Automatic Nerve Fiber Layer Segmentation And Geometry Correction On Spectral Domain OCT Images Using Fuzzy C-means Clustering

1880

M.A. Mayer[1,2], R.P. Tornow[3], R. Bock[1], J. Hornegger[1], F.E. Kruse[3]
[1]Chair of Pattern Recognition, [2]Erlangen Graduate School of Advanced Optical Technologies, [3] Departement of Ophthalmology
University of Erlangen-Nuremberg, Erlangen, Germany
mayer.markus@informatik.uni-erlangen.de

Friedrich-Alexander-Universität Erlangen-Nürnberg

Purpose

To propose a novel automated method for nerve fiber layer (NFL) segmentation on high resolution spectral domain OCT B-scan images.

Data

Circular B-scans (diameter 3.4mm, 512 or 768 A-scans with depth resolution of 3,87μm/pixel) around the optic disc were acquired using a Spectralis HRA+OCT (Heidelberg Engineering) (see board D771/#1862). For the evaluation data sets from 5 normal and 7 glaucoma eyes were used. For these images a manual segmentation of the NFL was carried out by the authors.

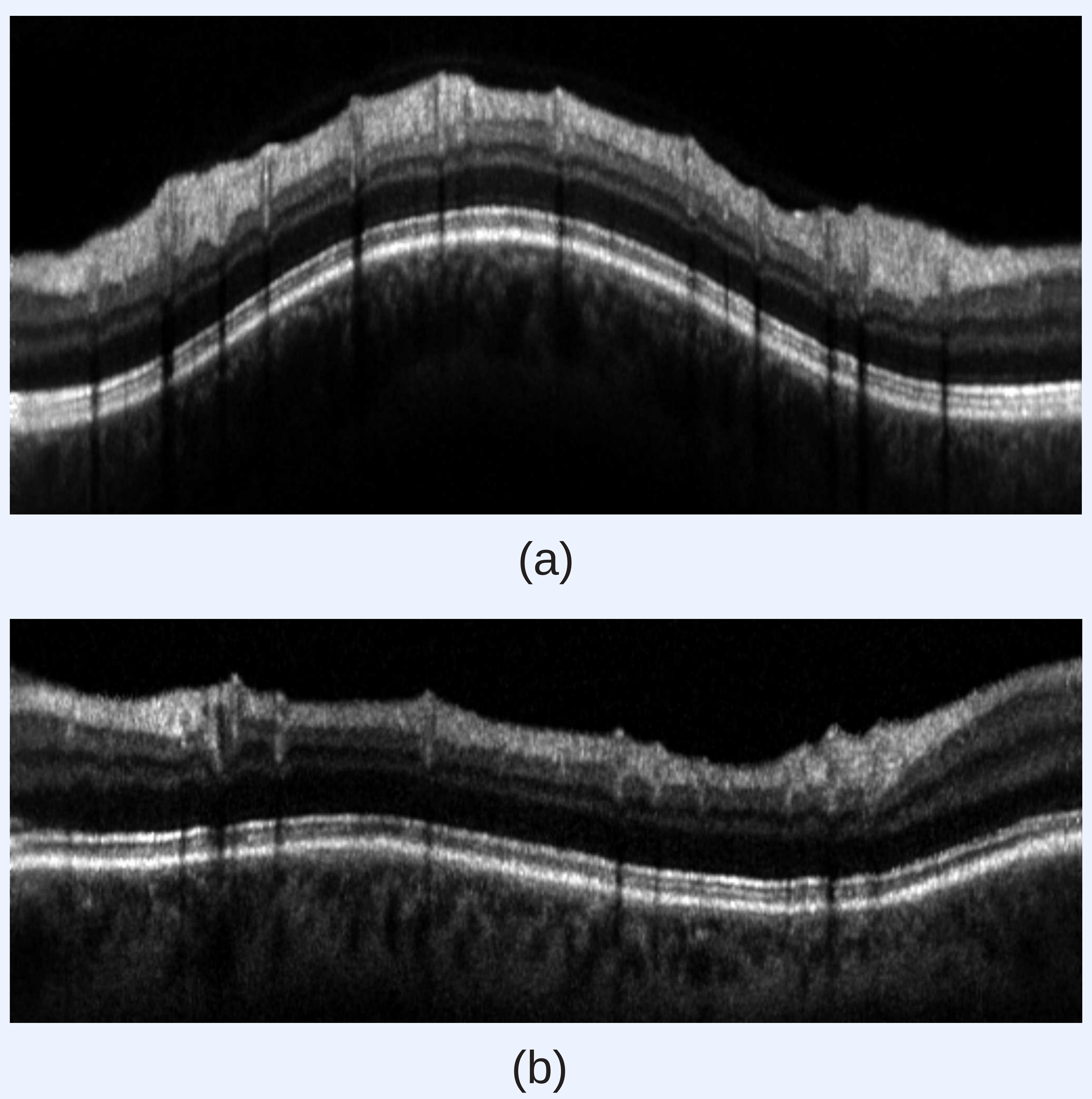

Figure 1: Circular Oct B-Scans with removed bias. Crops out of original 512x496 images. (a) Normal eye (b) Glaucomatous eye

Method

Previously published approaches for NFL detection make use of diffusion methods to provide a denoised image and enhance contrast on layer borders and thus separating the layers [1, 2]. A drawback of this methods is high computation time.

