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Eye Vibration Detection Using High-speed Optical Tracking and Pupil Center Corneal Reflection

S. Matsumura, T. Sueishi, S. Yachida, and M. Ishikawa

***Abstract*— Fixational eye moments, such as microsaccades, are a useful phenomenon to understand human internal states. Conventional detection methods of such eye vibration, however, have a limitation of a fixed head due to a trade-off between camera resolution and angle of view. In this paper, we propose a new method to detect small eye vibration using high-speed optical control. The high-speed optical control enables to observe dynamic eyes at high resolution, and to measure the small eye vibration from the unrestrained human using pupil center corneal reflection. Experimental results have showed the detected small eye vibration with the unrestrained head.**

I. Introduction

Conventional eye vibration detection methods have shown that microsaccades are correlated with human internal states such as health and attention. However, high resolution images are needed to detect eye vibration, and the human head must be fixed due to a trade-off between resolution and view angle. A main goal of this study is eye vibration detection with the unfixed head. We propose a new eye vibration detection using high-speed optical tracking for a dynamic iris [1].

II. Methods

The proposed method consists of two parts; the first part is a dynamic acquisition of eye images. The dynamic image acquisition utilizes a high-speed optical tracking system, which consists of a 1,000-fps tracking camera, an infrared light, high-speed rotational mirrors, a variable focus liquid lens, and wide-angle and observation cameras at 500 fps. The 1,000-fps camera tracks a retroreflective marker under the eye with high-speed visual feedback to the mirror angles. Triangulation using the wide-angle camera and mirror angles [1] also control focus of the liquid lens quickly. The observation camera (the same optical axis with the tracking camera) can capture high-resolution focused eye images.

The second part is the detection of vibration candidates using pupil center corneal reflection (one camera, one light source) [2]. We use distances between the pupil center and the corneal reflection in the image coordinates instead of eye angles using the positional relationship with the display [2] due to the unfixed head. We also utilize a microsaccade detection method [3] as outliers of the following velocity,

$$\vec{V}_n = \frac{\vec{X}_{n+2} + \vec{X}_{n+1} - \vec{X}_{n-1} - \vec{X}_{n-2}}{6\Delta t}. \quad (1)$$

S. Matsumura, T. Sueishi and M. Ishikawa are with The University of Tokyo, Hongo, 7-3-1, Bunkyo-ku, Tokyo 113-8656 Japan. {matsumura, sueishi, ishikawa}@ishikawa-vision.org

S. Yachida is with NEC Corporation, Shimommabe, 1753, Kawasaki, 211-8666, Japan. s-yachida@nec.com

This equation stands for both differentiation and low pass filtering. In this paper, we only deal with horizontal signals for the sake of clarity against noise. Then, microsaccades are detected when the absolute value of the velocity exceeds a threshold value in N samples. The threshold is calculated by

$$\eta_x = \lambda \sigma_x \quad (2)$$

where sigma is the square of the standard deviation of the velocity distribution and lambda is a constant set by the user. In this experiment, lambda was set to 0.04 and N was set to 2.

III. Results

The experiment was approved by The University of Tokyo (UT-IST-RE-200616-2b). The distance between the seated human and the device was about 1 m. Fig. 1 shows the results for an unconstrained, slightly moving head.

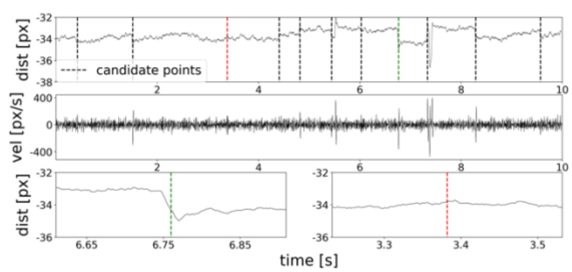

Figure 1. The upper row is the relative distance between the pupil center and corneal reflection. The vertical dashed lines are the microsaccade candidates. The middle row is the velocity. The bottom left/right plots are the enlarged plots of small vibrations and inappropriate candidates, respectively.

We could confirm some detected eye vibrations (e.g. green line) except for false detections that may be caused by noise or mirror vibration (e.g., red line). In our setup, 1 px corresponds to about 0.25 to 0.33 deg eye rotation. By assuming this scale transformation, many candidate locations are considered to be microsaccade-equivalent sized vibrations. For future works, we will investigate appropriate parameters of the algorithm, and evaluate the proposed method against microsaccades more precisely.

References

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