Motion tracking of iris features to detect small eye movements

Aayush K.Chaudhary (akc5959@rit.edu) Jeff B. Pelz(pelz@cis.rit.edu)
Chester F. Carlson Center for Imaging Science
Rochester Institute of Technology, Rochester, NY 14623

MULTIDISCIPLINARY VISION RESEARCH LAB

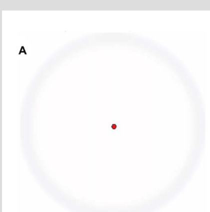
Chester F. Carlson CENTER *for* IMAGING SCIENCE

Abstract

- Current video-based eye trackers are unable to reliably detect very small eye movements, leading to confusion about the prevalence or even the existence of monocular microsaccades (small, rapid eye movements that occur in only one eye at a time).
- Because current methods often rely on precisely localizing the pupil and/or corneal reflection on successive frames, current microsaccade-detection algorithms often suffer from signal artifacts and low signal-to-noise ratio.
- We present a new video-based eye tracking methodology which can reliably detect small eye movements over 0.1 degrees with very high confidence.
- Our method uses motion tracking of iris features to estimate velocity rather than position, yielding a better record of small eye movements.
- We provide a more robust, detailed record of miniature eye movements by relying on more stable, higher-order features (such as local features of iris texture) instead of lower-order features (such as pupil center and corneal reflection), which are sensitive to noise and drift.

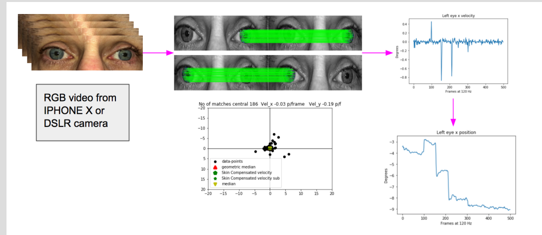
Overview

- To maintain vision and compensate for the drift between large eye movements, we continuously make small (miniature) eye movements including tremor, drifts and microsaccades.



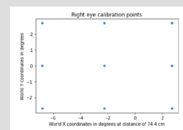
- Demonstration: Fixate on the red spot of the image. After a few seconds the ring fades, but as soon as you move your eyes the ring reappears. (Troxler effect)

Proposed Method

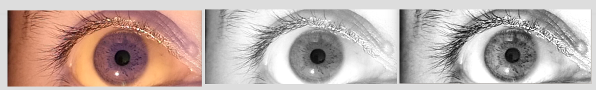


- Computer-vision technique *Speeded Up Robust Feature (SURF)* detection is used to compute feature vectors from the iris which are then matched in consecutive frames using brute-force matching followed by random sample consensus (RANSAC) and homography.
- Tracking the geometric median of these matched keypoints approximates the velocity which on thresholding identifies microsaccades.

Experiment



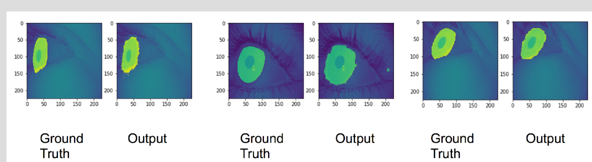
- Task: Participants were asked to fixate each calibration point for approximately 2 seconds.
- Setup: HD videos were recorded on at iPhone at 120 Hz and a DSLR at 96 Hz with the head stabilized in a chin rest.
- Calibration points were 74.4 cm from the eyes.



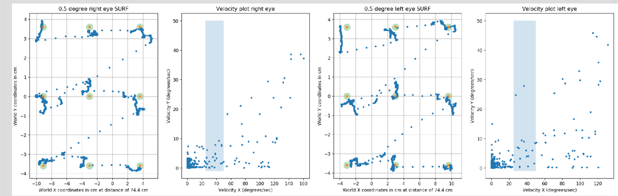
- (Left to right) RGB eye image, R channel and R channel after *Contrast Limited Adaptive Histogram Equalization (CLAHE)* which is used for feature matching.

Iris Segmentation

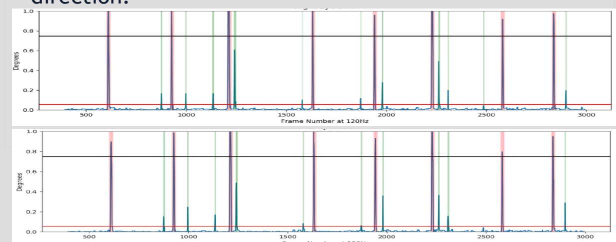
- CIELAB color separation was used to separate light irises.
- Dark-colored irises required a more complex solution:
  - Transfer learning on U-Net model for semantic segmentation of two classes (iris and non-iris region)
  - Trained on 880 images with a batch size of 8 images.
  - Result: Intersection over Union value of 86.8% for uncorrelated data and 87.9% for correlated data



Results

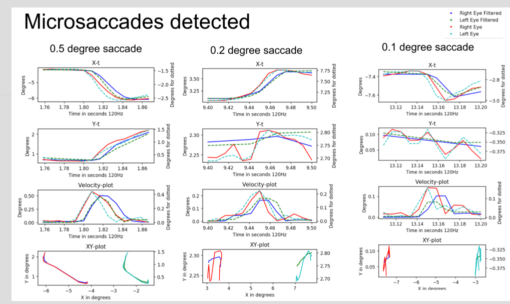


- Calibration targets as seen by participants. Green circle indicates 0.5 degree from the marker in horizontal direction.



- Velocity of right and left eyes in degrees per frame. Red and green highlighted area indicate saccades and microsaccades respectively.

Visualization of microsaccades



- Raw data is filtered using 1D total variation denoising to remove noise with regularization parameter of 0.1

Conclusion

It is possible to detect miniature eye movements with good confidence by computing the geometric median of the motion of the local features of iris, captured with a high-resolution camera.

References

- Martinez-Conde, Susana, Stephen L. Macknik, and David H. Hubel. "The role of fixational eye movements in visual perception." *Nature reviews neuroscience* 5.3 (2004): 229.
- Ronneberger, Olaf, Philipp Fischer, and Thomas Brox. "U-net: Convolutional networks for biomedical image segmentation." *International Conference on Medical image computing and computer-assisted intervention.* Springer, Cham, 2015.
- Condat, Laurent. "A Direct Algorithm for 1-D Total Variation Denoising." IEEE Signal Process. Lett. 20.11 (2013): 1054-1057.