Automated Glaucoma Classification Using Nerve Fiber Layer Segmentations On Circular Spectral Domain OCT B-Scans

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Purpose

To examine the possibility for glaucoma classification using an automated nerve fiber layer segmentation on circular OCT B-scans.

Data

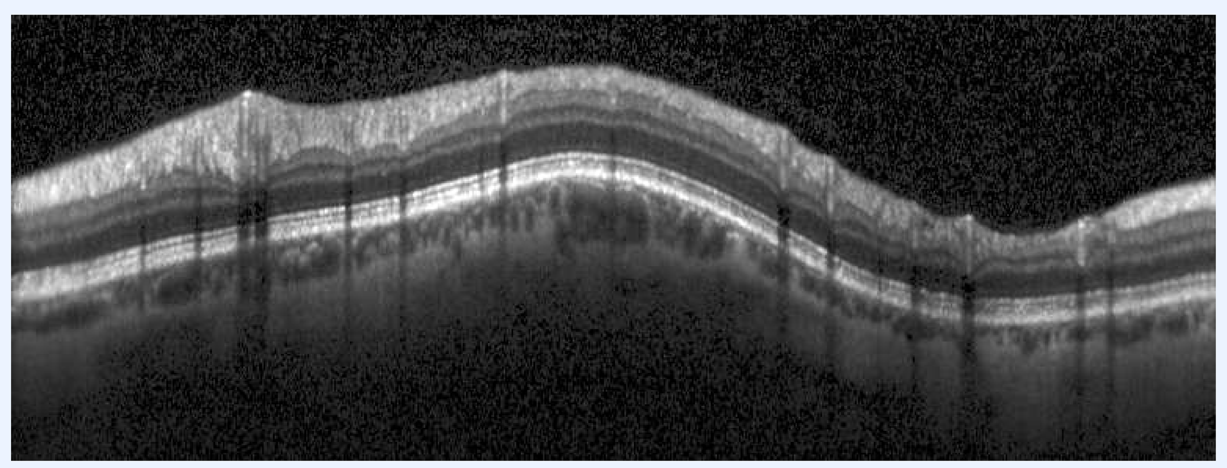
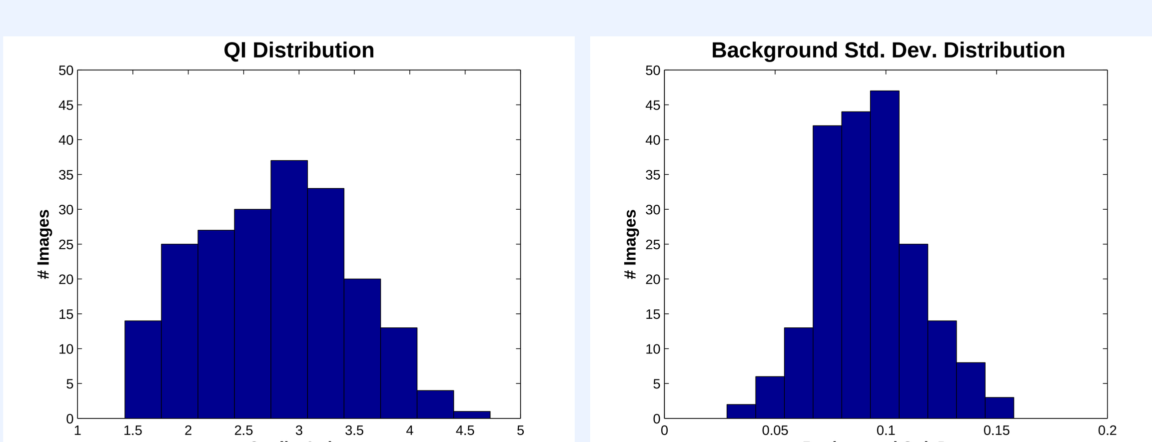


Figure 1: Circular OCT B-Scan from glaucoma patient. Crop out of 768x496 image.

Circular B-scans from 204 subjects: Centered at optic disk, diameter 3.4mm, 512 or 768 A-scans with depth resolution of 3.87μm/pixel. Spectral domain OCT system: Spectralis HRA+OCT, Heidelberg Engineering. Subject age 46.0$\pm$24.0 years.

Varying image quality: Distribution see Fig. 2. No images were excluded due to quality reasons.

Diagnosis by experts: Based on a complete ophthalmologic examination (criteria see [1] D1039 or [2]). Separation into *Normal (N, 132 subjects)* and *Glaucoma (G, 72 subjects)* group. This leads to a two-class classification problem.



