Report Seminar Presentation
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Paper: Interactive Graph-Cut Segmentation for Fast Creation of Finite Element Models from Clinical CT Data for Hip Fracture Prediction

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Project Objective:
Our goal is to develop an automatic segmentation method for spine CT that relies on max-flow/min-cut optimization methods.

Below are the four project milestones that have laid out for our project.

- **Minimum** deliverable (3/9): Have algorithm implemented for spine CT
- **Expected** deliverable (3/23): Evaluate parameter sensitivity on N=20 manual validation dataset
- **Expected** deliverable (4/20): Segmentation of the N=200 spine CT dataset
- **Maximum** deliverable (5/15): Extend algorithm to deal with abnormalities in CT scan.

Our project will serve as a main component of “Spine Cloud,” a multi-year project being worked on in the I-STAR lab. The goal of “Spine Cloud” is to use a database of patient data such as demographic data, image and specific anatomy, surgical procedures, and pathologies. Once collected, the goal is to achieve better surgical outcomes through the analysis of previous patients’ surgical outcomes.

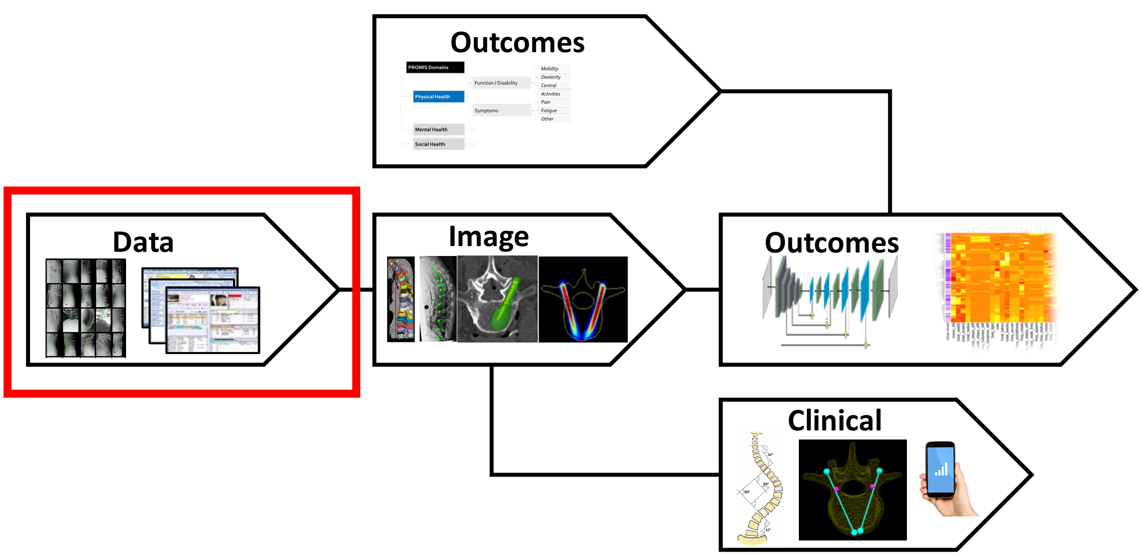

Figure 1: Spine Cloud workflow. Creation of the binary labeled spine segmentation is a part of the data collection portion of the project.

For “Spine Cloud” to be successful, an essential part is a large database of annotated spine CT images. To obtain these images, an accurate segmentation is needed. Currently within the I-STAR lab, segmentations are performed manually as they grant the greatest accuracy but are often time-consuming. While other segmentation techniques exist, they often fail to give the desired accuracy. We propose implement a graph cut segmentation algorithm that solves an energy minimization problem which accounts for special dependence among voxels.

Paper Selection:

I have chosen to review this particular paper since it closely aligns with the work that is being completed in our project and it is beneficial to see how various researches approach a similar problem. In the paper they also implement a graph cut segmentation method but for the femur instead of the spine. While the anatomy may have been different, a lot of the methods used remained the same. They too evaluate the accuracy using metrics such as Hausdorff distance, Dice Coefficient, and Surface to Surface. Reading this paper also allowed a greater sense of how our research should be organized and presented. There are a few visuals in the paper that illustrate the errors directly on the anatomy which would be a good visual for spine segmentation accuracy as well.

Paper Background and goals:

The overall goal of the paper is to assess a patients risk of hip fracture from a CT scan of the femur. This is done by looking at the stress profile of the femur from a purely anatomical, patient specific angle. However, to conduct this analysis a segmentation of the femur must be produced sot that a mesh of the anatomy can be analyzed. To achieve the most accurate stress profile, an accurate segmentation is essential, but to most accurate way to do this is with a manual segmentation. These manual segmentation are very time intensive. This coupled with the lack of engineers in a clinical setting and the extra radiation dose to the patient make the analysis infeasible and not worth the cost. The goal of this paper is to use graph cuts in a segmentation method. The hope is to make the segmentation more efficient and with as little human intervention so that it may be used in a clinical setting. The biggest questions when doing this however, is if a graph cut method can still result in as accurate of a segmentation as a manual segmentation and ultimately produce an accurate stress profile of the bone.

Paper Overview:

In this study, 48 CT scans of 3 different bone qualities were taken, including “normal”, osteopenic, and osteoporotic. For each patient a manual segmentation was created to be used as the ground truth segmentation. Then a segmentation using an interactive graph cut segmentation method was produced. From there both segmentations were advanced to meshes of the anatomy and later had their stress profiles analyzed and compared. The stress profile was meant to simulate the stress on a femur during a fall.

