Tissue Mechanics Lab: Increasing the speed and accuracy of the segmentation of the whole heart

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Introduction

- **Current methods:**
  - Generating a 3D segmentation of the whole human heart from CT images plays an important role in many clinical applications [1].
  - Intensity based features to detect segment boundaries before producing meshes
  - Successful in modeling the aortic valve but rely heavily on intensity changes along structures and extensive assumptions about the segment geometry [2].
  - Most accurate method of generating a whole-heart segmentation is manual labeling of the heart segments [1]

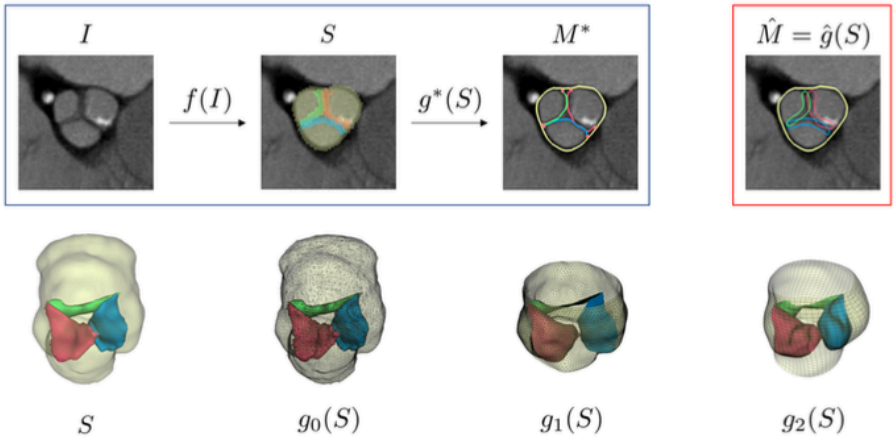
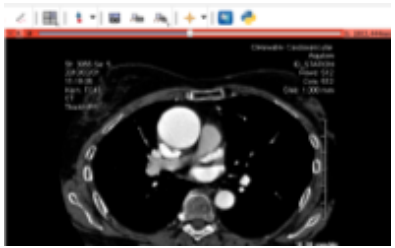
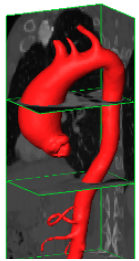


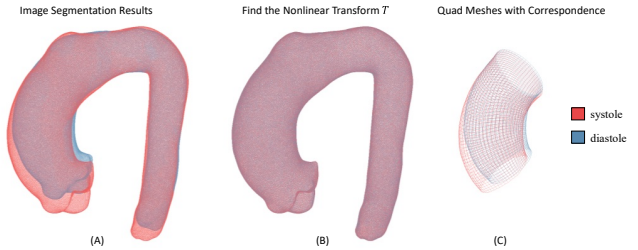
Fig 1. Ideal image to mesh process (blue) and faulty output (red)

Introduction

- **Goal:**
  - Develop a deep learning method to increase the speed and accuracy of generating Finite Element Analysis (FEA) meshes from pre-operation computed tomography (CT) images
  - Promising results for predicting patient outcomes and identifying better treatment strategies such as transcatheter aortic valve replacement (TAVR) for aortic stenosis







Project Details

- **Full heart segmentation dataset**
  - 88 CT scans from 74 different patients [2]
    - 73 scans from TAVR patients at Hanford Hospital
    - 15 Scans from Multi Modality – Whole Heart Segmentation (MM-WHS) public dataset
  - 10 phases of CT data over the cardiac cycle

