INTERPRETATION OF EOG DATA IN ORDER TO OBSERVE EYE MOVEMENTS

Tina Meißner and Harald Loose
Department of Computer Science and Media, Brandenburg University of Applied Sciences, Magdeburger Str. 50, 14770 Brandenburg, Germany

Keywords: Eye tracking, EOG, Eye movement.

Abstract: This paper deals with the possibilities of observing eye movements from EOG recordings. First the setup for the recording of eye movements, then the EOG method, which is used to obtain eye movements in the experimental context, are explained. The first recordings resulted in the detection of eye movements within the EOG data and the results were put into relation to the gaze points gained from the eye tracking system. In addition to these subjective observations a first attempt at quantification of the dependency between EOG signal and gaze points is presented. Though faced with a few problems, it was possible to put numerical values for distances in relation to signal amplitudes of the EOG.

1 INTRODUCTION

The capture and interpretation of eye movements have been done since the 19th century. Countless studies have been carried out with different interpretation goals regarding the eye tracking data. There are eye tracking studies which are focused on usability, on human-machine interaction, on behavior (psychological, physiological) and so on. The techniques have changed from simple observation of the movements and automatic capture of the eye to mobile head mounted eye trackers which work with digital cameras and LEDs. There are several publications on eye movement and eye tracking methods. Duchowski's work (Duchowski, 2007) is a fundamental approach to the topic of eye tracking methodology. In order to understand what exactly eye movements are and how it is possible to retrieve them on a less technical basis, Joos et al. (Joos et al., 2003) published an overview of eye movements and their applications.

Nowadays the commercial eye tracking systems which work with LEDs and camera recordings are the most common way to gain eye tracking data. They provide reliable gaze points with little effort. The disadvantages are the dependency on these systems and the limited adaptability to own experimental needs. Another negative aspect is the physical constraint of a subject. When the eye tracking system is permanently installed to a work space, the proband has to be in front of it during the whole experiment with small tolerated head movements. This side effect requires alternatives. The following paper follows the idea to replace the eye tracking system with EOG signals. An experimental setup was created in which eye tracking data is recorded and an EOG derivation is made. Aim of this experiment was to detect eye movements in EOG data and be able to derivate exact gaze points from the EOG signals.

2 RECORDING AND PROCESSING OF EYE MOVEMENTS

The commercial eye tracking system *Nyan 2.0XT* (Interactive Minds[1]) was used to get reference data. *Nyan 2.0XT* is a commercial software which is distributed with the eye tracking system of LC Technologies[2]. An alternative is the recording of EOG (Electrooculography) signals. In this setup a system from *Neurowerk* (SIGMA Medizin-Technik[3]) was used to derive eye movement signals. The characteristics of this method are introduced in subsection 2.2. In subsection 2.1 an overview of the experimental setup in which

[1] http://www.interactive-minds.com/de/eyetracking-software/nyan-2
[2] http://www.eyegaze.com/
[3] www.neurowerk.de

Meißner T. and Loose H..
INTERPRETATION OF EOG DATA IN ORDER TO OBSERVE EYE MOVEMENTS.
DOI: 10.5220/0003776603930397
In *Proceedings of the International Conference on Bio-inspired Systems and Signal Processing* (BIOSIGNALS-2012), pages 393-397
ISBN: 978-989-8425-89-8

the recordings and tentative interpretations were made is explained.

2.1 Experimental Setup

The experimental setup was based on former biosignal experiments as well as first test scenarios for collecting EOG data. A subject had to look at a screen presentation while the eye movements were simultaneously recorded using both devices. The screen presentation consisted of 24 slides. Each of them is shown for four seconds (details in section 3).

The subject was seated in front of the monitor within a distance of 60-70 cm. The recording was carried out two times to have the possibility to compare the recordings and their resulting interpretations.

The recorded eye tracking data were visualized using *Nyan 2.0XT*. A program called *EyeValuation* was developed to import, analyze and visualize eye tracking data. The proprietary EOG signals were imported into MATLAB[4] and splitted into slides or groups of slides for visualization.

2.2 Functionality of the EOG

The electrooculography is the measurement of the potential difference between the positively charged cornea and the negatively charged retina. The eye's electrical field is measurable through surface electrodes near the eye: Electrodes are placed left to the left eye and right to the right eye to obtain horizontal eye movements, above and under the left eye for vertical motions. Two separate signals with positive and negative amplitudes as an indicator of eye movement are received. When the eyes move to the right the voltage changes to a positive value. During a leftwards movements, the voltage inverts to a negative value (Malmivuo and Plonsey, 1995, p. 580). During an upward (vertical) motion of the eyes, the signal's voltage drops into the negative area and vice versa when the eyes move downward. By having both signals it is pretty easy to get a general idea of where the eyes are moving towards, but it is difficult to pinpoint the exact gaze position. The analysis of the EOG signals is presented in section 3.

