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AN ELECTRO-OCULOGRAM BASED SYSTEM FOR COMMUNICATION AND CONTROL USING TARGET POSITION VARIATION

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Abstract - In this paper we describe a novel mode of human computer interaction based on gaze tracking using the electro-oculogram (EOG). Despite the relative simplicity of recording this signal, it is often discounted as a reliable method of gaze tracking because of problems arising from changing sensitivity and DC drift. We describe an original technique, Target Position Variation (TPV), which addresses this issue by presenting moving icons which, when followed with the eye, create a corresponding pattern in the EOG signal which can be used to infer the correct gaze position and to compensate for variations in sensitivity.

I. INTRODUCTION

For people who, due to severe physical disability, depend on eye movements as their primary means of communication, gaze tracking technologies can play a key role in rehabilitation, often augmenting or replacing other computer input modalities, enhancing independence and quality of life.

Gaze tracking systems that use video processing techniques can be accurate and require no physical contact with the user. However, they require careful calibration and can be expensive.

An alternative approach is to use the electro-oculogram, a biopotential measured with electrodes suitably placed on the skin near the eyes. Eye movements can be recorded in the horizontal and vertical directions using two pairs of electrodes, one on the temples and one above and below either the left or right eye. The EOG varies by a few tens of microvolts per degree of eyeball rotation. Unfortunately, this sensitivity varies over time, as can the underlying DC level.

II. TARGET POSITION VARIATION

The principle of our original technique, TPV, is to present to a subject one or more targets, each moving in a distinctive fashion. The subject's EOG is monitored to detect intervals during which its variations correspond to the movement of one of the targets. During such intervals, the subject's absolute gaze position may be assumed to be that of the target.

TPV can be used to select one icon from a group of moving icons, simply by looking at it while it moves, possibly forming the basis of a menu system. Alternatively, it could augment a gaze tracking system, providing a means of automatic recalibration. For example, an EOG-driven mouse system could feature an oscillating icon at one edge of the screen to which the user looks for recalibration whenever the mouse cursor drifts away from the centre of his or her gaze.

For initial testing, we have restricted the icon position variation to a horizontal sinusoidal oscillation defined by,

$$s_i(t) = \cos(\omega t - \theta)$$

where ω is the angular frequency, θ is the phase offset (both in radians) and t is time in seconds. From the recorded signal, $s_e(t)$, we define the following complex valued function,

$$c(t) = \frac{2}{T}\int_{t-T}^{t} s_e(\tau).e^{j\omega\tau} d\tau$$

where T is the period of the oscillation. $c(t)$ is equivalent to the first complex coefficient of the Fourier series (excluding the DC component's coefficient) of the periodic extension of $s_e(t)$ on the interval $[t-T, t)$. The real and imaginary parts of $c(t)$ may be thought of as coefficients of a cosine component and a sine component respectively, which sum to give the sinusoidal function that most closely approximates $s_e(t)$, minus its DC component, over the T seconds leading up to t. A candidate reconstructed signal, $s_e'(\tau, t)$ is computed thus,

$$s_e'(\tau,t) = \mathrm{Re}\{c(t)\}\sin(\omega\tau) + \mathrm{Im}\{c(t)\}\cos(\omega\tau)$$

If this reconstruction proves to be a sufficiently good fit over the preceding T seconds, then we may assume that the user's gaze is tracking an object oscillating at the frequency in question. The closeness of the fit is quantified as follows. Firstly, the DC level is estimated using the following function,

$$a(t) = \frac{1}{T}\int_{t-T}^{t} s_e(\tau) d\tau$$

Then the following error function is calculated,

$$e(t) = \int_{t-T}^{t} \left| s_e(\tau) - s_e'(\tau,t) - a(t) \right| d\tau$$

If the fit function,

$$f(t) = \frac{|c(t)|}{e(t)} \geq f_{threshold}$$

then the user is assumed to be tracking a target with the frequency in question.

III. EXPERIMENT

A single-user pilot study was undertaken, consisting of two experiments - the first to establish suitable oscillation parameters and the second to explore the selection of one icon from a group.

