

RESEARCH QUESTION

Can eye movement and blinks be classified using signals provided by eyewear-mounted sensors?

INTRODUCTION

Eye movement are a direct reflex of a person's cognitive state [1]. The **MEME eyeglasses** manufactured by **JINS** (Fig. 1) provides us with an unmatched opportunity of registering such information in an unobtrusive way, and process it to obtain relevant measures regarding their level of fatigue, the activities they are performing or even some clinical events.

The aim of this study is to develop a fast algorithm to **classify eye movements and blinks using** electrooculography (EOG) and **acceleration** of the head provided by eyewear-mounted sensors.

METHODS

Using EOG and the acceleration of the head at a constant rate of 100 Hz, an adaptive filter combining a low-pass filter, linear regression and Wiener filtering was used to remove motion artefacts from the EOG data streams (Fig. 2). Batches of 20 seconds of data were decomposed by DB4 wavelets into 8 levels of detail.

The root mean square of the signal obtained by reconstructing the 3rd-to-5th levels was used to identify and distinguish horizontal and vertical movements, and the value of the 8th level was used to classify the orientation of the movement (left vs. right, or up vs. down) Fig. 3.

Five young adults participated in a controlled experiment to **verify** the efficacy of the wavelet-based **algorithm** to detect gaze movements in horizontal (left-right) and vertical (up-down) directions and blinks. The subjects wore the instrumented glasses, and sat in front of a computer. The JINS MEME data logger was started at the same time as the **Tobii T120** eye tracker, which was used as auxiliary measure to verify the movements of the eyes and blinks.

RESULTS

The decomposition of the discrete wavelet transform (DWT) contained alternating horizontal components (EOGH) in the first 10 seconds, alternating vertical components (EOGV) after 15 seconds, and combined blinks. All the events were observed as oscillations of different amplitudes in EOGV, while horizontal movements at the beginning were also observed in EOGH (Fig. 4).

The algorithm had a different behaviour for eye movements and blinks. It had a very high sensitivity for the detection of movements in all directions (greater than 90%). No type of movement was missed, although some were wrongly classified (5% of them on average), and there were also false movement detections; so all in all the specificity of the algorithm was between 70% and 90%, depending on the direction of the movement.

However, the algorithm had a poor sensitivity to detect blinks (35.7%), which were often missed or misclassified as movements in the upward direction. However, the blink detection was extremely specific (100%), i.e. there was no false blink detection (Table 1).

REFERENCES

- Henderson et al. (2013). "Predicting Cognitive State from Eye Movements". PLOS ONE

DISCUSSION

The major contribution of this paper is the fast algorithm to process 20 seconds of raw data in 2.8 ms implemented in Julia, with the possibility of providing real-time feedback of eye movements from normal eyewear.

The artefacts of head motion could be successfully removed at slow rotational velocities, compatible with normal visual task at rest.

Using machine learning techniques, certain daily life, such as reading, watching TV, etc. can be classified.

FIGURES



Fig. 1: JINS MEME

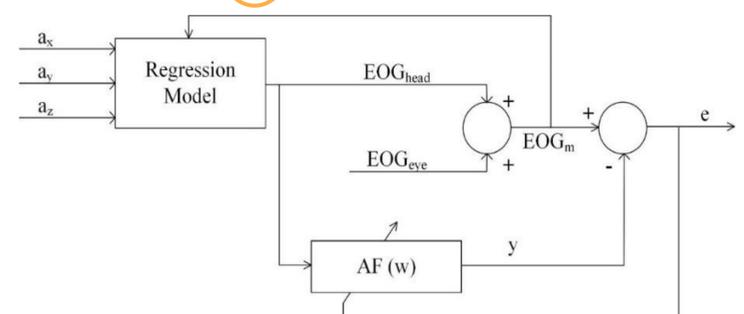


Fig. 2: Regression model and filter blocks diagram.

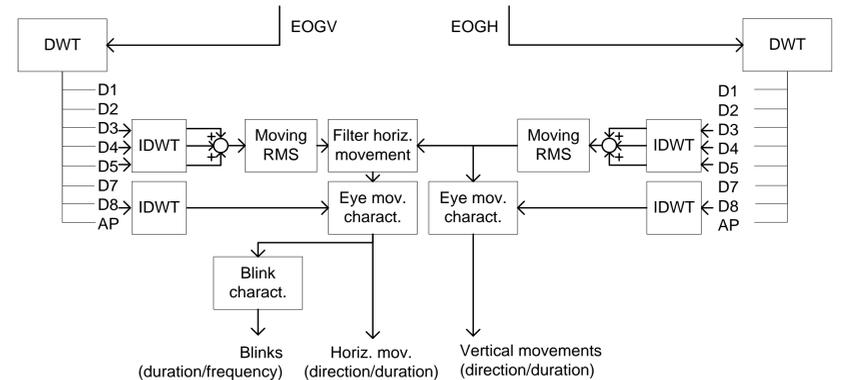


Fig. 3: Work flow of the EOG analysis.

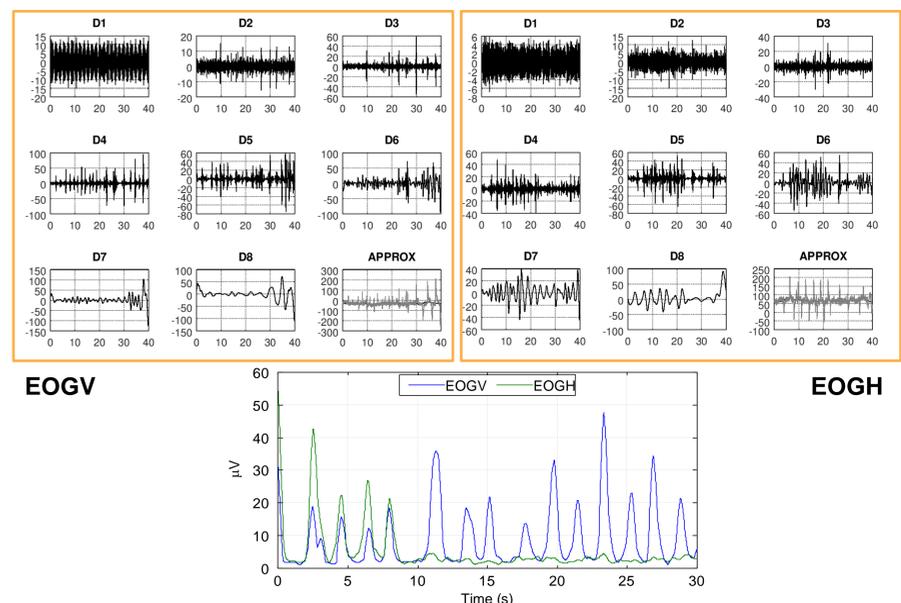


Fig. 4: Moving RMS of D3+D4+D5 in EOGV and EOGH.

	Up	Down	Left	Right	Blink	Overall
Sensitivity	92.0%	93.5%	100%	96.3%	35.7%	88.3%
Specificity	79.3%	90.6%	71.9%	86.7%	100%	82.8%

Table 1: Reliability statics.