Measuring Head Turns with Electro-oculography for Wearable Mobile User Interfaces

Jussi Virkkala[1,2]. Kristian Lukander [1]
[1]Brain Work Research Centre, Finnish Institute of Occupational Health, Topeliuksenkatu 41 a A, FIN-00250, Helsinki, Finland.
[2]Department of Clinical Neurophysiology, Medical Imaging Centre, Pirkanmaa Hospital District, Biokatu 8, FIN-33521, Tampere, Finland
jussi.virkkala@neuroupdate.com, www.neuroupdate.com/jussivirkkala

Abstract. Natural user interfaces are key elements in pervasive computing. One of the used techniques is the video based detection of gaze replacing the actions of a computer mouse. Here we demonstrate that it is possible to measure head turns relative to gaze using a simple wearable, one-channel electro-oculography setup and to use this information in novel mobile user interfaces. While holding a gaze on a small display, head turns are translated into one-dimensional input on a mobile phone. An example application scenario of scrolling a large image is demonstrated. The use of facial electro-oculography electrodes could also enable the detection of context for context aware pervasive systems.

Keywords: mobile, user interface, electro-oculography.

1 Introduction

Natural user interfaces are key elements in pervasive computing. User activity, context, physiological status, and intentions should be detected with minimal effort from the user. One approach has been the measurement of eye movements. Eye movements used include saccades, blinks, and fixations. Typically gaze fixations have been used to select an action from a screen for controlling for instance a wheel chair [1] or typing [2]. Another recent approach has been the use of eye gestures for selecting commands [3]. It is also believed that eye movements can provide access to underlying cognitive processes not accessible with current sensing modalities [4]. Eye movements can be measured using video-oculography (VOG) methods or electrically with electro-oculography (EOG). For now, most VOG systems are relatively large systems mounted on helmets or goggles[1]. Electro-oculography is based on the electrical potential difference between retina and cornea [5]. Using miniature electronics it is possible to develop a wearable system based on EOG [4, 6].

Recently EOG has also been used for detecting activity of the user. Bulling et al. separated activities of copying text, reading, taking notes, watching video and

[1] Commercial equipment exist like http://www.smivision.com or http://asleyetracking.com

browsing using various eye movements detected with EOG [8]. With facial electrodes it is also possible to record EMG activity for the detection of emotions [9]. Eye movements are also reliable indicators of sleepiness [10] and facial electrodes can be used to detect sleep onset and sleep stages [11]. These could be used for 24h context aware systems. Head movements can also be measured with different techniques [12] and have been used in commercial devices[2]. Usually EOG is used for recording only eye movements and not the actual gaze directions as with VOG based gaze tracking [7]. In this demonstration direct current (DC) coupled EOG with two electrodes is used to measure head turns relative to the gaze on a small mobile device. This rotation is then used as input for a mobile user interface in a wearable system.

2 Methods

A two-channel BlueGain EOG Amplifier (Cambridge Research Systems, Kent, England) was used for recording direct current (DC) coupled EOG. The unit has two bipolar channels but in this study only a single horizontal channel was used. Usually, an additional ground electrode is used but was left unconnected in this study to demonstrate the possibility of having only two electrodes in a setup. Connecting a ground would reduce the noise levels. The device has a sampling rate of 10 kHz, dynamic range of ±40 mV, with a 16 bit ADC converter and a bandwidth of 0-150 Hz. The device has a built-in moving average (MA) filter to reduce the amount of data transmitted over bluetooth. In this study a moving average window of 200 samples (reducing the sampling rate from 10 kHz to 50 Hz) was used. The Bluetooth protocol supported is SLIP (Serial Line Interface Protocol). Data is transmitted in 3 byte (int24) resolution together with a time code and possible markers. Buffer size is adjustable and was set to 250 samples (5 s). Data is transmitted on request and time codes are used to ensure that no samples are missed. Data is also saved to an ASCII file for review. Data is received over the bluetooth at the rate of 50 Hz. Mean and standard deviation of the last 1 s data (50 samples) are calculated at a rate of 10 Hz (once every 100 ms). Tracking is initiated with a key down event and the last *mean* is stored as a *calibration mean*. The horizontal position *x* of the displayed image is updated every 100 ms, based on the formula *x=gain*(current mean-calibration mean)*.

