Vertical Cup-to-Disc Ratio Estimation using Deep Learning: Does Model Trained on Ordinary Fundus Images Generalize to Other Image Types?

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1. Background

Ultra-widefield (UWF) fundus imaging has become an increasingly popular imaging modality for retina screening, as it can capture up to 200° view of the retina and provides greater insights into peripheral retinal pathologies. On the other hand, smartphone-based fundus imaging offers great portability and has potentials to scale to large population-based screening through community clinics or telemedicine programme.

The goal of this study is to assess the generalizability of convolutional neural networks (CNN) for vCDR estimation in UWF and smartphone-based images using only ordinary fundus images (30°–60° field of view) as training data.

2. Methods

- Two CNNs based on the U-Net [1] architecture were developed using 800 images from the publicly available REFUGE database [2]
- CNN #1 detects ROIs around optic disc (OD)
- CNN #2 delineates OD and optic cup (OC)
- To improve the robustness and quality of OD/OC delineations, test-time augmentations (scaling, rotation, and flipping) was used during inference

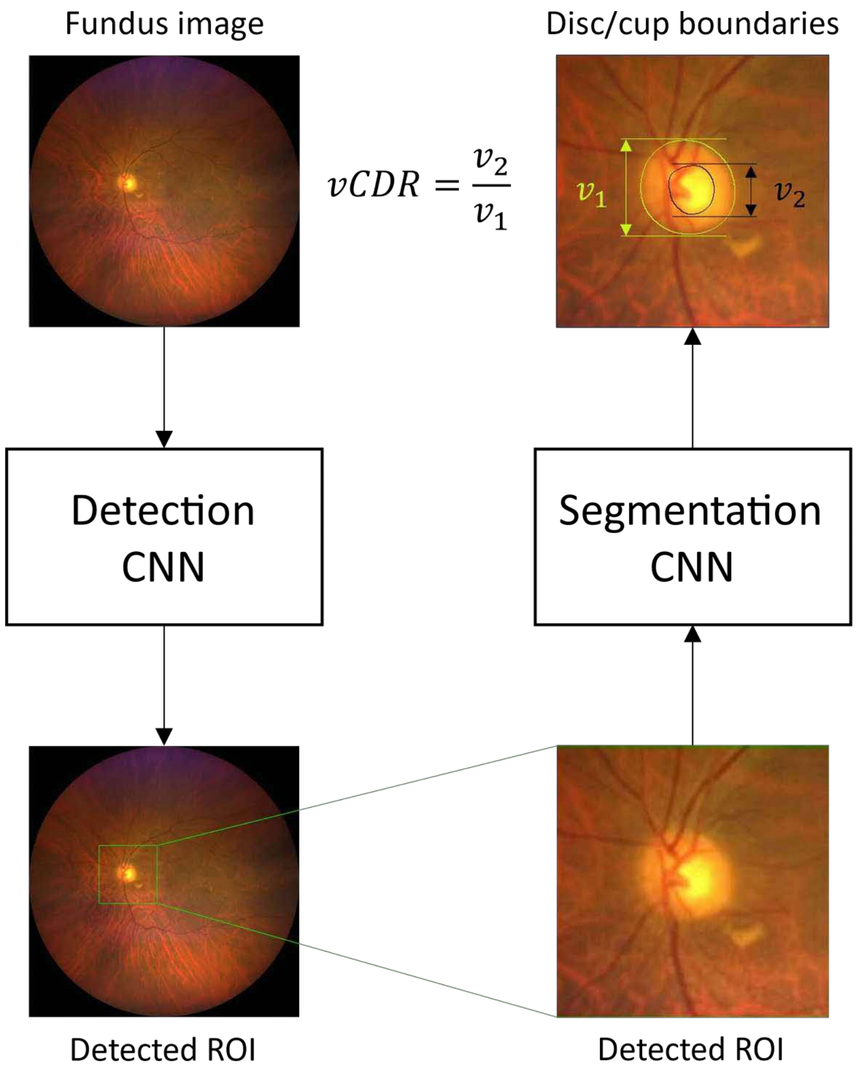

Figure 1. Pipeline of the automated vCDR estimation system

3. Results

- Estimated vCDRs were compared against reference values from ophthalmologists using mean absolute error (MAE)
- On REFUGE test set (N=400), the automated estimation system achieved an MAE of **0.040** (95% CI: 0.037–0.043)

3. Results

- On TTSH UWF images (N=245), the MAE was **0.068** (95% CI: 0.061–0.075)
- On TTSH smartphone images (N=240), the MAE was **0.081** (95% CI: 0.072–0.090)
- Differences between UWF and smartphone images in estimated vCDRs were statistically insignificant ($p>0.05$)