(a) (b)

Figure 2: Quality distribution in the dataset. (a) Modified (adapted to Spectralis RAW data) quality index of Stein et. al. [3] (b) Standard deviation in top background region (vitreous body).

Method

An **automated retinal nerve fiber layer (RNFL) segmentation algorithm** developed at our department was used to obtain RNFL thickness profiles. A sketch of the algorithm is displayed in Fig. 3.

In addition to the automated segmentation all outcomes were corrected manually by an expert in this field (see example Fig. 4 and 5).

The following **features** were generated out of the RNFL thickness profiles:

- The *minimum, maximum* and *mean* were calculated for: All profile values, the one-third largest and the one-third smallest ones.
- The thickness profiles (768 and 512 A-Scans) were reduced to 128 values by averaging neighbors. This vector was further compressed to five values using *principal component analysis*.

This results in 14 features. No anamnesis or OCT system output parameters (compared to [4, 5]) were included to the feature vector.

The **classification experiments** were carried out on the automatically generated thickness profiles as well as on the manually corrected ones.

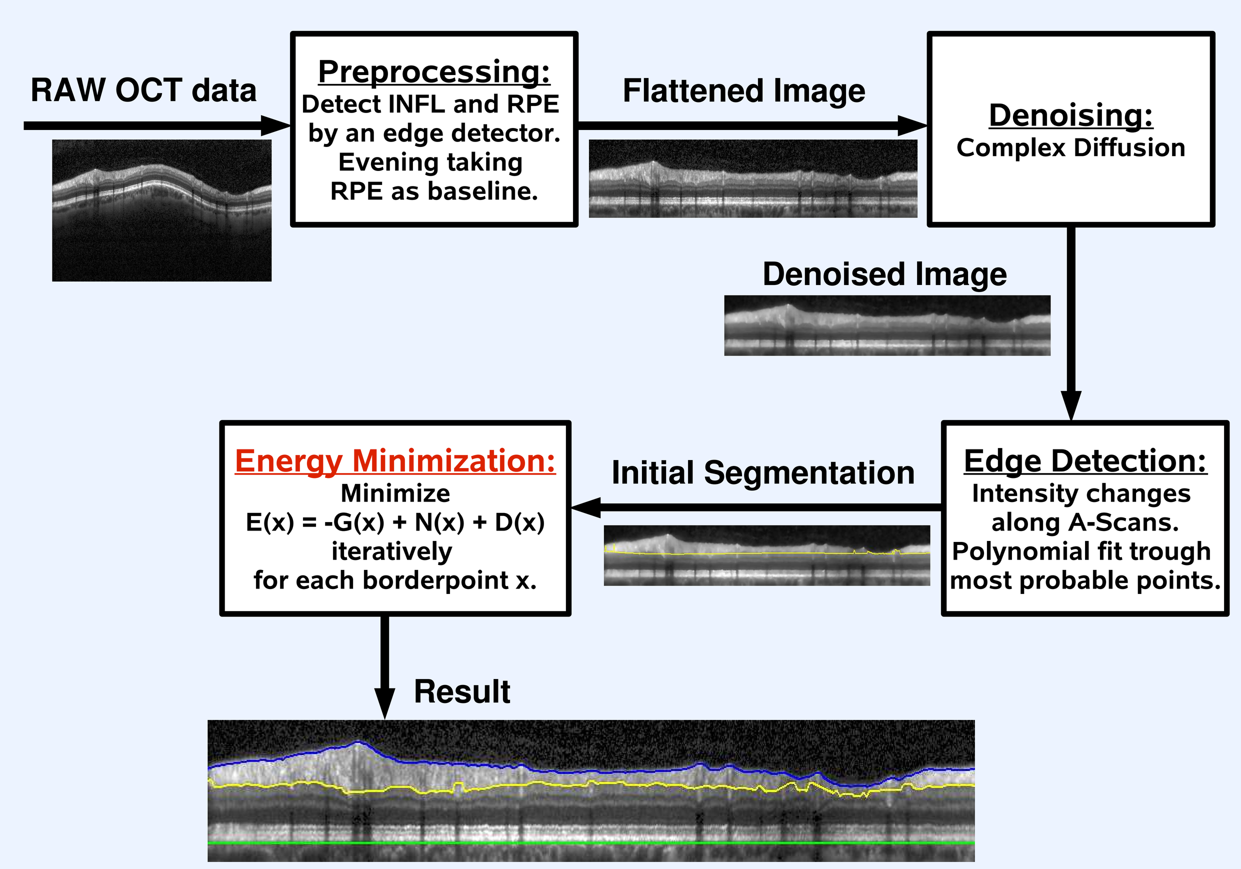
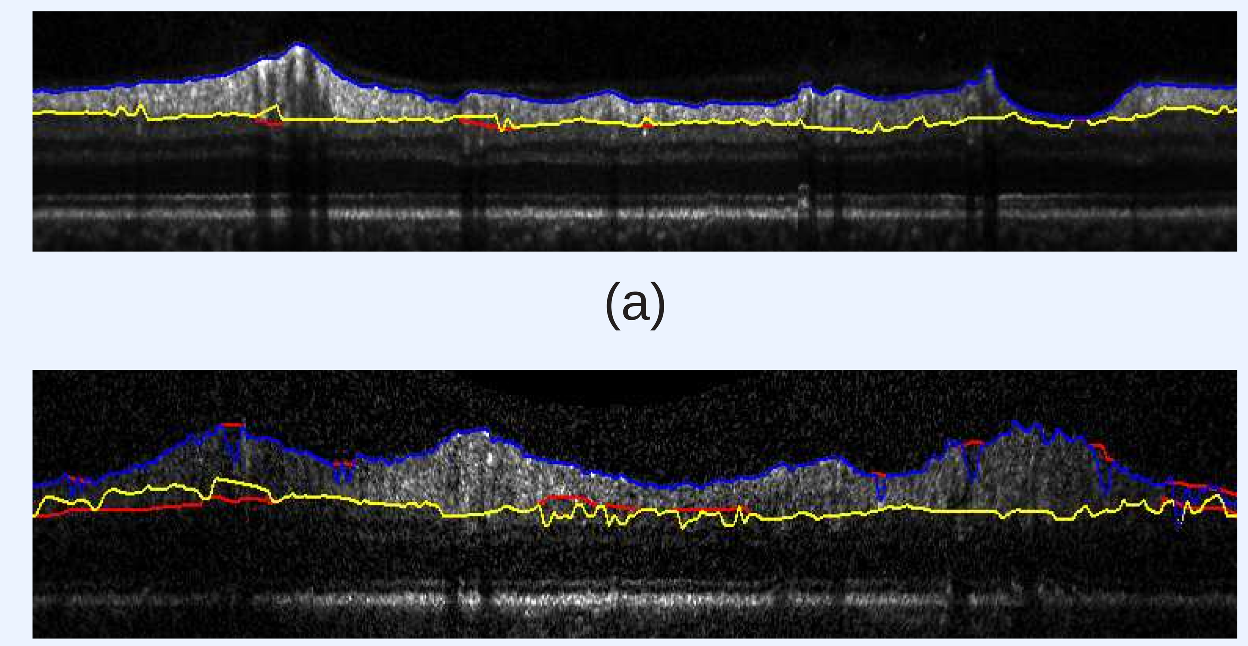