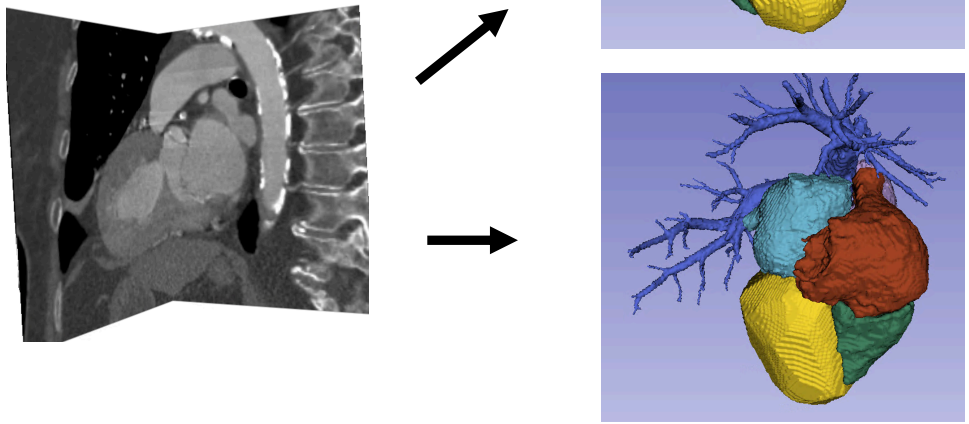
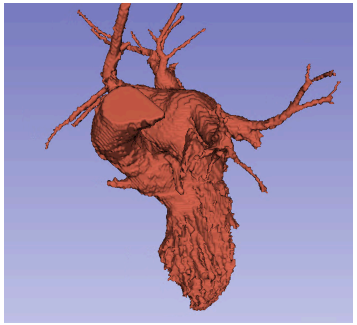


Fig 2: CT images to full heart segmentation

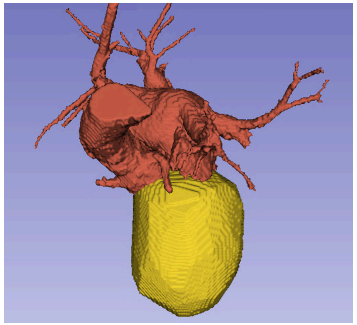
Methods – left heart segmentation

Step 1



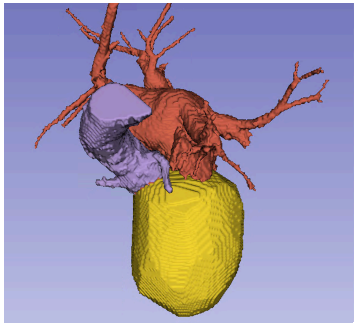
Rough segmentation of blood pool

Step 2



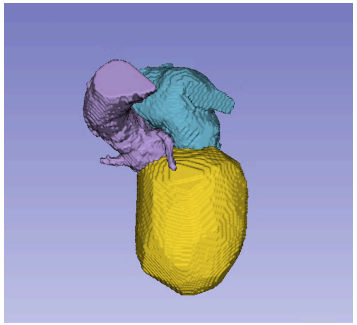
Left ventricle segmentation using surface cut tool

Step 3



Aorta segmentation using logical operators

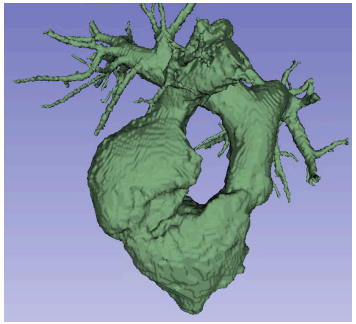
Step 4



Left atrium segmentation using scissors and eraser

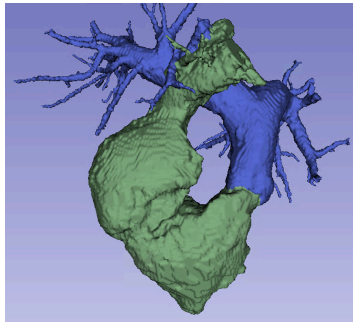
Methods – right heart segmentation

Step 1



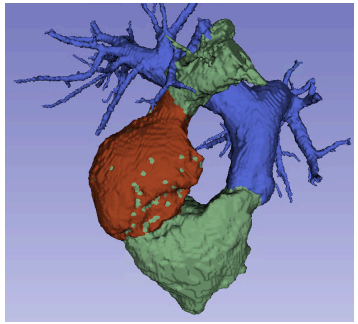
Rough segmentation of blood pool

Step 2



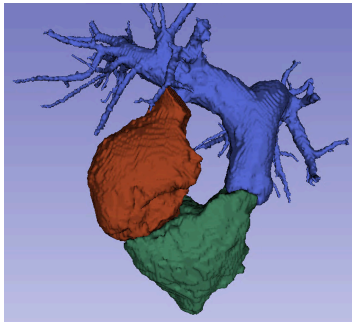
Pulmonary artery segmentation using scissors and eraser