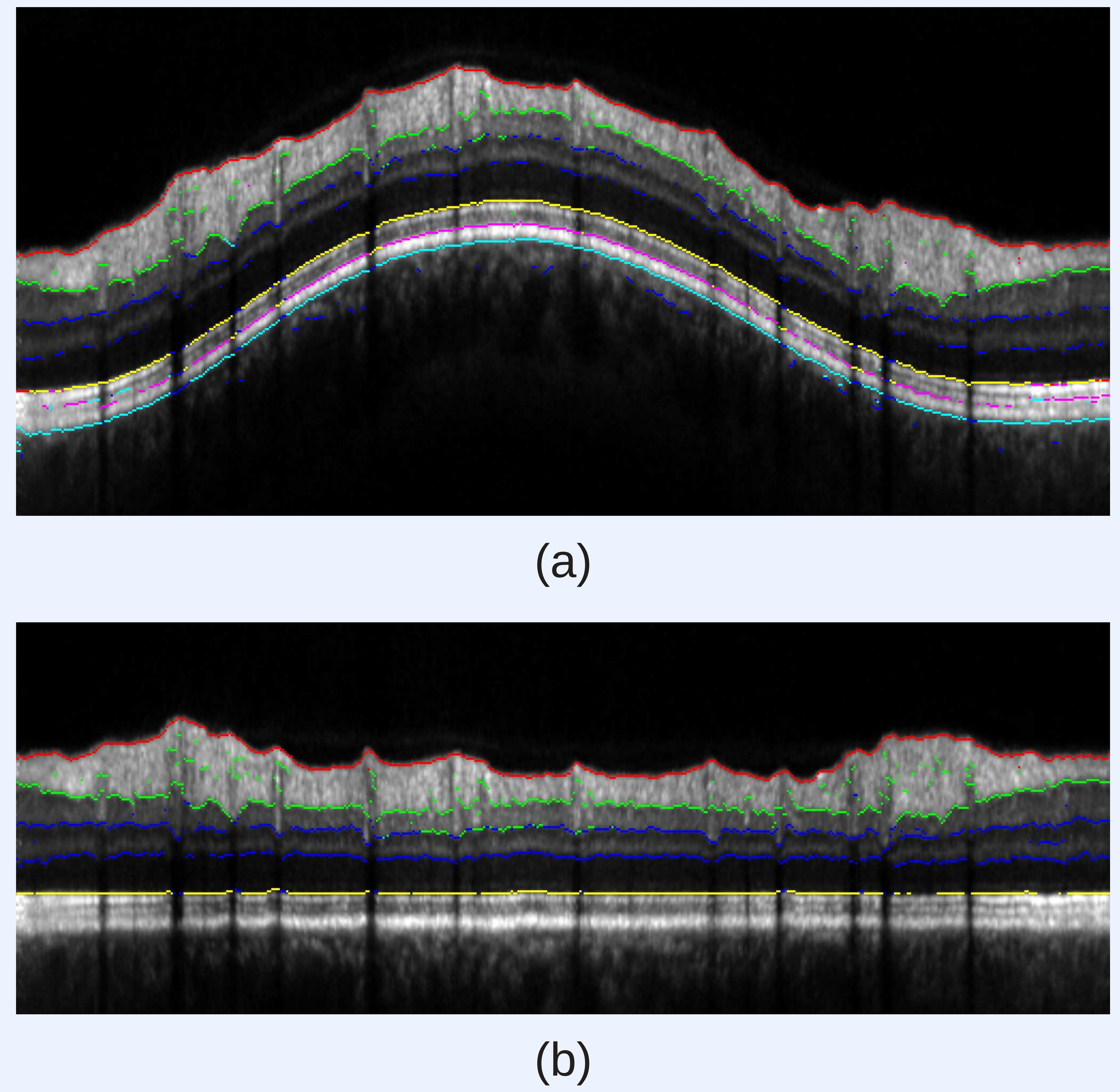

Figure 2: Processing step to obtain a geometry corrected image. (a) Detected 6 highest extrema along derivative of A-Scans smoothed with a gaussian filter of variance 3. Result after fuzzy C-means clustering into 6 classes. (b) Repetition of clustering on even image. Only extrema above baseline are taken into account. Clustering into 4 classes

Our approach reduces computation time significantly by taking only pixels into account that most likely lie on a retinal layer border. A geometry corrected version of the image and a segmentation of the NFL can be obtained by carrying out the following steps:

1. **Preprocessing** of the OCT image: Remove bias and normalize intensities.
2. **Detect the extrema** with the highest absolute values along first derivative of gaussian smoothed A-Scans.
3. **Calculate feature vector** for each extremum.
   Used features: Neighbouring intensities, intensity sums above/below in the A-scan, number of extrema in a defined neighbourhood etc.
4. **Cluster the feature vectors** with fuzzy C-means clustering. No further information is provided to the clustering algorithm.
   Assumption: Clusters correspond to Different retina layer borders
5. **Identify a cluster representing a flat border**. Possibilities: Borders of Retinal pigment epithel, outer photoreceptor segment or lower border of inner photoreceptor segment.
6. **Flatten the image** taking smoothed version of the identified cluster as a baseline.
7. Optional: Repetition of feature vector computation and clustering on even image improves results.
8. **Identify NFL**: Clusters corresponding to the upper and lower NFL boundary.
9. **Mark blood vessel regions** on the lower NFL boundary as invalid. These regions are identified by a thresholding approach on the intensity values around the baseline.
10. **Smooth the line** by perform a linear interpolation over gaps and invalid regions followed by an outlier detection, median and gaussian filtering.

