Limits in Measuring Torsional Eye-Position Using Video-Oculography-Devices

*K. Schreiber# and T. Haslwanter**

#Department of Neurology, Tübingen **Department of Neurology, Zurich*

Introduction

Recent developments in computer hard- and software have made video-oculography- or VOG-devices for measuring eye-position widely available. While in measuring the horizontal and vertical position of the eye the algorithms used are mostly based on detection of the pupil and subsequent calculation of the angular position of the eye thereof, torsional measurements are usually carried out using iral signature patterns and cross-correlation-methods. In a reference image of the eye a segment on the iris is chosen and the iral reference pattern extracted. In data images the same segment on the iris is then sought, making use of pupil detection and geometric corrections. Another iral pattern is then extracted there. The position of the maximum of the cross-correlation-function, which is calculated from this pattern and the reference pattern, then allows for the calculation of the torsional angle.
Due to the mathematics involved, it is more difficult to estimate the limits of measurement and the possible sources of error in measuring torsion than it is in measuring horizontal or vertical eye position. Specifically, when recording horizontally or vertically moving eyes, the recorded image will blur, making it less easy or even impossible to correctly measure ocular torsion. Simulations have been carried out to give an estimate of the eye velocity from which torsion measurement will be likely to fail.

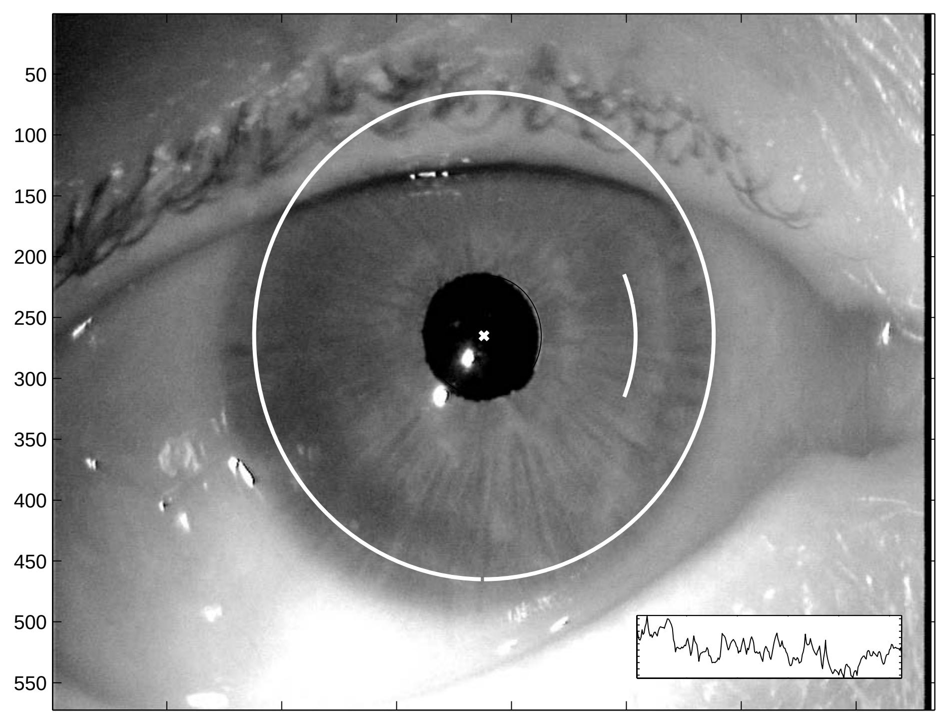


Figure 1. Used image of eye, iral segment and corresponding iral pattern.

