Final Project Proposal

Timothy Anderson
EE368 – Digital Image Processing

Overview

Title: Efficient Brain MRI Segmentation via Neuromechanics-based Edge Optimization
Project members: Timothy Anderson (timmya@stanford.edu)
Android Device: None.
Note: I am planning to also use this project for a final project in ME 234 (Introduction to Neuromechanics) and CEE 362G (Stochastic Inverse Modeling). As explained below, I believe this project suitably combines concepts from all three of these areas, and using a project for multiple classes will allow me to do a more in-depth exploration of the topic, as well as leave me with more time for research and graduate school/fellowship applications.

Background and Context

Developments in finite element method (FEM) simulation and additive manufacturing (3D printing) stand to revolutionize neuromechanics and neurosurgery. FEM simulation allows for efficient simulation of mechanical deformation of brain tissue, which is useful in analyzing brain injury and defects [3]. Similarly, additive manufacturing opens up the possibility of creating physically-accurate brain analogues for analysis and neurosurgery training. However, the primary bottleneck in this workflow is efficiently segmenting MRI images for conversion to a finite element mesh or printable STL file. While there are commercial medical image processing software packages available, these are often expensive and still require the user to manually segment much of the image.

Project Goals

The goal of this project is to develop an image segmentation system for brain MRI images by integrating and adapting existing segmentation techniques. The project will combine principles from image processing, neuromechanics, and stochastic inverse modeling to develop a robust algorithm for edge detection and extraction in brain MRI. The segmentation algorithm will be separated into three main steps. First, the image will be pre-processed using unsupervised segmentation, such as fuzzy c-means clustering (FCM) and small region removal, to eliminate structures such as bone and background noise which are not part of the brain. FCM has very limited success for fully segmenting complex features, but it is able to effectively remove features that are well-separated from the relevant features of an image [1]. The algorithm will then iterate between steps two and three. Step two is an image processing routine using wavelet-based edge detection, since this method has been shown to be successful at resolving multiscale edges, and in particular those found in brain MRI image [5]. Step three will be edge optimization via minimization of an energy functional of the surface folding, a method demonstrated to be effective in Yoon et al. [4]. The energy functional for cortical folding will be based on exiting cortical folding mechanics models, such as those shown in Budday et al. [2]. On each iteration, the scale of the wavelet-based edge detection will shrink, allowing for segmentation of progressively less-apparent edges, and eventual convergence to the final brain image. Overall, the hope is that this project can efficiently segment the boundaries of the main brain tissue accurately enough such that the resulting surface is useable in 3D printing and FEM simulation applications.

References

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[3] Matthew B. Panzer, Barry S. Myers, Bruce P. Capehart, and Cameron R. Bass. Development of a finite element model for blast brain injury and the effects of CSF cavitation. *Annals of Biomedical Engineering*, 40(7):1530–1544, February 2012.

[4] Sung Won Yoon, Hang Sik Shin, Se Dong Min, and Myoungho Lee. Medical endoscopic image segmentation with multi-resolution deformation. In *2007 9th International Conference on e-Health Networking, Application and Services*. Institute of Electrical & Electronics Engineers (IEEE), June 2007.

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