Results

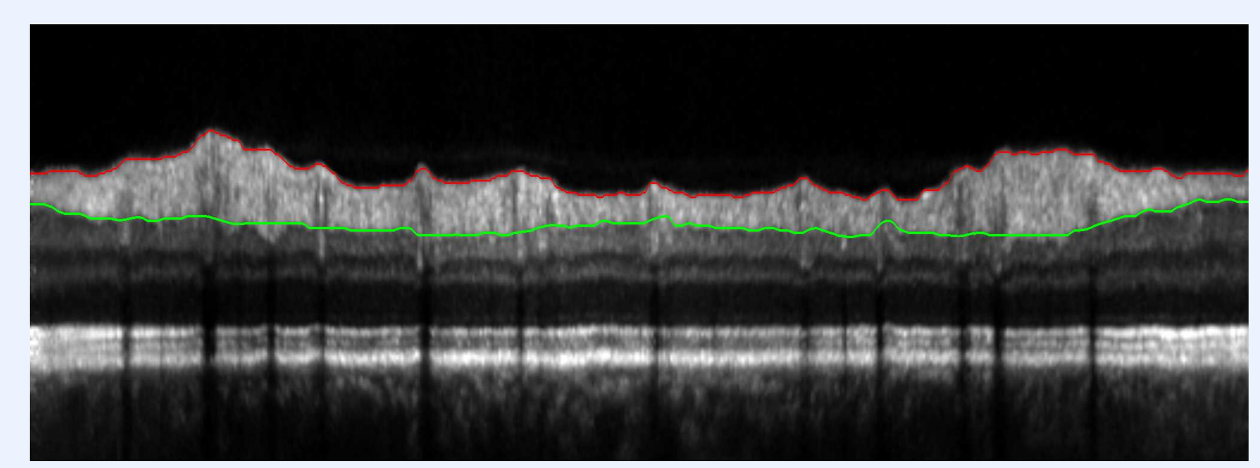

Figure 3: Result of the nerve fiber layer segmentation on normal eye

1. **High accuracy**: 97% of the upper and 74% of the lower nerve fiber layer boundary points lie within a 2 pixel range from the manual segmentation of the evaluation data set
2. **Improved comparability** between subjects and **valid neighbourhood** information between independend taken A-Scans due to geometry correction.
3. Algorithm parameters were the same for each image
4. Computation time is 45s on a 2Ghz Pentium IV for a 512x496 circular B-scan (Matlab implementation)

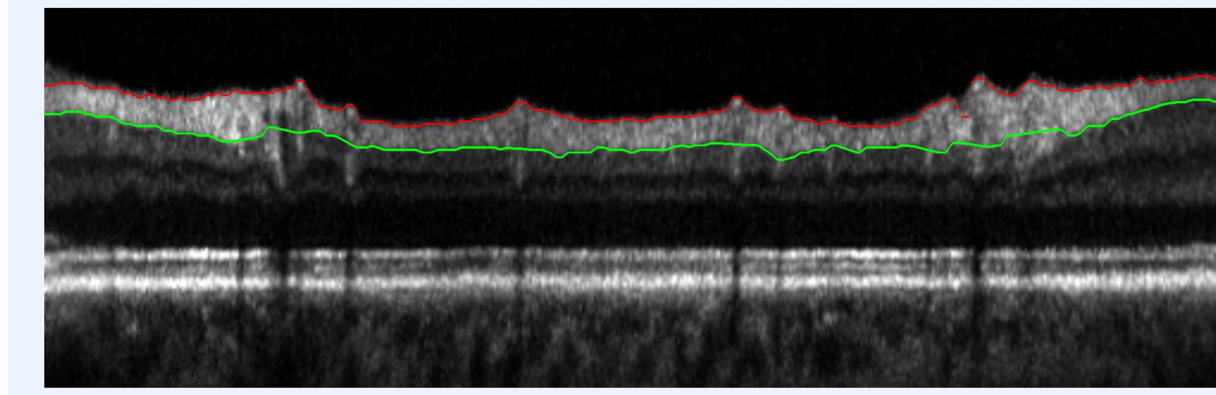

Figure 4: Result of the nerve fiber layer segmentation on glaucomatous eye

Conclusion

We present a NFL segmentation method on circular OCT scans that is applicable to normal as well as pathological data, different patients and varying scanner settings without parameter adaption.

No previous knowledge about the image is needed.

An ophthalmologist is assisted in his diagnosis by this new objective and reproduceable measurement.

In addition a visually more informative image with corrected geometry is generated during the same process.

Support

This contribution was supported by the School of Advanced Optical Technologies, University of Erlangen-Nuremberg.

Commercial Relationship

M.A. Mayer, None; R.P. Tornow, None; R. Bock, None; J. Hornegger, Siemens AG, C; F.E. Kruse, None.

References

[1] M. Mujat, R.C. Chan: Retinal nerve fiber layer thickness map determined from optical coherence tomography images. Optics Express 13(23), 9480-91, 2005

[2] D.C. Fernandez, H.M. Salinas: Automated detection of retinal layer structures on optical coherence tomography images. Optics Express 13(25), 10200–16, 2005