Automated Construction of Peripheral Nerve Finite Element Models

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Background

- Neuroprosthetics can help to restore motor function after neurological injuries by sending and receiving signals from peripheral nerves.
- This "communication" relies on the interface between the device and peripheral nerves, which faces some design challenges:
  - Structure of peripheral nerves is complex and not well understood
  - The structure varies across the population
- Understanding nerve structure will inform design of more effective peripheral nerve interfaces
- Finite element (FE) models of nerves can be used to simulate bioelectric activity at nerve interfaces for different device configurations

Project Motivation

- Creating peripheral nerve FE models is currently a manual process[1], which is inefficient and time-consuming
- We aim to develop an automated FE model generation process
- The process must accurately and rapidly convert medical images to FE models that are ready for simulations without the need for manual supervision

Methodology

3D Reconstruction

- Histology slices were selected from a rat sciatic nerve dataset representing a 2.85 mm section
- Random forest classifiers were used to identify nerve fascicles in each slice and converted into binary masks
- A stack of 1000 layers of binary fascicle masks were interpolated, forming a 3D reconstruction (Fig. 1) which is inputted into the automation process

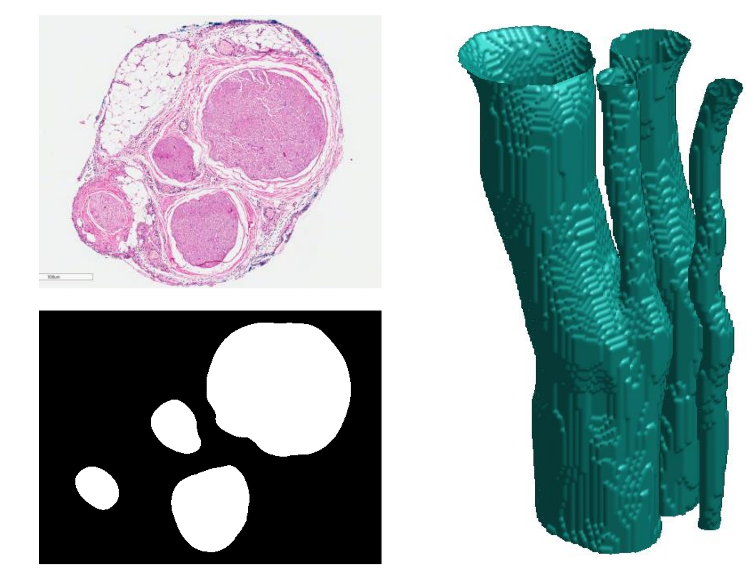

Fig. 1. Histology images converted into binary masks into 3D reconstruction

Generate key features

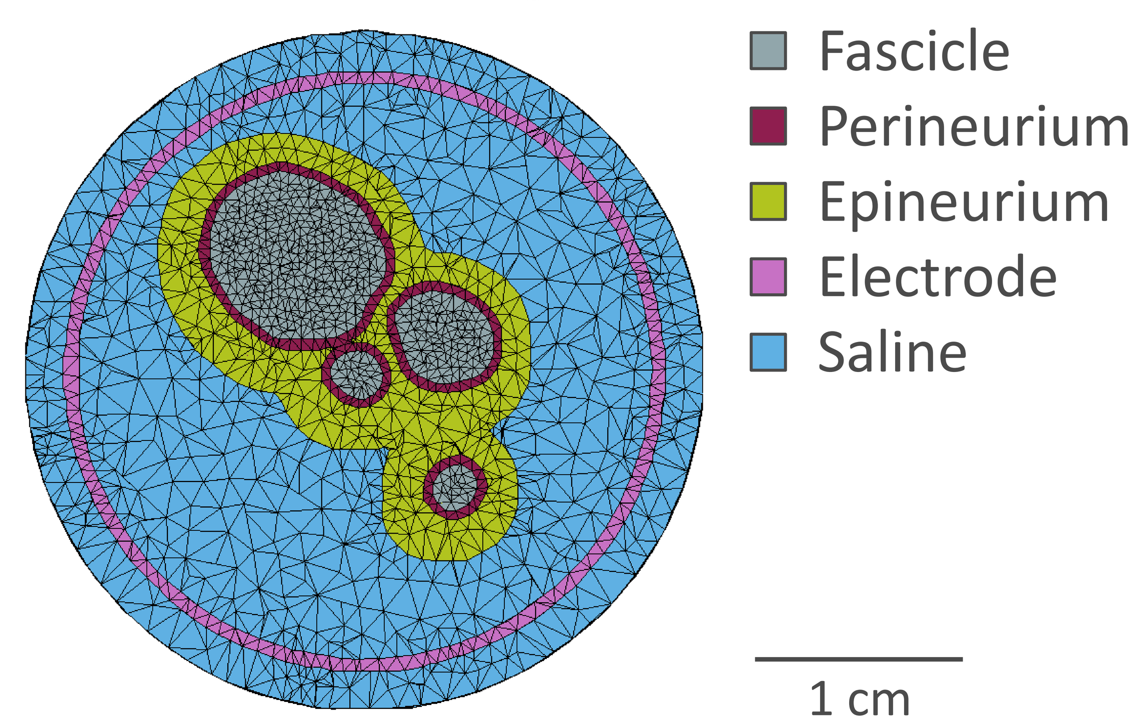

Fig. 3. Mesh cross section with key structures

- Nerve features and surrounding structures were generated in MATLAB as separate binary images
- The nerve perineurium and epineurium are generated using dilation functions applied to fascicle masks
- Binary masks of the 5 regions were summed, such that each region is indicated by a number from 1 to 5
- Each region is assigned a different mesh element size (Fig. 2)