The software was written with Visual Studio 2005 Professional (Microsoft Corporation, Redmond, USA) using .NET Compact Framework 2 without additional third party libraries (binaries can be downloaded from http://www.neuroupdate.com/bluegain/hturn). The mobile phone used was an entry level Samsung SGH-i200 (Samsung Electronics, Seoul, Korea), running Windows Mobile 6.1 standard version on a 2.3" screen with a resolution of 240*320 pixels. For testing, also a .NET Framework 2 version was created for Windows laptop use. The use of the .NET Framework enabled the use of same class libraries between platforms reducing the effort for multiplatform development. Interfaces between platforms were almost identical.

[2] Pure head tracking has been used in devices like http://www.naturalpoint.com/smartnav

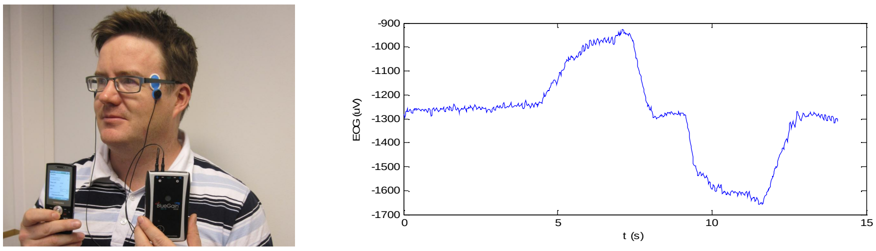

Fig. 1. On left used Mobile phone, BlueGain device, and the location of two electrodes lateral to eyes. On right recorded EOG with head turn to left (5 s), middle position, right (10 s) and back to middle (15 s) while holding the gaze at the screen.

3 Discussion

In this demonstration, head turns relative to the gaze were measured using DC coupled EOG and applied to a wearable mobile user interface. The setup needs only two electrodes. In this study the electrodes were standard disposable electrodes (Ambu A/S, Ballerup, Denmark) but other applications have demonstrated that also dry electrodes can be used for measuring EOG [4, 6, 13, 14]. With EOG it is difficult to measure gaze position accurately but relative eye movements can be easily detected. In contrast to video based methods, the use of eye glasses or variable outdoor lighting is not a problem with electro-oculography (EOG). Here, only horizontal eye movements were measured so vertical gaze shifts or blinks do not affect the results. Extended use of head turns as input can result in neck strain and thus the suggested input modality should not be used as the only input modality, rather than complementing other techniques. In future studies the actual bit rate obtainable with the current setup should be measured. As there is no one-to-one direct relationship between head turns and input to the user interface (as is with gaze interfaces) users can easily compensate head turns based on visual feedback. Here a head turn leftward moved the map to the left but opposite movement could easily be obtained by changing the sign of the gain value. The current technique sets no limitations to the size of the mobile screen. For instance a wrist worn device could be easily controlled with the developed system, which would be hard with a gaze controlled device or with physical buttons. Another benefit is that the gaze is maintained at the same point of the screen which can be critical in, for instance, head up displays in transportation or with aiming devices. As opposed to rapid, saccadic eye movements exhibited when repositioning the gaze, here the recorded eye movements with gaze fixed and the head turning resemble smooth pursuits which are usually manifested only with slowly moving pendulum-like visual stimuli [15]. As these are uncommon in natural settings they could provide the ideal eye gestures for mobile wearable interfaces complementing the traditional use of fixations and saccades [3]. Gestures (e.g. head rotation to the left and back while maintaining the gaze on the screen) could be easily recognized and used for instance to initiate or end the capture mode or produce a predefined set of commands. There are also other techniques to measure head turns [12]. With a camera on a mobile device pointing toward the user or with a camera attached to the head, rotations could be measured with advanced video processing. To measure relative head turns also the gaze must be measured. The use of facial electrodes also enables the measurement of physiological signals like EMG and EEG for context aware systems.

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