EFFECT OF PIXEL INTENSITY THRESHOLD AND IMAGING PARAMETERS ON LUNG SEGMENTATION FROM CHEST CT SCANS

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I. INTRODUCTION

- Lung vessel segmentation is an important step in image analyze and has important implications in vascular diseases and insults including:
  - Chemotherapy-related lung or tumor insult
  - Chronic pulmonary arterial hypertension[2,4]
  - Altered vascular development in children with extreme pre-term gestation
  - Injury resulting from radiation or other environment insult [3]
  - Angiogenesis around tumors

- The process of accurately identifying, characterizing and segmenting the lungs including density and morphology from a Chest CT scan can be severely impacted by the intensity tolerances selected by the user. Furthermore, tolerances can respond accordingly to image parameters for the CT Scan.

HYPOTHESIS: Varying thresholds in lung segmentation with different scan parameters (differences in voxel size, slice thickness and reconstruction filter) can be characterized and modelled.

OBJECTIVE: Analyze the effect of using different tolerances and determine the relationship between them and image parameters.

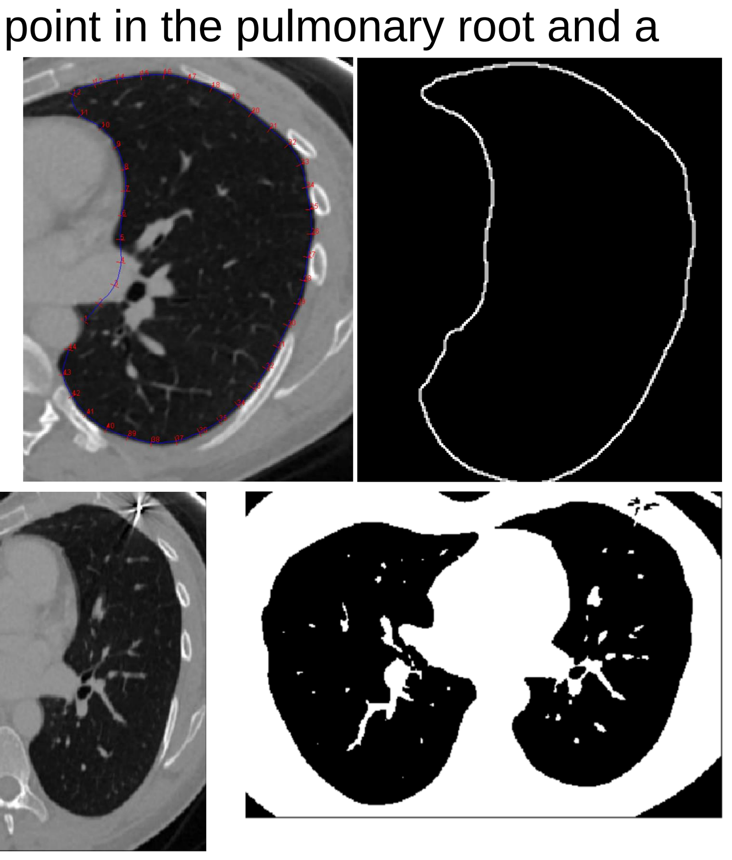
II. IMAGING METHODOLOGY

MATERIALS AND METHODS

- A diagnostic-quality representative chest CT scan of a human subject was acquired and the raw data, previously saved on the CT scanner console, was used to reconstruct a set of 16 CT data-sets including
  1. slice thicknesses: 0.5, 1, 2 and 3 mm (no overlap)
  2. isotropic in-plane pixel dimensions: 0.543 and 0.702 mm
  3. with/without a Lung enhancement filter.
- For each of the image sets, the 3D lung vascular system was segmented and characterized semi-automatically via flood-filling starting from a manually-selected seed point in the pulmonary root and a pixel-intensity threshold for distinguishing vessel from background.
- The same seed point and thresholds were used for all runs.
- A radius-histogram for vessel count was tabulated for each data set.