3 RESULTS

As mentioned before the commercial eye tracking system was used in former experiments and its reliability was tested. In this experiment the eye tracking system acts as a reference for comparing the EOG data to the correct eye movements and gaze points. It provides information about the location and duration of a gaze point and enables an interpretation of the EOG data. The following subsections presents the eye tracking and EOG data received during the experiment for selected slides and a first quantification of the EOG values in regard to exact gaze points.

3.1 Task Slides

After an initial slide there are task slides with instructions for the proband. The fixation points of the subject and saccades are visible in fig. 1.

Figure 1: Fixation points and saccades from task slide.

The gaze points that exceed a certain gaze time duration (fixations) are represented by circles. The larger the diameter of the circle, the longer the gaze duration. The sequence of reading is apparent through the movements from one fixation point to the other (saccades). The subject started at the top left and successively read the four lines. Looking at the EOG data of the task slide (see fig. 2) the reading rhythm is recognizable. On both sides (horizontal and vertical movements) the reading of the four lines of the task slide can be identified. The horizontal eye movement follows a regular flow from left (negative) to right (positive), then the eye moves left to the beginning of a new line and moves to the right again. This happens for each line. The length of the lines corresponds to the transition from the negative to the positive voltage range. The third left to right development is the

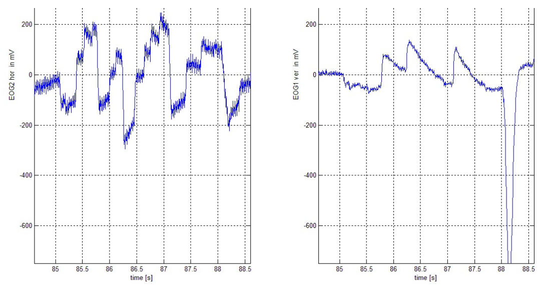

Figure 2: EOG data for task slide (left: horizontal movements, right: vertical movements).

[4]The MathWorks, Inc.: MATLAB http://www.mathworks.com/

longest which is in conformity with the length of the third line. This similarity indicates a direct dependency between distances on screen and values between negative and positive peaks.

The vertical movements show the same dependencies between distance and voltage values like the horizontal movements. The difficulty of analyzing the EOG signals is the quantification of the voltage values.

3.2 Angle Slides

In the experiment there were angle slides where a red dot wanders from the center of a bar to the right in steps of six, back to the center, then six steps to the left and back to the center. The distance between each step covers about 10 degrees, which is about 100 pixels on the screen (of the experiment). The sequence of the moving point can be detected best in the fig. 3 which was generated in the *EyeValuation* program.

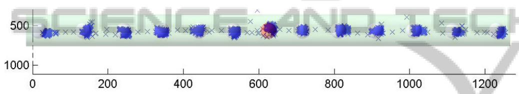

Figure 3: Gaze points for angle slide (slide is integrated).

Every point had to be fixated for four seconds which the subject did quite smoothly. The complete EOG signal for the angle slide section is shown in figure 4. The horizontal movements were made evenly.

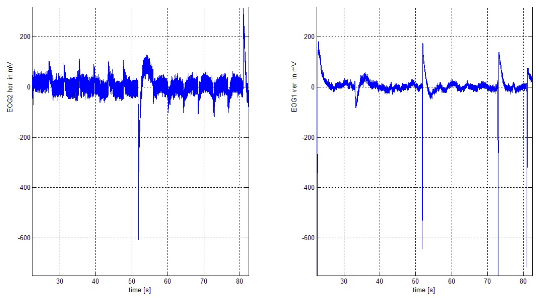

Figure 4: EOG data for angle slides (left: horizontal movements, right: vertical movements).

It is possible to detect the six steps to the right (ca. 100 μV each). The distance between the steps on screen was about 100 pixels, ergo 100 pixels are represented through 100μV. The noticeable drop towards the negative voltage spectrum is due to the jump from the outer right point to the center (movement to the left). The six steps to the left can be detected as well (-100 μV). Though, not in this figure apparent, both peaks from the sides to the center have approximately the same value which proves the dependency between distance on screen and the measured EOG amplitude. If 100 pixels are represented by 100 μV, 600 pixels must be aquivalent to 600 μV and this is what was measured (see fig. 4).

Since the task was to follow the red dot on a bar, there are no major vertical movements. The noticeable outliers are simply blinks of the subject and should not disturb the analysis.

3.3 Fixation Crosses

In order to receive vertical movements, a fixation cross sequence on five slides was created: cross right, left, up, down and center. The gaze points for the whole fixation cross process as well as the combined cross slides are presented in fig. 5.

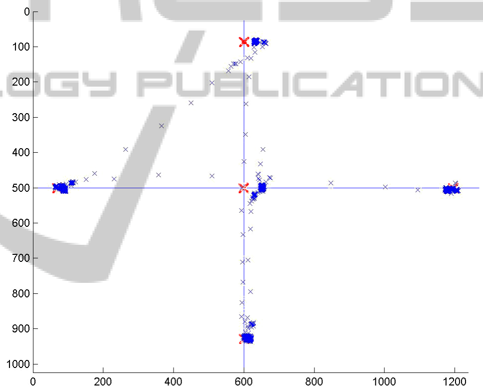

Figure 5: Gaze points from fixation crosses slide (red crosses: fixation crosses from slides).

