Nerve Segmentation

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02506 - Advanced Image Analysis

Introduction

Obtaining 3D morphological information of peripheral nerves from X-ray tomographies can be used to study nerve disorders and its progression. Thus, this projects aims to perform a volumetric segmentation of myelinated axons using Markov Random Fields (MRF) and deformable models followed by the extraction of microstructural measurements such as nerve areas and radius and myelin density.

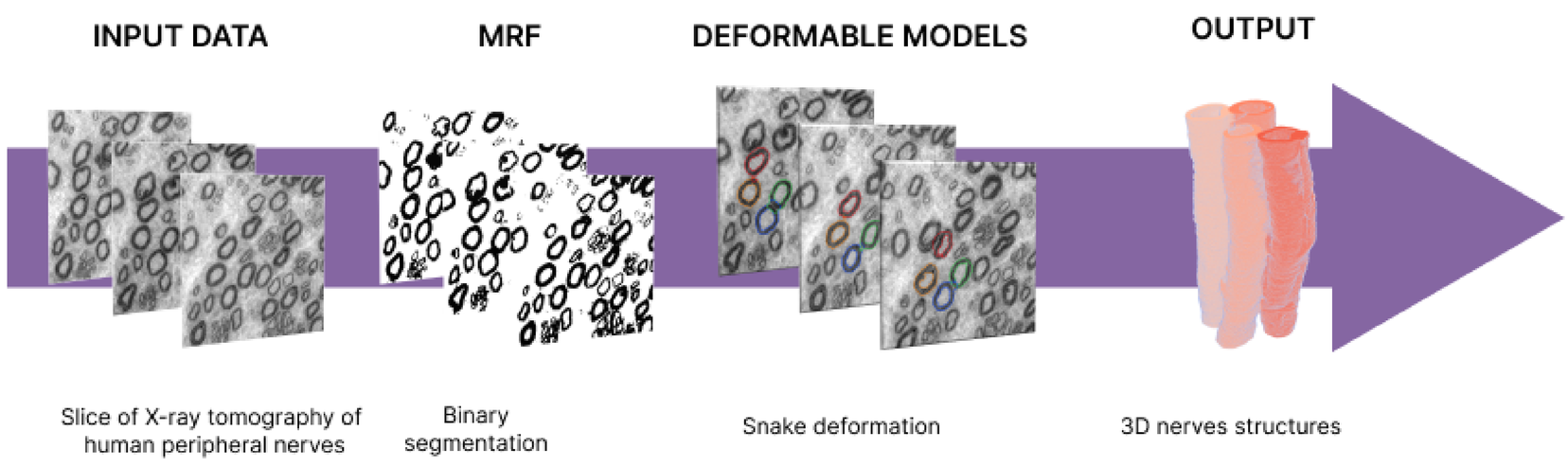

Figure 1. Methods: Nerve segmentation with MRF and deformable models pipeline.

Markov Random Fields

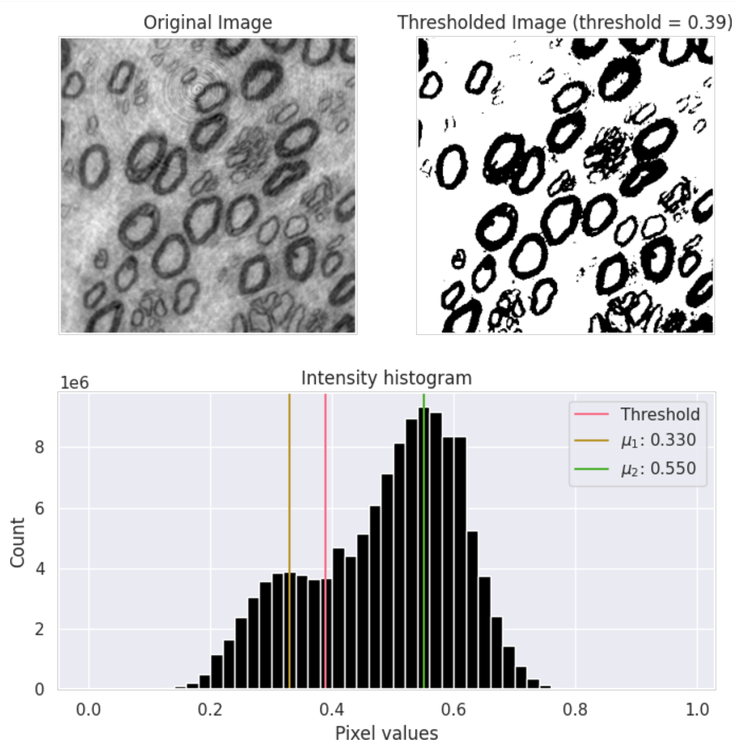

Figure 2. Prior knowledge of MRF.