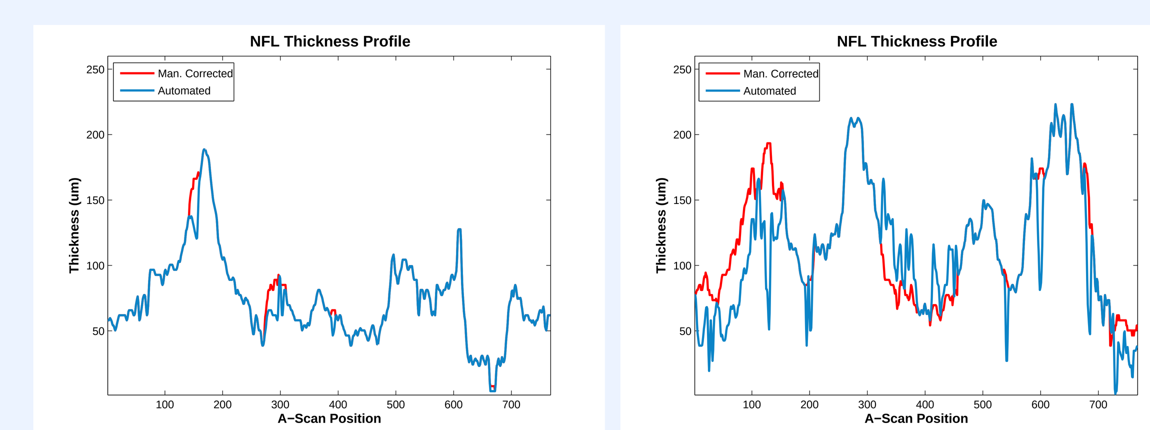
Figure 3: Segmentation Algorithm. The terms in the final energy minimization stage are: $G(x)$ gradient along A-Scan, $N(x)$ sum of pixel distance to left and right neighbor, $D(x)$ distance to mean height between two blood vessels. A preliminary evaluation of the algorithm on the dataset (comparison to manual correction by expert) showed a mean absolute error of $3.7\mu m \pm 3.6$ per A-Scan on the dataset.