The gaze points are almost identical to the fixation crosses; the paths from one cross to another are recognizable. The EOG data for the whole fixation crosses section is shown in fig.6.

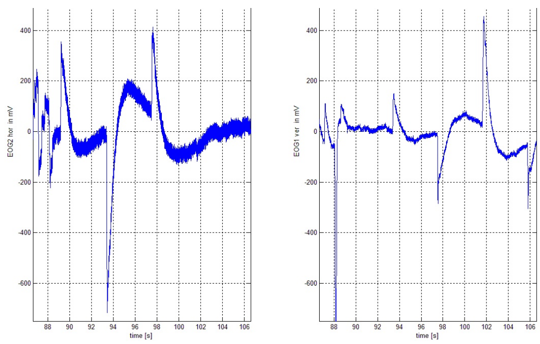

Figure 6: EOG data from fixation crosses (left: horizontal movements, right: vertical movements).

At 94 seconds there is a very strong amplitude in the negative voltage area of the horizontal signal. This is due to the crossing of the slide from the right cross to the left cross. The values validate again that the distance the eye has to cover is proportional to the change of the EOG signal.The same is observable when the subject had to look at the upper cross. During the left-to-top-movement the signal of the vertical movement changes, too. The upward eye movement is clearly detectable (-300 μV). The same is observed for the down movement from the top cross to the lower cross (450 μV). Afterwards the signal converts into a negative run because the eye moves from the lower cross to the middle cross and the sequence is over. During those movements the horizontal signal evens out at around zero because no further left-right-movements are made.

It was easy to detect eye movements through an EOG system. The proband is not restricted in the usual movements and a technical calibration, like it has to be done for the commercial eye tracking system, is not needed. The disadvantage of the EOG system, compared to the gaze positions from the eye tracking data, is the lack of quantification of the voltage values in order to receive pixel positions. An attempt of such quantification is mentioned in subsection 3.4.

3.4 Quantification of EOG Data and Eye Movements

The filtered (Notch filter) EOG signal, provided by the *Neurowerk* software, was analyzed to derive exact gaze points from voltage values. The quantification was done for a task slide which consists of four lines to be read (see figure 1). The signal has been "splitted" into four parts to be able to measure and compare voltage values and gaze points (see fig. 7). The amplitudes of the line breaks (end of one line to the beginning of the next line) for vertical and horizontal movements were chosen for a sample quantification. The length of the signal change was measured and quantified. In order to compare those values to a distance covered on screen, the gaze points for the reading section have been examined within *EyeValuation*.

During vertical movements one pixel can be represented by 0.95 μV, during horizontal movements one pixel covers about 1.76 μV. It was possible to calculate approximated values for the vertical movements. First the starting point had to be determined from the position of last upward movement until the peak of normalization (striving towards 0). The calculated starting point is around 385 px. The starting point according to the gaze points in *EyeValuation* is 375 px, so it is a pretty good result.

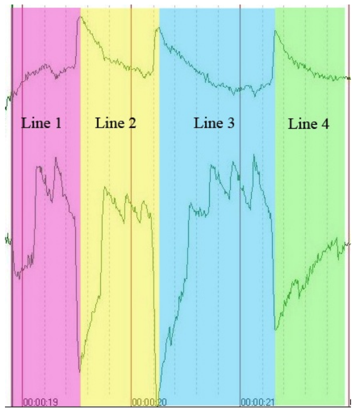

Figure 7: Filtered and labeled EOG data (from *Neurowerk*).

For the starting point of line two the distance from the last peak up until the starting of the downward movement (maximum amplitude) is needed. The calculation of the starting point of line 2 result in a value of around 478 px. Compared to the gaze point from *EyeValuation*, which is around 480, the result is very satisfying. The same happens with the other two lines, the results are always in the proximity of the eye tracking position.
The calculation of horizontal positions is a bit more complicated. The micro jumps caused be fixations and saccades while reading have to be included into the calculations, therefore increasing the amount of work. These calculations are not part of this paper.

4 CONCLUSIONS

The information gain of the EOG when compared to proven measuring systems (eye tracking system) is high. It is recommendable to use the EOG system in combination with commercial eye tracking systems to obtain verified results. EOG data is useful in the field of eye movement analysis. The problems described in section 3 are the initial point for the continuation of this experiment. The first results were satisfying for vertical eye movements.

The development of an eye tracking system with an integrated EOG system to visualize and interpret both data sets could be the next goal, offering fields of application in health business.

REFERENCES

Duchowski, A. (2007). *Eye Tracking Methodology: Theory and Practice*. Springer Verlag.

Joos, M., Ritting, M., and Velichkovsky, B. (2003). Die Bewegungen des menschlichen Auges: Fakten, Methoden, innovative Anwendungen. In *Psycholinguistik: Ein internationales Handbuch*, pages 142–168. De Gruyter.

Malmivuo, J. and Plonsey, R. (1995). *Bioelectromagnetism: Principles and Applications of Bioelectric and Biomagnetic Fields*. Oxford University Press.