Create mesh

- The full 3D image was converted into FE mesh using ISO2MESH, a MATLAB mesh generation toolbox[2]
- Discontinuous nerve regions were connected by "caps" in added layers to be recognized by meshing functions (Fig. 3)

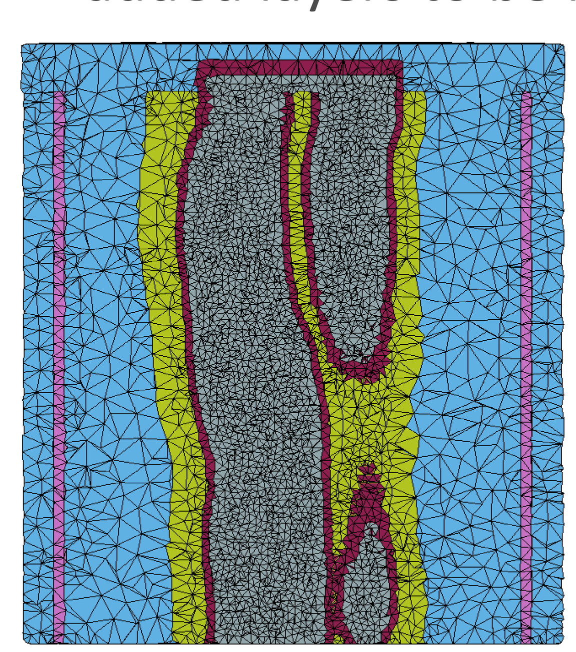

Fig. 3. Frontal plane cross section of the FE mesh

- Added layers were removed using a cropping function
- The mesh is checked for erroneous elements from the meshing process
- The final FE model (Fig. 4) is exported, including:
  - Node and element coordinates
  - Region indices for each element
  - Conductivities of each region

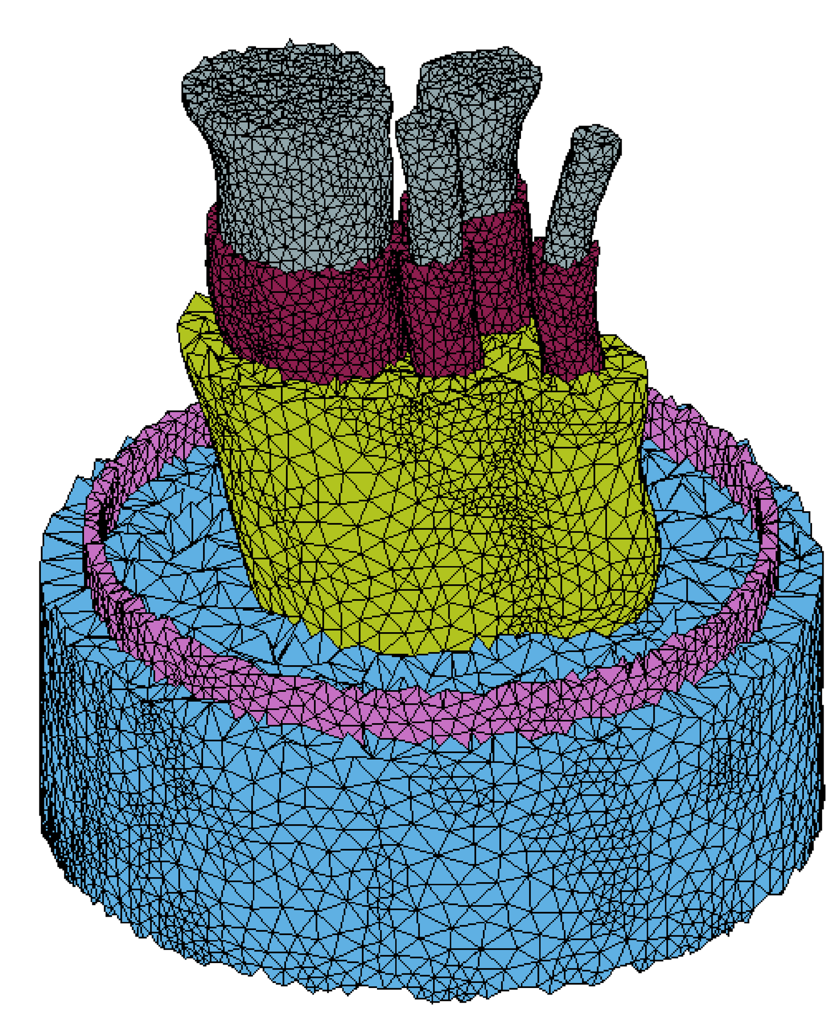

Fig. 4. Final FE model, sectioned to display all nerve features

Results & Discussion

- The final FE model was generated free of holes and computational errors
- The automation process is feasible for rat nerves of known dimensions
- The process significantly reduces time, especially when generating nerve features
- The process is scalable with additional computing power rather than manpower

Next Steps

- Run peripheral nerve recording simulations on the exported model
- Test and adapt the process on human peripheral nerve datasets, which have additional nerves and increased complexity
- Use a wider range of datasets to test the process' versatility for variations in nerve structure across populations

References

1. Garai P, et. al., IEEE TNSRE, 25(9), 1653-1662, 2017
2. Fang Q, et. al., IEEE ISBI, 2009, 1142-1145

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