Automated System for Template Matching Using SLO Images

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Vessel junction–guided template matching enables accurate gaze estimation

Emily Chen, Yifan Zhang, Christian Sinnott, PhD, Jacqueline Theis, OD,
Francesco La Rocca, PhD, Yasin Karimi, PhD, Reynaldo Quintana, Christy K. Sheehy, PhD and Joe Xing, PhD

Purpose

Automated scanning laser ophthalmoscopy (SLO) registration of the retina is challenged by motion and variability. To mitigate the above limitations, we propose junction-guided adaptive template matching.

Goal: accurate gaze estimation relative to the fovea

Methods

Experimental setup

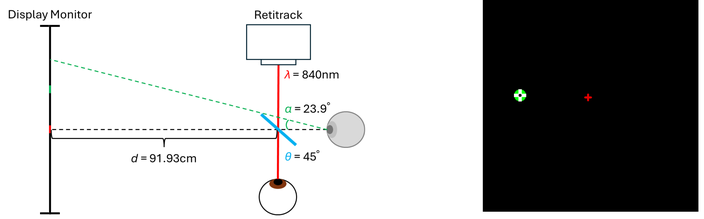

Figure 1: Dual-path optical setup and stimulus target example

Optical layout with a 45° pellicle beamsplitter enabling simultaneous imaging and stimulus projection along two paths. The display monitor is located ~91.9 cm from the participant.

Automated Gaze Estimation Pipeline

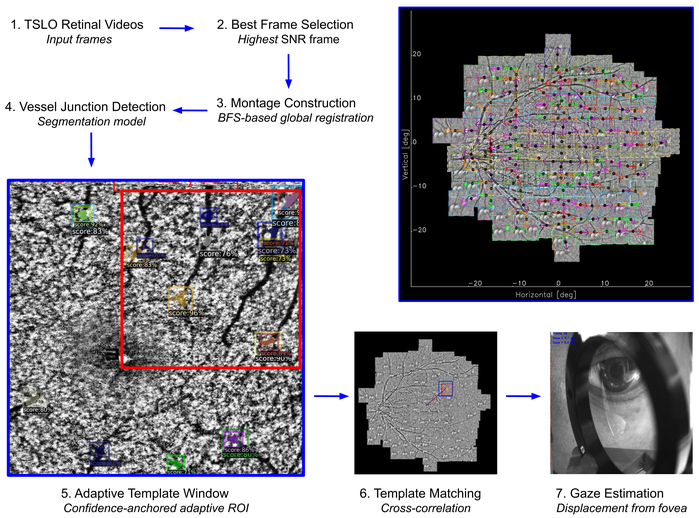

Figure 2: SLO data collection and adaptive template generation pipeline

SLO videos from 179 stimulus positions were used to build a reference map (±23.9° horizontal, ±23.9° vertical). Vessel bifurcations were detected to generate adaptive templates for automated registration and gaze estimation.

Experimental Results

Slope ≈ 1.0

R^2 = 0.9998 (horizontal & vertical)

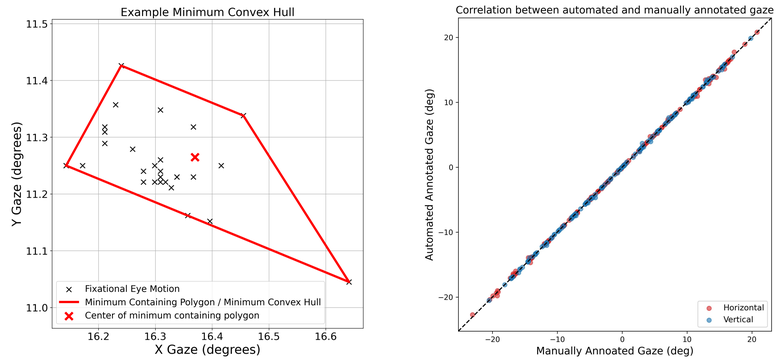

Figure 3: Example centroid gaze calculation from fixational eye motion recorded (left). Correlation between automated and manually annotated gaze (right)

There are 94.4% valid frame matches (169 / 179 frames) between automated and manually measured gaze.

Errors tightly centered at 0°

μ ≈ 0°, σ ≈ 0.68–0.69°

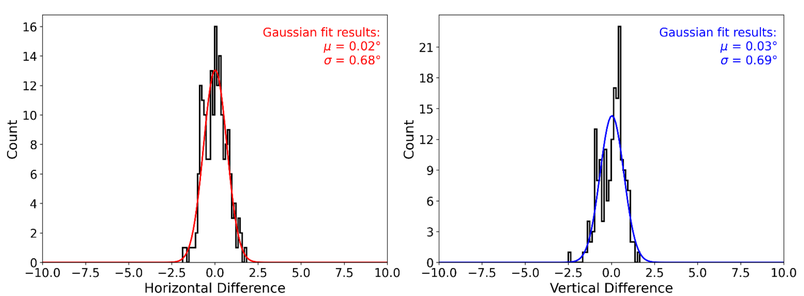

Figure 4: Distribution of horizontal (left) and vertical (right) differences between measured gaze and visual stimuli positions

Discussion

Handling edge cases in template matching

Back-reflections introduce non-corresponding features in edge cases; a displacement threshold enforces temporal consistency and filters implausible gaze shifts.

Good Case	Edge Case
Clean vessel junction match enables accurate registration.	Non-corresponding reflections disrupt cross-correlation matching.

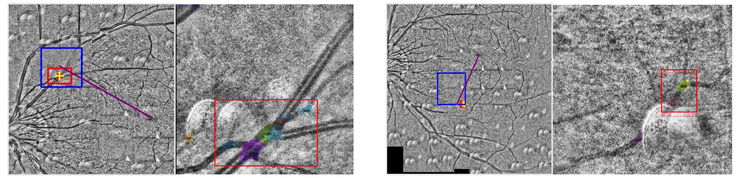

Figure 5: Template matching: success and edge cases

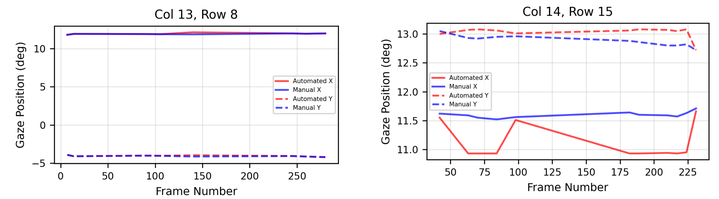

Figure 6: Frame-by-frame comparison of automated vs manual gaze estimates: success (left), edge (right)

Conclusions

- Built a fully automated system for retinal-based visual angle (gaze) measurement.
- Used AI tools to detect landmarks and stitch visual field images in ±23.9 deg in both X and Y directions.
- Achieved precise, reliable visual angle (gaze) aligned with stimuli positions.

References

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2.Fischer J, Otto T, Delori F, Pace L, Staurenghi G. Scanning laser ophthalmoscopy (SLO).In: Bille JF, ed. *High Resolution Imaging in Microscopy and Ophthalmology: New Frontiers in Biomedical Optics.* Cham, Switzerland: Springer; 2019:35–57.
3.Martinez-Conde S, Macknik SL, Hubel DH. The role of fixational eye movements in visual perception. *Nat Rev Neurosci.* 2004;5:229–240.