LUNG SEGMENTATION

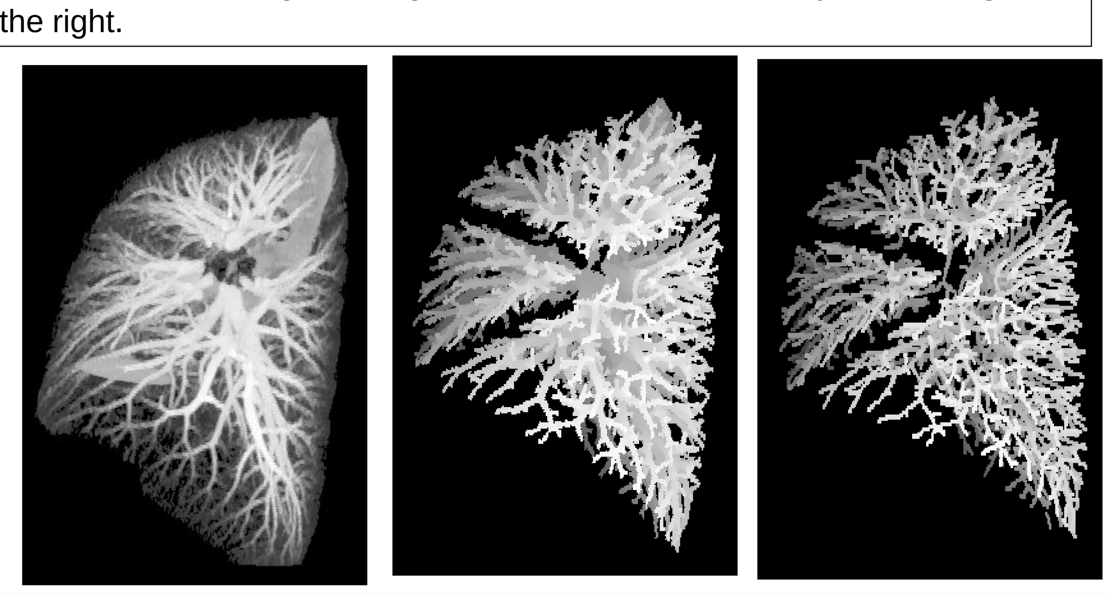
- Lungs are initially segmented to create a binary image that defines the position of the lung in the CT scan.
- Steps:
  1. Initial lung volume mask generated through a series of thresholds, inversions and 3D flood-fills.
  2. Use active contours (snakes) to trace lung outline and adjust manually when needed (Fig. 1).
  3. Erode snake mask by 2 mm, to remove chest wall pixels.



Figures 1-4: The figures depict the image of lung segmentation for a single slice of the CT scan. The original image is on the left and the binary result image is on the right.

THRESHOLD SEGMENTATION

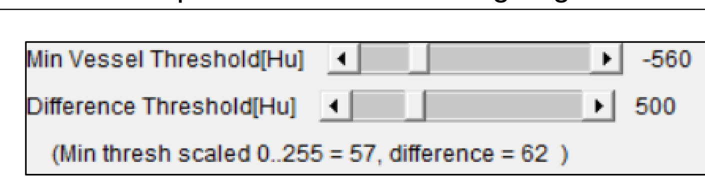
- Steps:
  1. Crop to chest. Get lung volume and airway masks.
  2. Choose and apply appropriate minimum vessel and difference thresholds (-560Hu and 500Hu respectively was used)
  3. Select seed and fill vessel using thresholds.
  4. Remove internal holes and fibrosis.
  5. Change outputs to obtain more readable data.
  6. Vary parameters and thresholds.



Figures 5-7: These figures show the visual representation of the lung segmentation

DATA ANALYSIS

- $a_0(s,t)$ was determined to be patient and time frame specific
- Equation was developed with respect to a universal baseline
- scan of 1 x 1 x 1 mm voxel size
- A calibration model was formulated as:
  - $V = a_0(s,t) + a_1*(T-1) + a_2*(T-1)^2 + a_3*(p-1) + a_4*(1-L)$
  - V = Voxel Size, T = slice thickness [mm], p = in-plane pixel size[mm]; L = {0,1} for Body vs. Lung filter.



