

Application of higher-order statistics to the identification of retinal layers in OCT scans

Agata Gut^{*a}, D. Robert Iskander^a

^a*Department of Biomedical Engineering, Wrocław University of Science and Technology, Wrocław, Poland*

[#]*corresponding author email: 282134@student.pwr.edu.pl*

1. Background

Modern methods for segmenting retinal layers in OCT images primarily rely on denoising techniques and subsequent characterization of tissue macrostructure by analyzing the slope of the intensity signal. However, this approach may not be suitable for determining layer morphology where such slope changes are negligible. A solution to this type of problem was proposed by Williams et al. [1], who noted that two-sample statistical tests enable more effective edge detection based on higher-order moments where mean intensity changes are not guaranteed. The aim of this study is to demonstrate that with an adequately chosen battery of statistical tests it is possible to identify statistical edges of different characteristics, providing supportive information to that based on standard retinal layer segmentation techniques.

2. Methods

Define an edge as a substantial change in signal intensity. Consequently, define a statistical edge as a substantial (also statistically significant) change in some parameter of the raw OCT signal, such as, for example, the k -order moment. A tool for delineating retinal layers using speckle information from raw OCT retinal B-scans has been proposed [2]. It consists of two parts. The first part identifies the potential points of statistical edges based on distributional changes in localized speckle, using the Kolmogorov-Smirnov (KS) test, whereas the second part assigns those points to anatomically relevant boundaries, using the DBSCAN algorithm [3].

This work focused on improving the first part of this tool. In particular, the KS test was found to be ineffective for changes in higher-order moments showing good results only for those statistical edges that are well differentiated by changes in mean speckle values. Therefore, the two-sample F-test (for identifying changes in the 2nd order moment) and the projective ensemble test adapted from [4] (for identifying mostly changes in the 3rd and 4th order moments) were considered. The two latter tests were applied in the same way as the KS test, where an image is scanned column-wise using a moving window divided in half. The results of a two-sample statistical test applied to the two halves of the moving window provides identification of potential points of the statistical edge.

3. Results

Here, an illustrative example of a retinal B-scan of a healthy young adult is considered. The results show the differences in determining potential points of statistical edges using three different approaches: the KS test (Fig. 1A), the F-test (Fig. 1B), and the projective ensemble test (Fig. 1C). Note that the KS test adequately characterized major retinal boundaries such as the ILM (internal limiting membrane) or the RPE (retinal pigment epithelium) whereas the result of the projective ensemble test identifies potential points in other retinal boundaries that are not intuitive as they do not correspond to changes in mean image intensity. Comparing all point identifications using the above-described tests (Fig. 2) showed different results in point identification despite using the same input information. This indicates that the retinal OCT scan contains local areas that may have the same mean speckle characteristics values but differ in higher-order moments.

4. Conclusion

According to the presented results, the order of the statistical moment used in the two-sample test influences the identification of potential statistical edge points. Combining these points from several different statistical tests could capture more irregular but clinically significant structures (e.g., retinal epithelial layers) or changes (e.g., in the vitreous humor) in the eye. Future tool development should focus on leveraging the potential of unique feature identification by filtering out excessive points to provide a level of detail that is diagnostically and scientifically relevant.

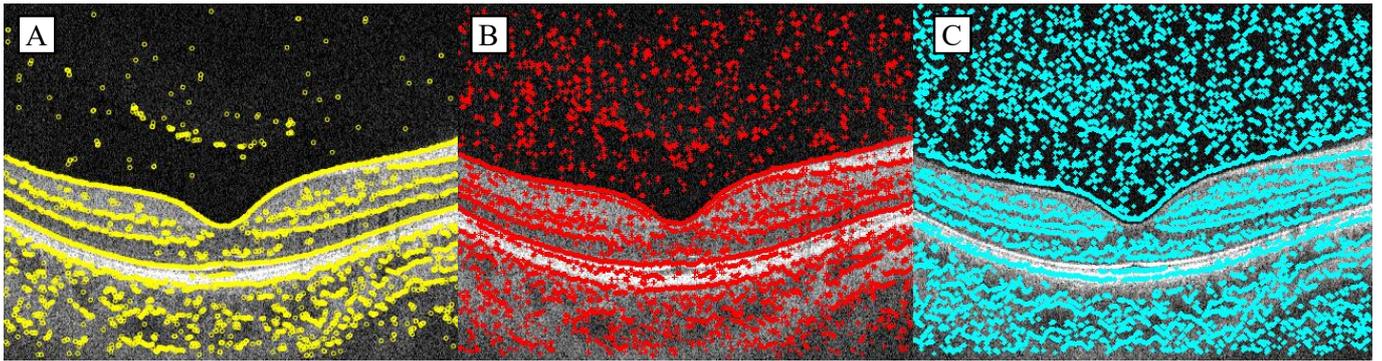


Fig. 1. The identified potential points of statistical edges for the three considered two-sample statistical tests. Fig. A — KS test (yellow circles), Fig. B — F-test (red crosses), and Fig. C — projective ensemble test (blue diamonds).

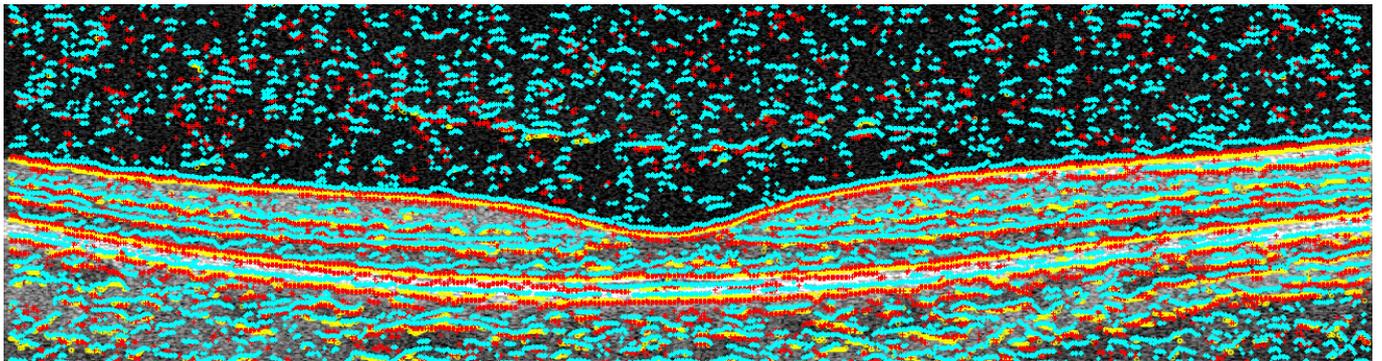


Fig. 2. The composite result for the tests from Fig. 1.

5. Acknowledgment

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6. References

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