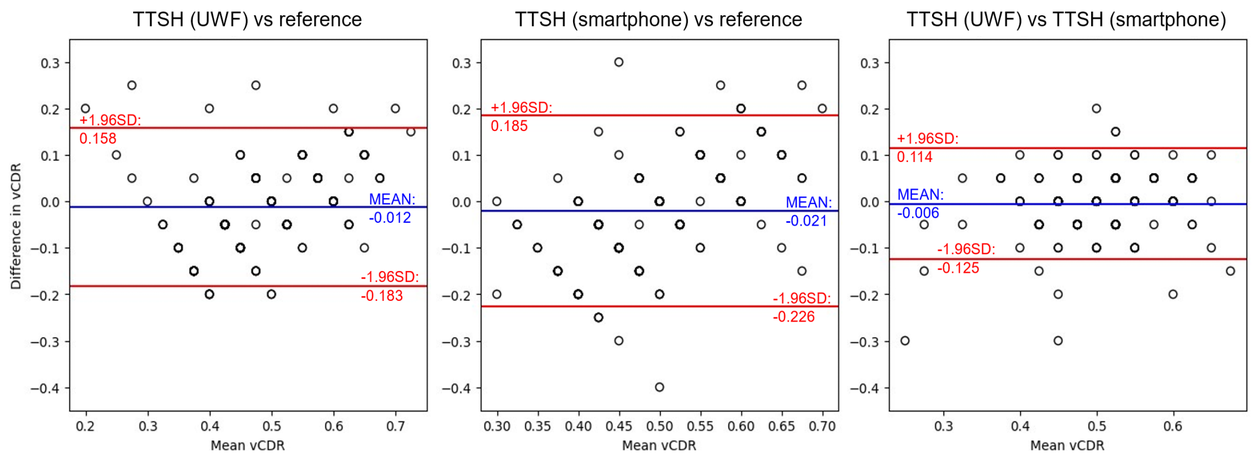

Figure 2. Bland-Altman plot analysis with 95% limit of agreement

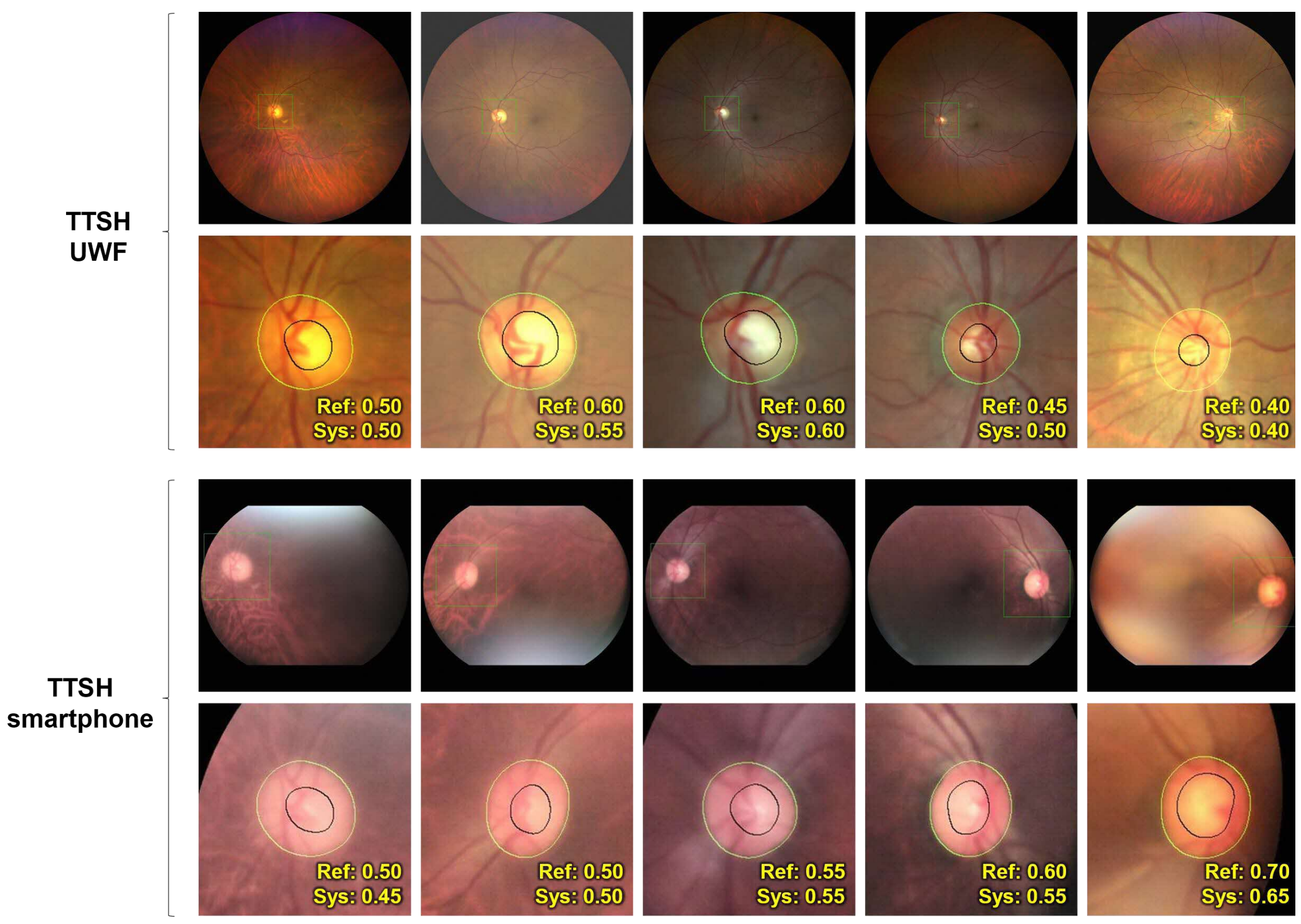

Figure 3. Examples outputs of the automated vCDR estimated system

4. Discussion

- Automated vCDR estimation system promotes scalability and accessibility to large-scale screening
- Potentials to be integrated with other parameters, e.g., intraocular pressure and visual acuity for fully automated pre-disease screening, reducing the workload of clinicians

5. Conclusion

The results suggest that deep neural networks trained on ordinary fundus images are largely generalizable to UWF and smartphone-based images, provided appropriate test-time augmentation and post-processing techniques were used.

[1] O. Ronneberger et al., "U-net: Convolutional networks for biomedical image segmentation," MICCAI, 2015.

[2] J. I. Orlando et al., "Refuge challenge: A unified framework for evaluating automated methods for glaucoma assessment from fundus photographs," Medical Image Analysis, 2019.