Step 3



Right atrium segmentation using scissors and eraser

Step 4



Right ventricle blood pool using logical operators, smoothing, and paint

Analysis

- Due to the number of cases, full labelling of the entire dataset was not possible so a quantitative analysis could not be performed
- Segmentations were visually inspected to determine a qualitative match between CT images and 3D segmentation

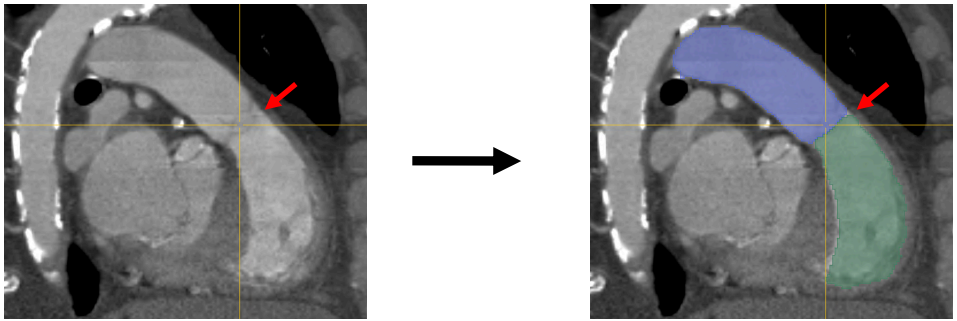
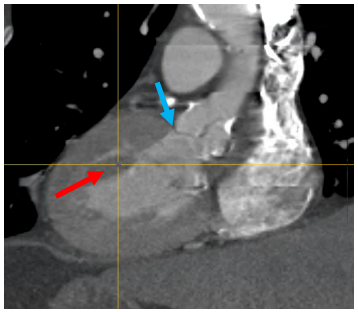
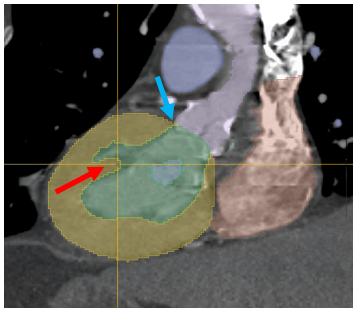


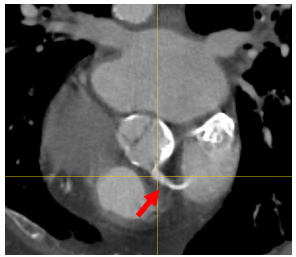
Fig 3: Boundary between pulmonary artery and right ventricle (left)

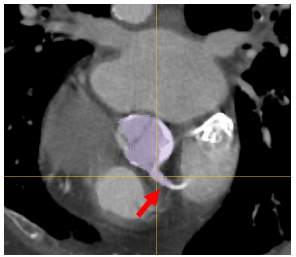
Analysis

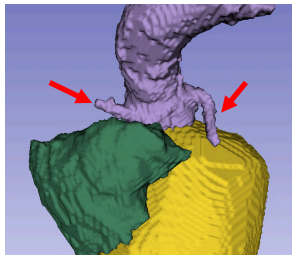
- **Points of focus:**
  - Identify boundaries between heart segments
  - Two distinct openings in left ventricle myocardium to allow blood flow in through the left atrium and out through the aorta
  - Smooth blood pool in left/right ventricle
  - Preserve structure of the papillary muscles in the left ventricle for more accurate dynamical simulations
  - Coronary arteries, which deliver oxygenated blood to the heart











Acknowledgements

- Thank you to the SURE program and Dr. Wei Sun for the opportunity to contribute to this project
- Thank you to my research mentors Dr. Minliang Liu and Dr. Tongran Qin for their continued support and feedback throughout the summer
- Thank you to Daniel Pak for creating the segmentation training video

Sources

1. Kong et al, 2021: 2102.07899
2. Daniel H. Pak, Minliang Liu, Shawn S. Ahn, Andrés Caballero, John A. Onofrey, Liang Liang, Wei Sun, and James S. Duncan. Weakly supervised deep learning for aortic valve finite element mesh generation from 3d ct images. In Aasa Feragen, Stefan Sommer, Julia Schnabel, and Mads Nielsen, editors, Information Processing in Medical Imaging, pages 637–648, Cham, 2021. Springer International Publishing.
3. Sun et al, 2014. Annu. Rev. Biomed. Eng. 2014.

Questions