Measuring Corneal Collagen Fiber Distribution Using PS-OCT

Valerio Mollet

Supervisor: Prof. Dr. Patrik Arnold
Institution: University of Applied Sciences Bern, Institute for Human Centered Engineering
Examiners: Prof. Dr. Patrik Arnold, Dr. Harald Studer

Introduction

Over a quarter of the world's population suffers from visual defects. Nowadays, this defective vision can be corrected by glasses or contact lenses. Another option is to correct the visual defect surgically by changing the shape of the cornea and thus improving vision. Such correction cannot be done perfectly these days because it is not known exactly how the cornea will deform after surgical intervention. Therefore, it is crucial to know the exact structure of the cornea in order to plan the procedure. To this day, collagen fibers can only be investigated by destructive methods. With optical coherence tomography (OCT), imaging of the cornea can be performed non-destructively. Nevertheless, collagen fibers are not detectable with conventional OCT. However, by polarization sensitive OCT (PS-OCT), the change of polarization caused by the collagen fibers can be measured. The goal of this thesis was to measure the collagen fibers in the cornea from different viewing angles and thus to have not only a 2-dimensional projection of the collagen fibers, but a 3-dimensional orientation.

Materials and Methods

To measure the collagen fibers 3-dimensionally, the cornea must be examined from at least two viewing angles. In order to accomplish this, a mirror holder was designed which allows to scan the cornea from five viewing angles. The resulting five volume scans have to be registered to each other. For this purpose, a calibration target and algorithm was developed which finds the transformations between the volumes. This functionality allows to visualize more complex structures such as a bug (see Fig. 1).

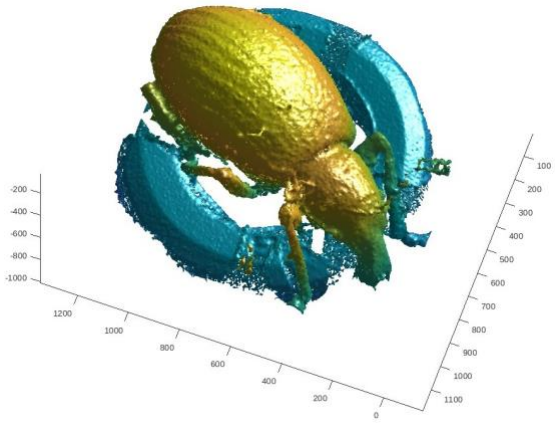

Fig. 1 Reconstructed bug measured from five viewing angles.

Since the cornea refracts the laser beam of the OCT measurement, distorted volume tomograms are recorded. To correct this distortion, a sophisticated refraction correction algorithm was developed based on the implementation of Ortiz et. al.[1]. PS-OCT can be used to measure the optical axis of collagen fibers. However, only the cumulative polarization change effect is measured. To obtain the local optical axis, an iterative algorithm was developed which extracts the local optical axis.

Results

It was possible to measure the cumulative optical axis produced by the collagen fibers by PS-OCT. In Fig. 2, an enface image of the cumulative optical axis of a porcine cornea is visualized. Unfortunately, due to noisy data, the local optical axis could not be extracted successfully. However, the underlying reason could be determined. Nevertheless, all algorithms were successfully tested.

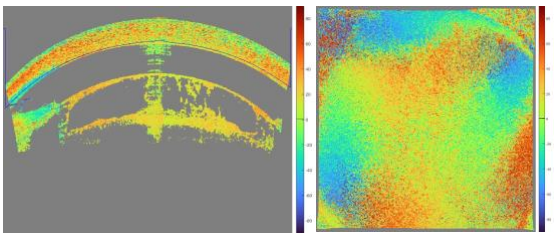

Fig. 2 On the left we see a B-scan and on the right an enface of the cumulative optical axis in a porcine Cornea.

Discussion

The results were compared with different scientific works and correlate. However, the cumulative optical axis could not be measured with sufficient quality to allow the determination of the 3-dimensional orientation from collagen fibers. But this could be achieved by using the developed algorithms with adequate data.

References

[1] S. Ortiz, D. Siedlecki, I. Grulkowski, L. Remon, D. Pascual, M. Wojtkowski, and S. Marcos. Optical distortion correction in optical coherence tomography for quantitative ocular anterior segment by three-dimensional imaging. Optics express, 18(3):2782 2796, 2010.