

3D Reconstruction of Collagen Fibers in Cornea

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Introduction

I work in the graphics group with Gopi and Aditi. The group was approached by the Department of Ophthalmology to see if we can reconstruct various parts of the eye using the images provided. I decided to work on the part that involved reconstructing collagen fibers in the cornea. I attempted to take the cross-sectional images of them and use that data to display their shape in a 3D environment. The images are somewhat noisy and grainy and the fibers vary in shape and thickness so I had to use a variation of clustering and filtering in order to accurately locate the fibers in each image. I then took the segmented image and made it a slice in a volumetric data set. At the end, I took the data set and used a volume renderer to show it. Here are the steps at a glance that I will go into detail on:

1. Do Initial Smoothing of the Image
2. Do Clustering to get the fibers
3. Smooth the segmented image
4. Compare image to previous one and put results into 3D data set
5. Add image from step 3 into data set
6. Repeat Steps 1-5 for all images in data set
7. Use Volume Renderer to show the images in a 3D environment

There was an attempted step here of trying to align the images together. I tried various methods to see what the best overlap would be between segmented images but in the end, it made sense to just overlay the images on top of each other without doing any transformations of them.

Initial Smoothing

Clustering

Smoothing of Segmented Images

Alignment

Making and Displaying the Data Set

Results and Conclusions

Future Work

The pictures above show a data set of collagen fibers for the cornea of a rabbit. There are other data sets that we were given. I ran the above algorithms on them but the segmentation was not as successful. The above tools turned out to be the ideal choice and their parameters were tuned for the rabbit data set. Since the other data sets have images that look different though, a different set of tools and parameters with those tools are required. In addition to finding a different set of tools for segmenting a different data set, there is work to be done on improving the current segmentation. There are also further things we plan to do with the 3D data.

Work on improving segmentation

Qualitatively, my results seemed good and the ophthalmologists seemed to think they looked nice, but there is definitely room to improve the segmentation. When evaluating a clustering, I ended up relying on my subjective comparison between the clustered image and the original image to decide how well the fibers were brought out. It would be great if I could get a few preliminarily segmented images to compare my results with so that I can have a quantitative evaluation of how well the clustering performed. I could then compare the error rates that the various methods produce and use whichever method has the least error overall.

The other problem was that I did not have a great template of what the fibers should look like. Without a good template, it was difficult to do object detection as a way to detect the fibers. As it turns out, the fibers are long thin strips but they vary in thickness. If I incorporate this information into an object detector, then I might end up with a very well segmented image.

It has come to our attention that when there are spots that are lined up in the image, there is likely a fiber there. We will use this and make sure to use a clustering method that favors cases where that happens.

Work on 3D reconstruction

The Ophthalmology department really liked seeing the fibers in the data set and their concern lies with analyzing these fibers. They want to know how many fibers there are and how they branch off each other as well as know their shape and size. In order to enable this type of analysis, the next step then will be to take the 3D data set and generate a series of meshes for the isosurface that corresponds to a voxel value of 1. This will give us a mesh for each of the fibers that we can then move around, analyze, and run simulations on.