Improving autofocus performance in a widefield fundus imaging system using peripheral defocus measurements

Conor Leahy, PhD; David Nolan, MS; Keith O'Hara, PhD; Michael H. Chen, OD; Keith Brock, BS; Wilson Hunder, MS; Jochen Straub, PhD

Carl Zeiss Meditec, Inc., Dublin, CA

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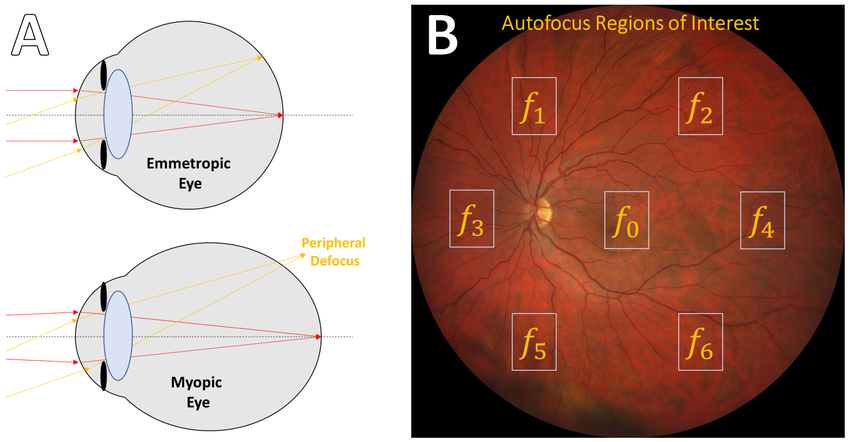
PURPOSE

Traditionally, fundus camera designs incorporate a large collection aperture to allow for comfortable levels of illumination, which limits the depth-of-field. For widefield systems, maintaining good focus across the full field-of-view (FOV) can be challenging due to the wide range of human retinal curvatures. In this study, we propose an autofocus scheme for a widefield fundus imaging system, aimed at balancing focus quality throughout both the central and peripheral field.

METHODS

A widefield slit-scanning ophthalmoscope, CLARUS™ 500 (ZEISS, Dublin, CA), with prototype software, was used for imaging the retina over a 90° FOV. During alignment, the displacement on the retina between two illumination beams entering the pupil at different locations was measured and used to infer the best instrument focus setting. In the proposed approach, best-focus is estimated for both central and peripheral retinal regions simultaneously (Figure 1A).



Instrument Focus

$$\frac{\sum_{k=1}^{N} w_k f_k}{\sum_{k=1}^{N} w_k}$$

f_k: Estimated Best-Focus at Location k

w_k: Weight at Location k

Figure 1. (A) The displacement between two illuminating beams is used to infer focus error at different retinal locations; (B) 90° FOV fundus image, showing the 7 regions-of-interest used for the proposed autofocus scheme.

An aggregated focus setting is then applied to balance focus quality across the 90° FOV. Color fundus images were captured from 12 eyes at a variety of fixation orientations, totaling 22 different imaged retinal fields. Each field was imaged using (i) autofocus based on an estimate of focus error near the center of the FOV, and (ii) the proposed approach. The captured images were graded for overall focus quality by a licensed clinician; the assigned grades were normalized to a range of 1-5 (with 5 signifying the best focus quality).

Email: conor.leahy@zeiss.com

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RESULTS

The mean scores for focus quality were 3.32 ± 0.84 for central autofocus, and 4.05 ± 0.79 for the proposed autofocus strategy. Using the proposed strategy, 16/22 images achieved a grade of 4 or better, compared to 7/22 using central autofocus.

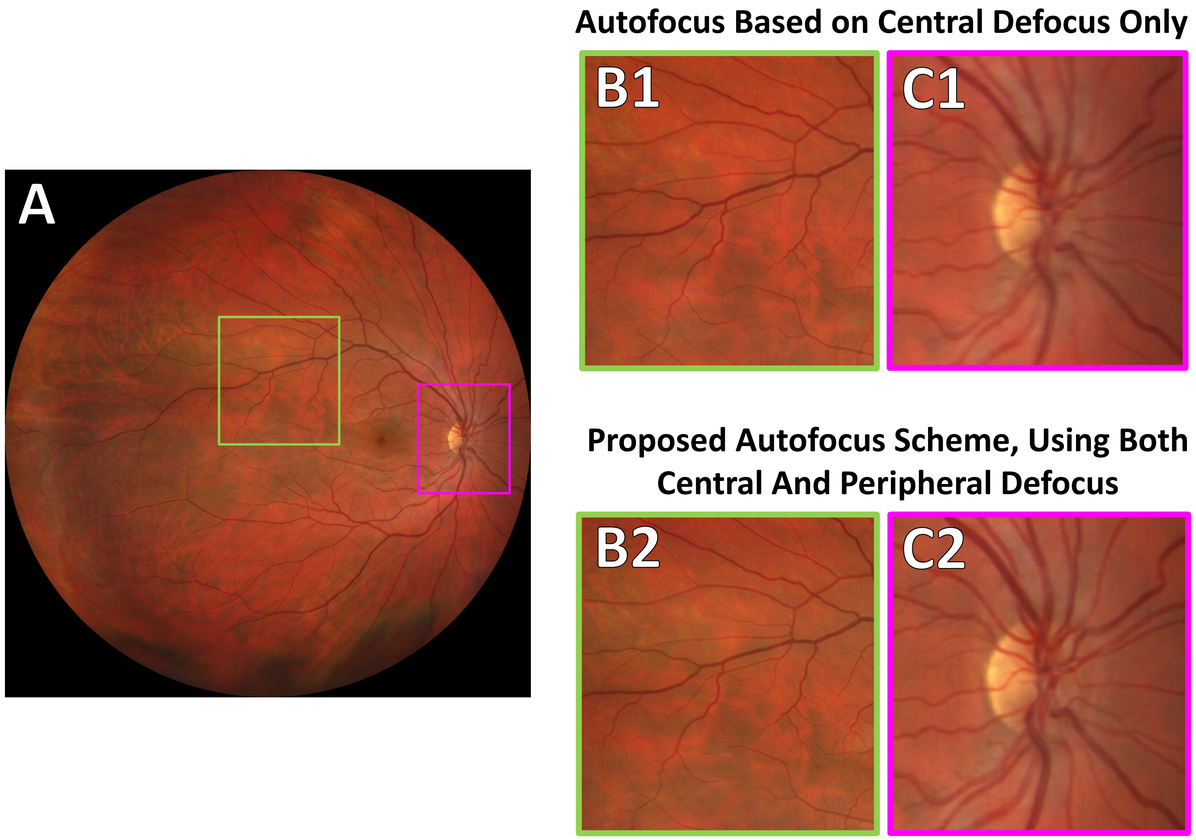

Figure 2. (A) Widefield 90° fundus image of a myopic eye. Using central autofocus, features in the green-highlighted region near the center of the FOV appear sharp (B1), but important detail in the periphery exhibits defocus (C1). The proposed autofocus scheme finds an instrument focus setting that maintains good image sharpness both at the central retina (B2) and in the periphery (C2).

CONCLUSIONS

Our results suggest that an autofocus strategy during image acquisition that attempts to compensate peripheral defocus, as well as central focus error, has the potential to improve the overall quality of focus in widefield fundus images.