(a)

(b)

Figure 4: Segmentation examples. OCT B-Scans with segmentation boundaries. Blue: inner nerve fiber layer boundary. Yellow: outer nerve fiber layer boundary. Red: manual corrections. (a) Glaucoma patient. Low quality: Quality index 2.31, Black STD: 0.076. (b) Normal. Very low quality. Quality index 1.61, Black STD: 0.158.



(a) (b)

Figure 5: Thickness profile examples. Blue: result of automated segmentation. Red: manual corrections. (a) and (b) correspond to image examples of Fig. 4

Age-distribution was equal in all age decades: Achieved by random exclusion. 61 N and 61 G patients left in each experiment.

Support Vector Machine classifier. 10 fold crossvalidation. 20 repetitions of each experiment to capture the variation of the different random exclusions. Averaging of the results.

Results

The area under the ROC is 94.4% using the automated segmentation. For a specificity of 90.0% a sensitivity of 89.7% is achieved. Using the manually corrected segmentations the area under the ROC is 95.7%. For a specificity of 90.0% a sensitivity of 92.6% is achieved in this case.

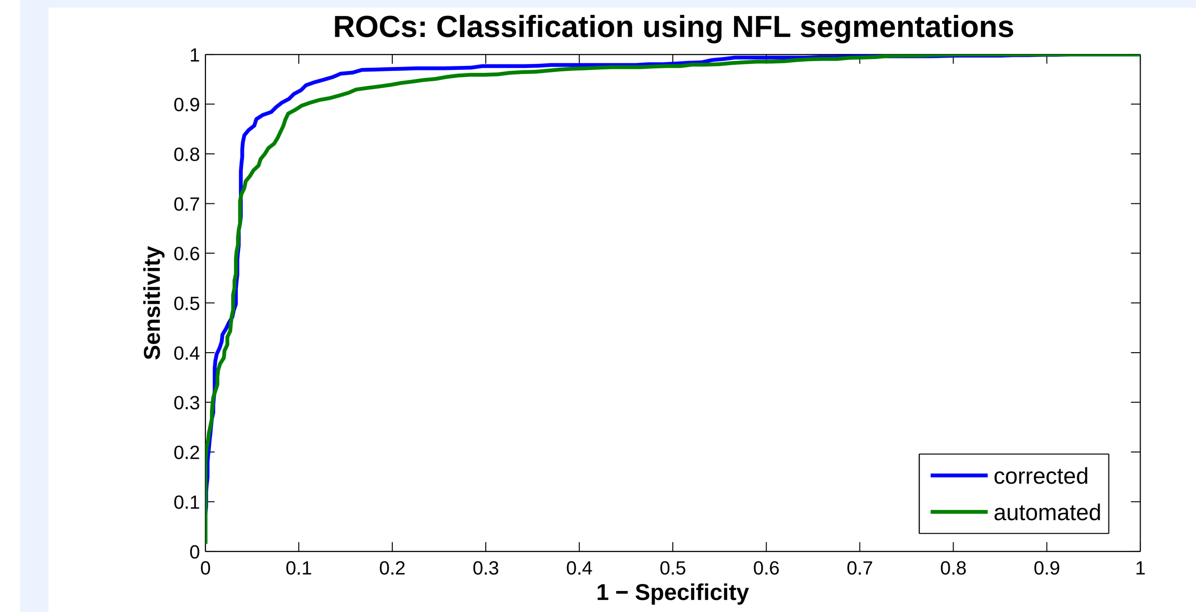


Figure 6: ROC curves of classification results.

Conclusion

1. **A pure automated segmentation nearly reaches the result of the manually corrected segmentations.**
2. **The features presented are extracted from the RNFL thickness profile of a single circular OCT B-Scan. They are useful glaucoma indicators that allow classification with a high accuracy of 94.4% ROC area.**

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Commercial Relationship

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