XIV Jornadas
Investigación Departamental
"San Alberto Magno"
8 – 12 de nov. de 2010

Determination of eye movements from pupil tracking

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SUMMARY

The human eye is constantly moving even when it is maintaining a stable fixation point. Stable images on the retina rapidly saturate the photoreceptors and fade. The visual system needs of constant stimulation to which it adapts. These constant changes are achieved by fixation micromovements consisting of microtremors, drifts and microsaccades. Thus, accurate determination of pupil center is useful for precise eye tracking.

We present a technique for pupil segmentation and contour analysis which will provide valuable information about fixational eye movements. The method is based on fitting an ellipse to the pupil contour. Pupillary hippus, microsaccades and drifts are obtained, as well cyclotorsions

MATERIAL AND METHODS

FIG. 1. Slit-lamp and digital video camera used to capture the images of frontal cornea.

Images of the frontal cornea were obtained by illuminating the eye with a Haag-Street style slit-lamp (SL-990). Video sequences were captured with a digital video camera working at 63 fps and a spatial resolution of 800x560 px attached to the lamp (see Fig.1). Diffused illumination was used to obtain uniform illumination on the whole cornea and a red filter was additionally used to avoid discomfort to the subject.

Three different sequences were registered for each subject's right eye with the left eye occluded. Measurements were taken in total darkness to avoid reflections and discomfort to the subjects. During the measurements a red LED was used as a fixation point. Residual head movements were restrained by the use of a dental bite bar and firmly fastening the head to the chinrest frame. Finally, the chinrest structure was reinforced with lateral supports, as can be appreciated in Figure 1.

Obtained images are analyzed off-line using MATLAB. Edge detection algorithms were applied to determine the pupil contour which is fitted to an ellipse. Position of the center of the ellipse gives information about slow (drifts) and sudden eye movements (microsacaddes), while rotation of the axes describes spontaneous cyclo-torsional movements. Furthermore, variation of the pupil area provides information about spontaneous changes un pupil aperture, known as "hippus" .

First step for image processing consists of selecting a threshold value for hard clipping of the image thus obtaining a black region of interest which corresponds to the pupil. Edge detection determines the border of the black area and thus traces the pupil contour. An example of the fitting results is shown in figure 2. *(a) Image representing the pupil contour. (b) Adjustment of contour data. (c) Image representing the pupil contour and adjustment*

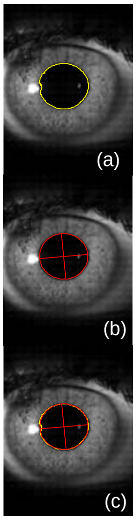

FIG. 2.

RESULTS

Eye movement has been analyzed by tracking the centre of the ellipse, *(X0,Y0)*, as can be seen from the figure 3(a). If we represent separately both coordinates, we can distinguish the different eye movements. Microsaccades can be clearly identified as sudden jumps. Their duration is of about 25 ms (1-2 frames) and they occur 1 or 2 per second along a straight path mainly in the horizontal direction (Figure 3). Drifts can be seen as a smooth variation in the position of the eye. Fine variations of the eye position around the drift path may come from eye pulsations or undersampled tremors.

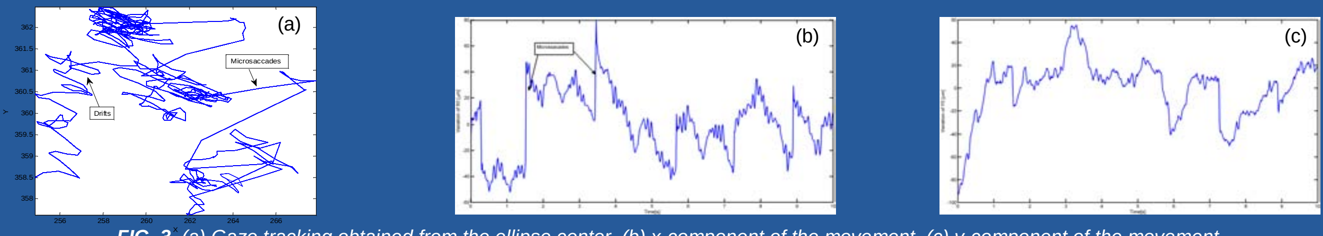

FIG. 3. *(a) Gaze tracking obtained from the ellipse center. (b) x-component of the movement. (c) y-component of the movement*

From the area of the pupil and its orientation one can obtain the variation of the area (hippus) as well as corneal cyclotorsions (Figures 4 and 5)

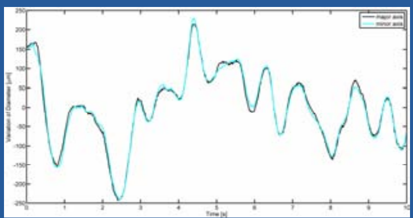

FIG. 4. *Variation of the pupil diameter for a typical subject.*

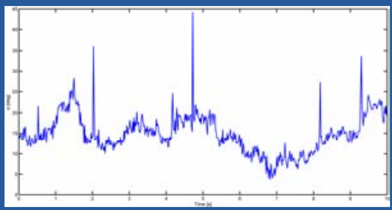

FIG. 5. *Variation of the pupil orientation for a typical subject.*

Applied method for detecting pupil contour allows tracking the fixational eye movements. With a simple setup and software application, we are able to detect small microsaccades and drift movements, as well as cyclotorsional movements.

REFERENCES

Roig, A.B.; Morales, M.; Espinosa, J.; Pérez, J.; Mas, D.; Illueca, C.; "Pupil detection and tracking for analysis of fixational eye micromovements", Optik 2010 (accepted)