Segmentation Methods:

The **Manual** segmentation method was completed using MITK. Initially region growing would be used and then the output would be manual touched up to remove any inaccuracies. In cases where the region growing produced bad outputs, manual contouring was done exclusively. Only every other slice was segmented so that in the end an interpolation was performed to fill in the remaining gaps.

The **Graph Cut** segmentation method was implemented in a 3D fashion. Commonly priors are created from histograms intensities but in this implementation, there were manual selections made to indicate what was bone and what was background. Once the graph cut was made, and the binary label of bone vs. background was identified, the user would go back through the segmentation and touch up any inaccuracies.

Stress Profile:

The creation of a stress profile needs the input of a mesh. Therefore, from the binary label output of both segmentation methods, a Gaussian filter was applied followed by marching cubes to create a mesh. An important metric to use in the stress profile is the density of the bone which was extracted from the voxel Hounsfield units. The paper relied on models made to analyze both the stiffness of the bone as well as the force applied to the bone. These models were implemented on matlab script that the lab created.

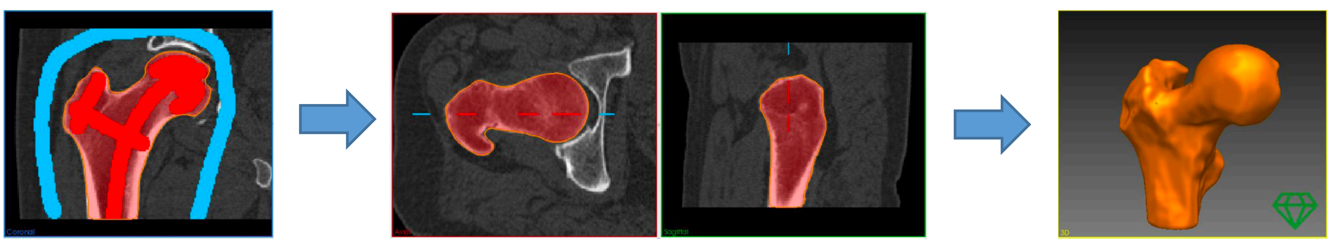

Figure 2: Manual identification of bone vs background(left). Binary labeled segmentation(center). The mesh of the femur(right).

Results:

Comparisons of the two segmentation methods were done using three different metrics. Haursdorff distance, Dice Coefficient, and signed Surface to Surface distance. The metrics were all calculated comparing the manual method to graph cut method. The Hausdorff distance was 3.75 ± 1.26 while the Dice Coefficient was 0.973 ± 0.005 and the surface to surface distance was -0.22 ± 0.12. The negative value in the surface to surface difference indicates that the graph cut method resulted in a consistently slightly smaller segmentation that the manual method. The stress profile of each method output was then analyzed. A linear regression was preformed indicating a strong linear relationship between the two segmentation methods. However, due to the nature of the stress profile analysis selecting the most lateral and medial nodes on the femoral head. This is very unstable as a slightly different femoral head segmentation could result in a very different point being chosen on the femoral head for the stress profile analysis

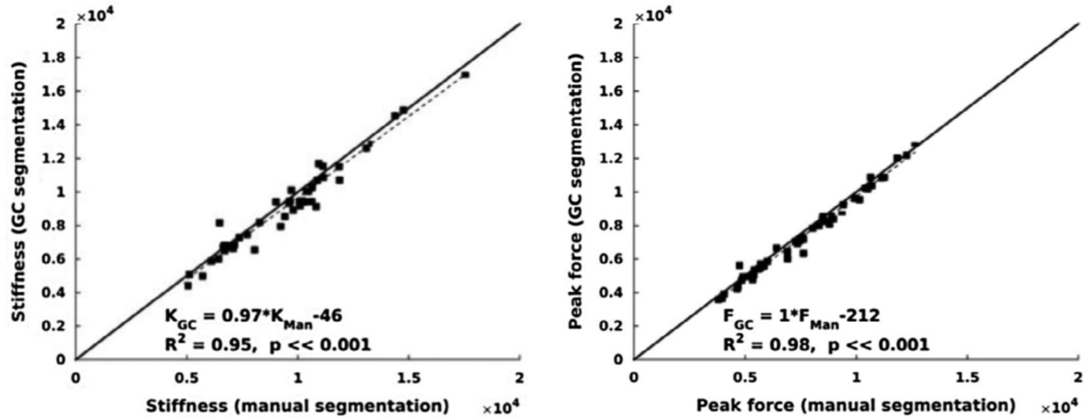

Figure 3: Linear regression of the manual(x-axis) and the graph cut(y-axis) methods. Stiffness analysis(left). Peak force analysis(right).
Conclusion / Paper Assessment:

Pros
•Graph cut method achieved similar bone stress profile to the manual method
•Graph cut method is much more efficient than manual method
    •Graph Cut: 2-5 min
    •Manual: 20-35 min
•Graph cut method is consistent for different operators

Cons
•The stress profile can be volatile with regards to the femoral head segmentation
•Graph cut method still requires manual input(semi-manual)
•Would like to have seen the graph cut output without manual correction
•Manual ”truth” varied based on operator
•Didn’t analyze the performance based on bone quality (“normal” to osteoporotic)

Reference

Yves Pauchard, Thomas Fitze, Diego Browarnik, Amiraslan Eskandari, Irene Pauchard, William Enns-Bray, Halldór Pálsson, Sigurdur Sigurdsson, Stephen J. Ferguson, Tamara B. Harris, Vilmundur Gudnason & Benedikt Helgason (2016) Interactive graph-cut segmentation for fast creation of finite element models from clinical ct data for hip fracture prediction, Computer Methods in Biomechanics and Biomedical Engineering, 19:16, 1693-1703, DOI: 10.1080/10255842.2016.1181173