We used MRF to perform binary segmentation using as prior knowledge the fact that the myelin is colored and can be seen in darker pixels than the background and the axons.

For the likelihood, we decided to use a 6-neighbors (4 from the same slice, and 2 more to connect to the next and previous slice)

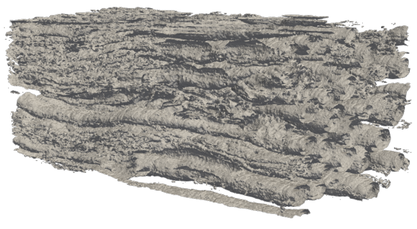

Figure 3. Nerve Segmentation using MRF binary segmentation.

Deformable models

After obtaining the binary segmentations, we decided of using an area around the deformable snakes to calculate the forces, instead of the full images.

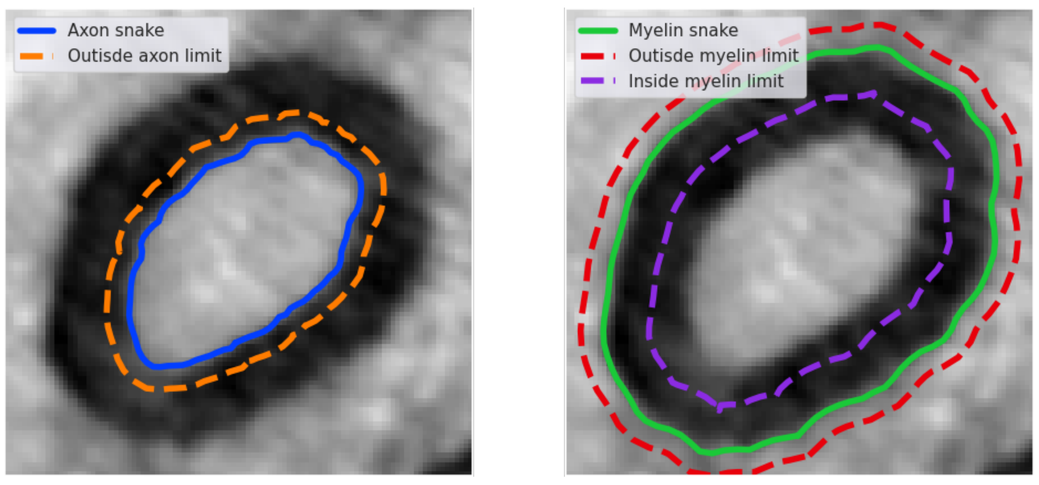

Figure 4. External forces calculated using an area around the snakes.

For each nerve, we decided on using 2 different deformable snakes. The first being the detector of the limits of the axon, and uses the full area on its inside and a band around itself to calculate the forces. The second is the one that limits the size of the myelin, and uses a band both on the inside and the outside. It is also conditioned on the first, so it cannot be further or closer than some ranges.

Figure 5. Nerve Segmentation using deformable models.

Results

Myelin density	39,06 %
Number of axons	18
Avg nerve radius (px)	20,21
Avg nerve area (px)	1301,39
Avg axon radius (px)	11,96
Avg myelin radius (px)	8,25
Avg axon area (px)	356,76
Avg myelin area (px)	841,49

Table 1. Metrics: Microstructural measurements.

Limitations

- **Snakes Initialization**: The center and radius of the snakes has to be preselected by human decision.
- **Partial Peripheral nerves**: The nerves where only a portion of it is visible, can not be detected.
- **Model Evaluation**: The performance of the model can't be evaluated in an analytical way.

3D Morphological information were extracted from the volumetric data from the segmented nerves, which could be then used to determine whether nerve disorders influences the radius, trajectory and organization of myelinated axons in peripheral nerves.

Although some improvements could be made, such as **blob detection**, **morphological operations** and **crossing points**, the combination of MRF and deformable models has proved to be a powerful tool to segment objects in volumetric images and seems a promising pipeline for medical purposes.