EMORY REU Cardiology Project, Comparison of Segmentation Techniques

Allison Dennis, Michele Perry, Mohamad Hindawi, Kai Chang, Shannon Lee, and Minxing (Matt) Zhang

Introduction

- Imaging has been revolutionizing medical research and clinical practices for decades.
- Segmentation is the image processing step to identify a region of interest (an artery, a bone, etc.) in an image.
- Here, we focused on Optical Coherence Tomography (OCT) of Coronaries.
- We analyzed two segmentation approaches: the Level-Set Method and Machine Learning based on Convolutional Neural Networks.

Level Set Methods & VMTK Results

The Level Set Method utilizes implicit functions to identify the region of interest in an image, where the implicit function is the numerical solution of a Partial Differential Equation (PDE) that is defined on the image that is being segmented. The level set function $\phi$ is evaluated by

$$\frac{\partial \phi}{\partial t} + \nabla \cdot (u \phi) = 0$$

where the vector $u$ depends on the grey levels of the image.

The solution $\phi$ describes the time-dependent position of the interface $\Gamma(t)$

$$\Gamma(t) = \{ x \in \Omega : \phi(x, t) = 0 \}$$

The basic idea of the Level Set is to correlate the velocity to the gray level of the image in such a way that the gray level of the image is driving the evolution of the $\phi$ close to the boundary.

The Level Set is a very powerful method that extracts the border of a region or image, and it can handle changing topology well. It is also a great tool because it utilizes physical concepts, such as velocity, mean curvature, and elastic energy for image segmentation problems. We used the image segmentation software, Vascular Modeling Toolkit (VMTK), that is based on the Level Set. VMTK is a collection of tools and libraries for image-based modeling of medical images. This segmentation method is model-driven, meaning that the technique is established on physical concepts of the problem.

FEniCS and MATLAB

The FEniCS Project is a research and software project, which is effective to generate mathematical methods and software to solve computational mathematical modeling problems. As the implicit function, the numerical solution of a PDE is involved in our project, we tried to use FEniCS in Python for solving PDEs using finite element methods.

For MATLAB, our group used Image Segmenter App under Image Processing Toolbox and applied Thresholding, Active Contours, Graph Cut, Auto Cluster, etc. to segment 2-D images. For 3-D volumetric images, we used Volume Segmenter to create and refine binary or semantic segmentation masks to segment the images by means of automated, semi-automated, and manual techniques.

Convolutional Neural Networks & PyTorch

Convolutional Neural Networks are a deep learning algorithm for image classification. The CNN’s convolutional layer parameters comprise of filters, where the values of the filters are learned during the training phase. The layers are for feature learning and classification, specifically for classifying the pixels in an image with respect to a background or vessel. We used the image processing software, PyTorch. The deep learning (DL) based method involves using training data from a database of images to train the algorithm in PyTorch.

Our Activities/Experiences

Figure 1: VMTK Results
Figure 2: PyTorch Results

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