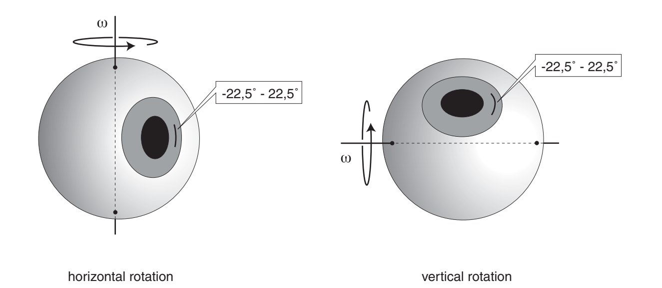


Figure 2. Simulation setup

Method

The simulations of torsion measurement in moving eyes were based on one frontally taken ("input") image on an eye (Fig. 1). The position of the iral segment is fixed in the camera plane during exposure time, but the simulated eye's iris slides through as the eye rotates.
To obtain the simulated, blurred iris pattern, the momentary position of the eye in space was calculated 20 times during the exposure period. This was in turn used to calculate the line on the iris that projected to the sample segment's position in the camera plane at that time. At the found coordinates on the iris the actual signature was then extracted from the input image. The mean value of the 20 found iris patterns was taken for the blurred pattern.
These calculations were carried out for eye velocities from 0 degree/second to 300 degree/second in pure horizontal and in pure vertical direction (Fig. 2), thus covering the physiologically relevant range. To give an estimation of how large an effect on the measurements should be expected, figure 3 shows the parts of the iris contributing to the blurred pattern at a speed of 300 degrees/second with realistic parameters for radius of the eye and used camera equipment (exposure time 18ms). In addition, figure 4 shows the iris pattern with increasing eye velocitiy. Note how details of the pattern "wash out" rather quickly.

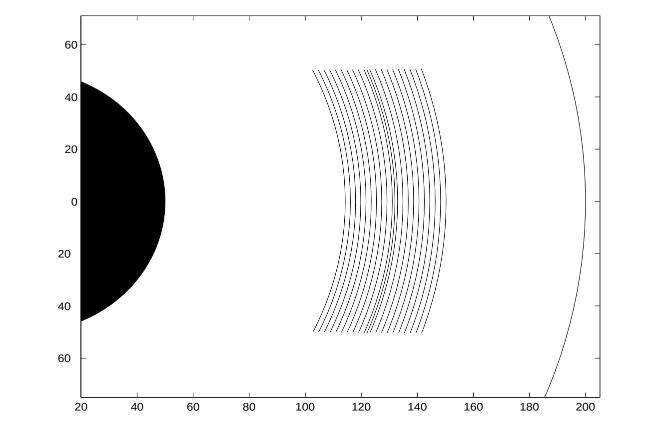


Figure 3. Parts of the iris contributing to the pattern; left is the pupil, right the border of the cornea

