b) is designed for acquiring EOG. Both horizontal and vertical channels are sampled and digitized at a rate of 250 Hz using ADS1299 as the analog front-end and arduino to communicate with the PC. The digitized data is streamed continuously to PC via serial cable for processing. On the receiver side (i.e. PC), Processing (language) based applet is designed to acquire, filter (passband 0.1-30 Hz) and classify the data into commands and send to a Virtual Keyboard applet.

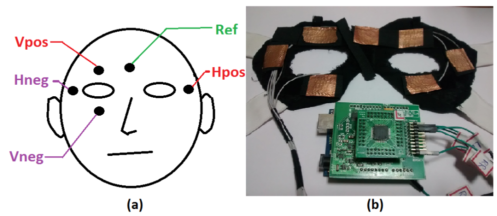

Figure 1. (a) Electrode arrangement (b) Wearable EOG mask with electronics

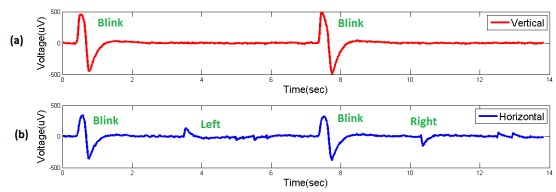

Figure 2. EOG signals in vertical channel (a) and horizontal channel (b)

III. Calibration

Figure 2 shows EOG signals for blink, left and right eye movements. All these movements can be classified just by the voltage thresholds. During calibration, the subject is asked to follow a sequence of commands comprising blink, look left, return to center, blink, look right and eventually return to center as per synchronized instructions. The limits of eye movement are confined within the edges of the screen.

The acquired training data gives us the information about the possible maximum and minimum EOG signal amplitudes when the user moves his/her eye within the screen boundary. We analyze and store the following classification parameters from the training data set. Blink threshold B_{th} = a x maximum positive voltage in the vertical channel when the user blinked.

978-1-4799-8360-5/15/$31.00©2015 IEEE

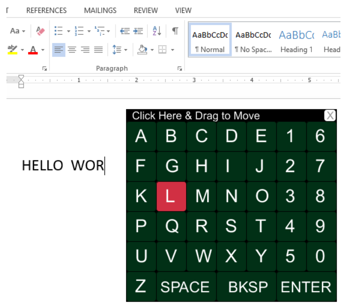

Figure 3. EOG based Assistive keyboard implemented using 'Processing'

Left threshold L_{th} = b x maximum positive voltage in the horizontal channel when the eyeball moved left. Right threshold R_{th} = c x maximum negative voltage in the horizontal channel when the eyeball moved right. Here, the values of the coefficients are empirically chosen as a=0.9, b=0.7 and c=0.7 after careful offline analysis. For identification of inactivity in a 2 sec window, we estimate the energy threshold E_{Vth},E_{Hth} as the minimum possible energy during any eye activity (blink / eye movement) in the vertical and horizontal channels respectively.

IV. Assistive Keyboard (AsKey)

Figure 3 shows a virtual keyboard, which is controlled by eye movements. Blink, left and right movements of the eye are used to navigate and select the characters on the keyboard. This virtual keyboard is designed in 'Processing' environment and can help the user to type a text using his eye movements. In this application, there is a highlighter scrolling vertically from cell to cell at a speed of 1 cell/sec. The user needs to blink when a particular character of his/her choice is highlighted . The user needs to move his/her eyeball to left/right outside the dimensions of the monitor to move the highlighter to the left/right column.

V. Detection and Classification

Streamed data from arduino is stored in a 2 sec buffer, which is updated every 0.2 sec. This corresponds to processing windows of length 2 sec with 1.8 sec overlap, which ensures robust and speedy operation. The algorithm checks whether the signal energy (E_V,E_H) is greater than the energy thresholds (E_{Vth}, E_{Hth}) in at least one channel to ensure noise rejection. If this condition is satisfied, then the maximum voltage in vertical channel V_{max}, the maximum and minimum voltages in horizontal channel H_{max} and H_{min} are computed. V_{max} is then compared with B_{th} for blink detection . The current character highlighted on the keyboard is written on the text document if V_{max} is greater than B_{th} . Otherwise, H_{max} and H_{min} are compared with L_{th} and R_{th} to identify whether it is left or right command and the highlighter is shifted to the left or right column accordingly.

VI. Results and Discussion

We deal with a three-class problem here to classify blink, left and right movements of an eyeball. We did not use up/down movements of the eye since some of the involuntary blinks could be misinterpreted as up/down with this basic thresholding algorithm. EOG signal amplitudes are essentially subject dependent and hence we designed a training mode to calibrate, which takes around 1 min. It was found that the eye movement amplitudes are dependent on the speed of movement, with higher amplitudes correlating with higher speeds. Hence, subjects were asked to move their eyes quickly for left/right selection and slowly while returning to the screen center. The implemented system achieved 100% accuracy online with an average speed of 1 char/12 sec by an untrained subject.

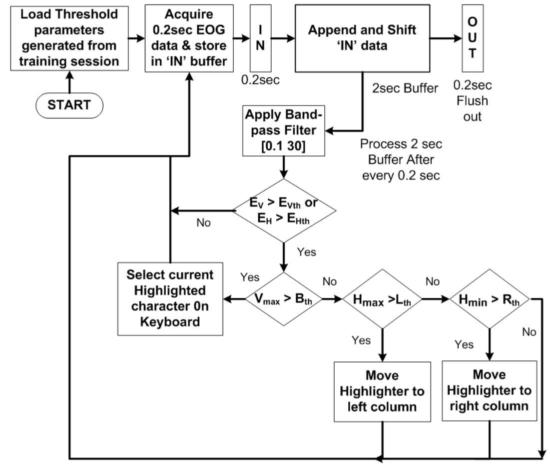

Figure 4. Flowchart of algorithm used for classifying blink, left & right

VII. Conclusion

Since the algorithm is based on basic thresholding, any low-power microcontroller can be used for processing and classifying the EOG data instead of a computer. This is useful for designing a complete wearable assistive system where the user can send commands to any device or a machine like wheel chair or other assistive applications in PC via bluetooth. Current typing speed can be significantly improved by using word prediction algorithms. Also, the three-class problem can be converted to a five-class problem where up/down can be used as additional commands for switching the keyboard layout to include special characters. Further the keyboard layout can be optimized to attain higher typing speeds.

References

[1] Venkataramanan, S., Prabhat, P., Choudhury, S. R., Nemade, H. B., & Sahambi, J. S. (2005, January). Biomedical instrumentation based on electrooculogram (EOG) signal processing and application to a hospital alarm system. In Intelligent Sensing and Information Processing, 2005. Proceedings of 2005 International Conference on (pp. 535-540). IEEE.

[2] Bulling, A., Roggen, D., & Tröster, G. (2008, September). It's in your eyes: towards context-awareness and mobile HCI using wearable EOG goggles. In Proceedings of the 10th international conference on Ubiquitous computing (pp. 84-93). ACM.

[3] R. Barea, L. Boquete, M. Mazo, and E. L´opez, "Wheelchair guidance strategies using eog," Journal of intelligent and robotic systems, vol. 34, no. 3, pp. 279–299, 2002.