A. Equipment

Two PCs were used, one to display the moving icons and one to record the EOG data. A low-cost, custom-built EOG amplifier was used (voltage gain $\approx$ 1000). The design is based on a classic instrumentation amplifier topology [1] and uses only a single quad op-amp (LTC1053). Since the horizontal EOG was used in conjunction with horizontally oscillating icons, the active and reference electrodes were fixed to the subject's temples. The ground electrode was attached to his right earlobe. Data was acquired at 200Hz using a NIDAQ PCI 6023E card.

During both experiments, the subject was seated facing the display PC's monitor, 50cm from the screen, and instructed to sit still and relax. All oscillation amplitudes were specified in pixels. The three oscillation amplitudes used - 25, 50 and 100 pixels - corresponded to peak-to-peak amplitudes in the horizontal gaze angle of 1.79^{o}, 3.58^{o} and 7.15^{o} respectively.

B. Experiment 1

The subject was instructed to track a single icon oscillating at various frequencies (0.2Hz, 0.4Hz, 0.8Hz and 1.6Hz) and with various amplitudes (25, 50 and 100 pixels). At each combination of frequency and amplitude, the steady state EOG signal was recorded. Some example data recorded during this experiment is shown in Figure 1.

While the subject successfully tracked all oscillations in the experiment, of the four tested, 0.8Hz was deemed to strike the best balance between comfort and speed of detection. The 25-pixel setting of oscillation amplitude was found to be too small to reliably detect the oscillation from one period of data.

C. Experiment 2

The second experiment investigated the selection of one icon from a group of four horizontally oscillating icons. Firstly, all icons were assigned the same frequency, and a different phase offset. Secondly, each icon was assigned a different frequency. By way of example, the upper graph in Figure 2 shows the EOG as the user looks at each of the four icons in turn (oscillating at 0.2Hz, 0.4Hz, 0.8Hz and 1.6Hz). The lower graph shows the fitting function $f_{0.8}(t)$ for 0.8Hz. When the user was looking at the 0.8Hz icon this function is above the threshold, as hoped.

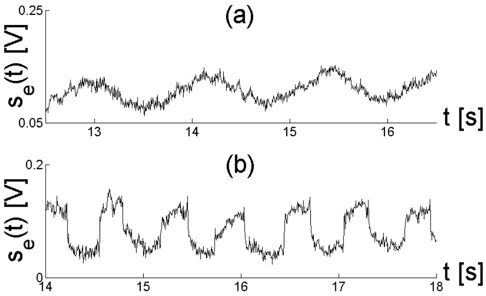

Figure 1. EOG data recorded during the first experiment: (a) amplitude 50, frequency 0.8Hz, (b) amplitude 100, frequency 1.6Hz.

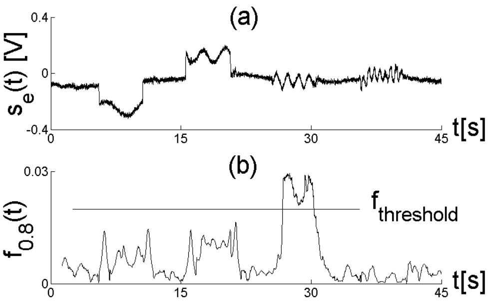

Figure 2. (a) EOG data from the second experiment, in which the user's tracking of each of the four frequency icons in turn is clearly visible. (b) The function f(t) for 0.8Hz shows how well the data can be modelled by an 0.8Hz sinusoid at any moment during the 45 seconds. Note that it exceeds the threshold only while the user follows the 0.8Hz icon.

IV. CONCLUSIONS

Our preliminary experiments indicate that Target Position Variation constitutes a simple and reliable method of determining eye-gaze position. It is the authors' hope that further experiments using multiple subjects will establish with a greater degree of generality the range of oscillation frequencies and amplitudes that are appropriate.

REFERENCES

[1] A. S. Sedra and K. C. Smith, *Microelectronic Circuits*, Oxford University Press, 3rd Ed., 1982.