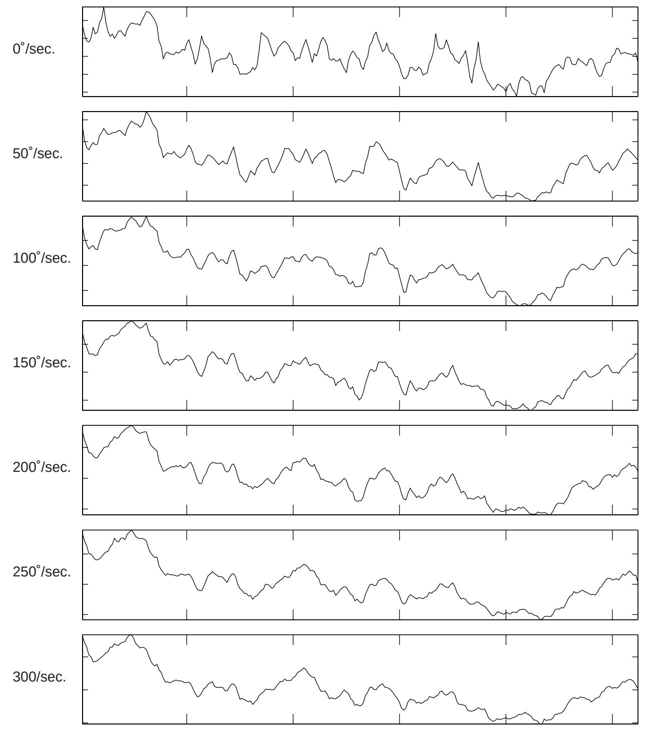


Figure 4. Iral pattern wash out

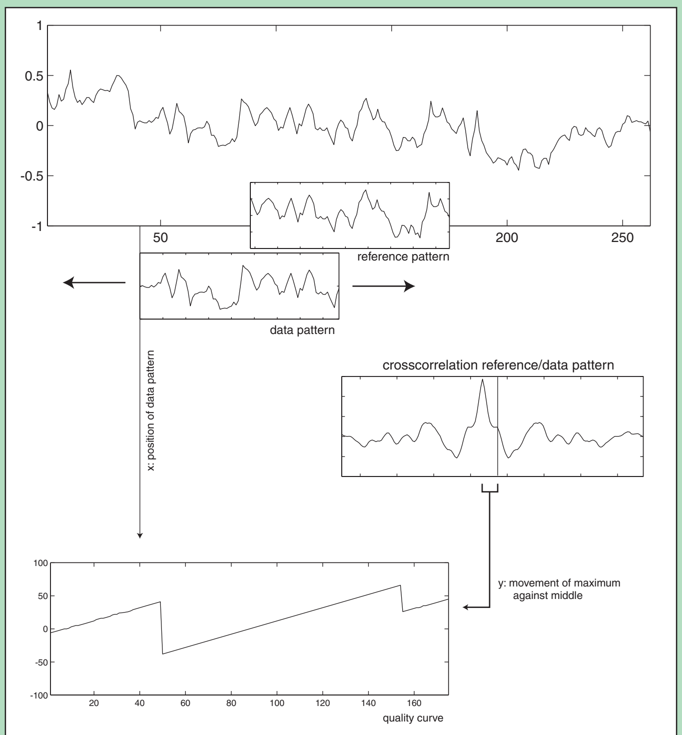


Figure 5. Quality curve used for calculation of the MAD

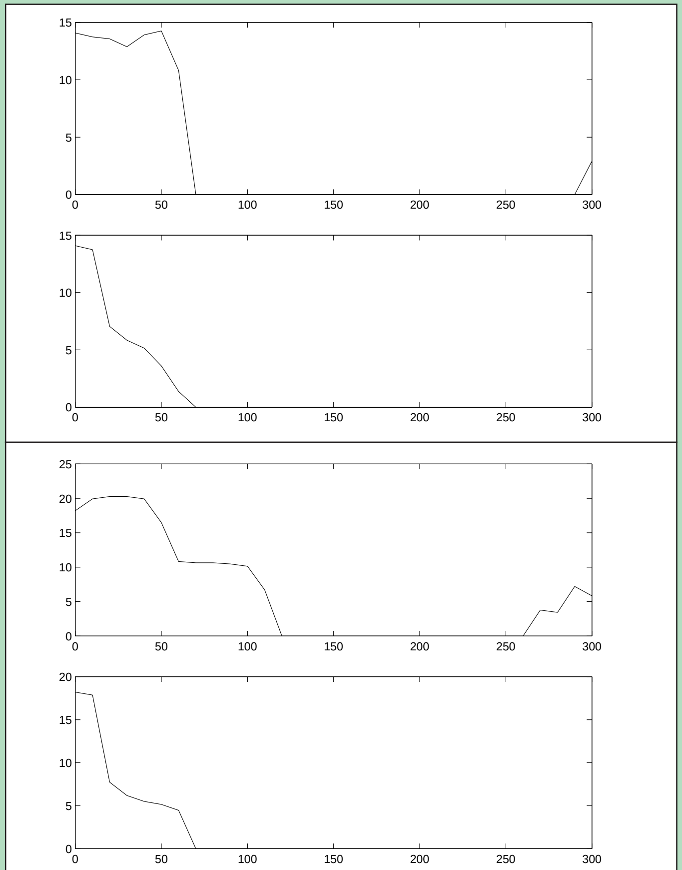
To be able to estimate the suitability for measurement of a simulated blurred iris pattern, one needs a solid criterion. I used the "measurable angular distance" (MAD) (Fig. 5). To calculate the MAD of a given pattern, measurement of torsion is simulated using the method described above, using the central third of the pattern as the reference pattern and variable thirds of the pattern as data patterns. From the cross-correlation of the data third with the reference third the position of the maximum is taken and compared to the actual position of the data third. Ideally the maximum should move according to the movement of the data third on the analysed pattern, resulting in a quality curve y = x - a, where a is an offset representing half the original patterns length. Since deviation from this ideal curve is due to measurement errors from poor pattern quality, the wanted criterion MAD is the range (measured in degrees) around the middle of the quality curve, wherein the deviation of the curve from it's ideal form (i.e. the error in measurement) stays below a certain limit.
The MAD of an iral pattern thus represents the maximum torsion angle that can be expected to be measured correctly using that iral pattern.
For estimating the quality of the simulated blurred images, however, a slightly different form of the MAD had to be used. Since real measures would be taken using a unblurred reference pattern from a still, the quality curve was likewise calculated, using the middle third of the unblurred iral pattern that was under the segment in the camera plane at the middle of the exposure period.

Results

Plotting the MAD against increasing eye velocity (Fig. 6 and 7) shows that beginning at 70 degrees/second exact measurements of torsion become impossible for even little torsional angles. When the allowed error is increased, so is the maximum velocity (Fig. 7).

Conclusion

Results of the simulations show that, with typical values for exposure time and eye velocity, measurement of torsional eye position will be very difficult when the eye moves while the recording takes place. So exposure time has to be significantly decreased to allow for torsion measurement.



Figures 6 and 7. MAD against angular velocity. Shown is the MAD for horizontal (top) and for vertical (bottom) movements, with an error limit (see text) of 0.085 degrees in figure 6, 0.17 degress in figure 7.