Figures 8: Visually shows GUI of how the vessel and difference thresholds were adjusted

III. RESULTS

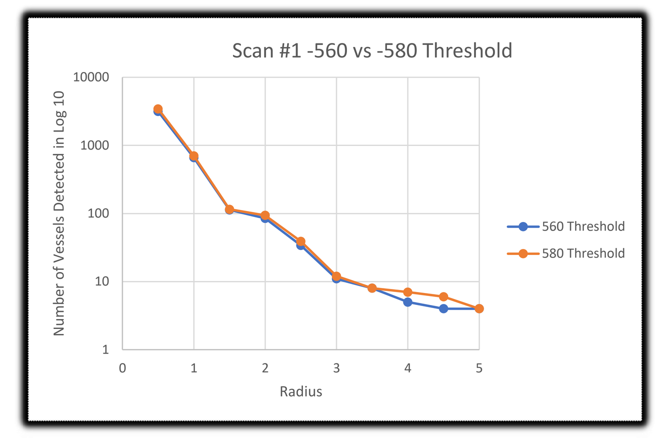


Figure 9: The Figure on the left shows the vessel count with the -560 and -580 Hu thresholds.

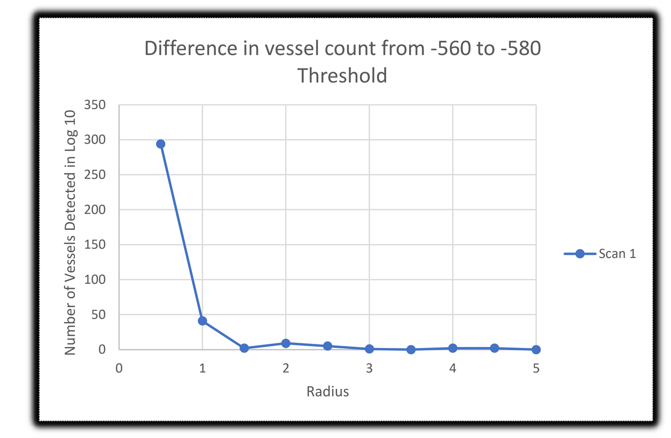


Figure 10: The Figure on the left shows the vessel count difference between the two thresholds. Larger differences occur as the vessel radius size decreases.

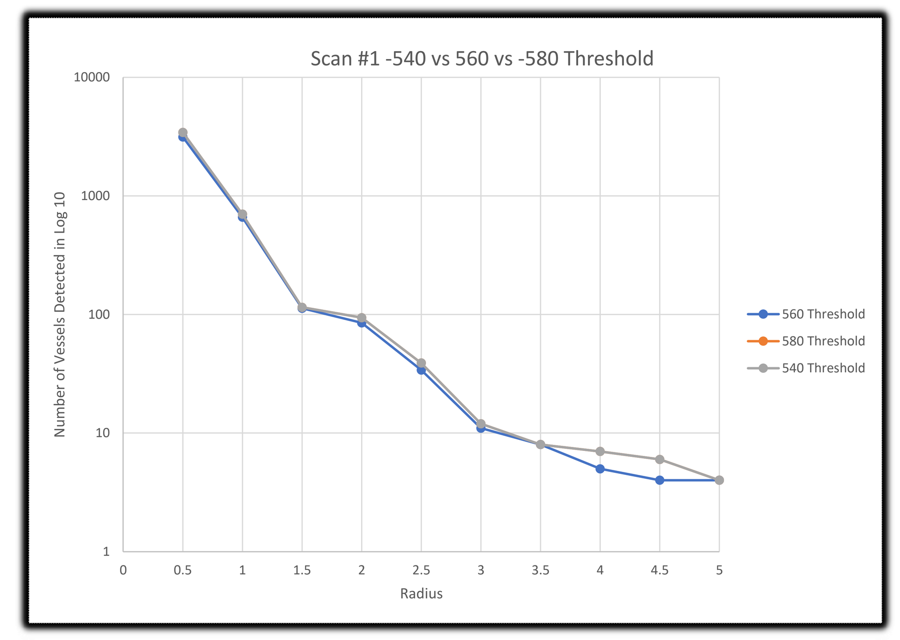


Figure 11: The figure above shows the effect of increasing and decreasing the thresholds. Smaller vessels will be picked up more frequently at lower thresholds.

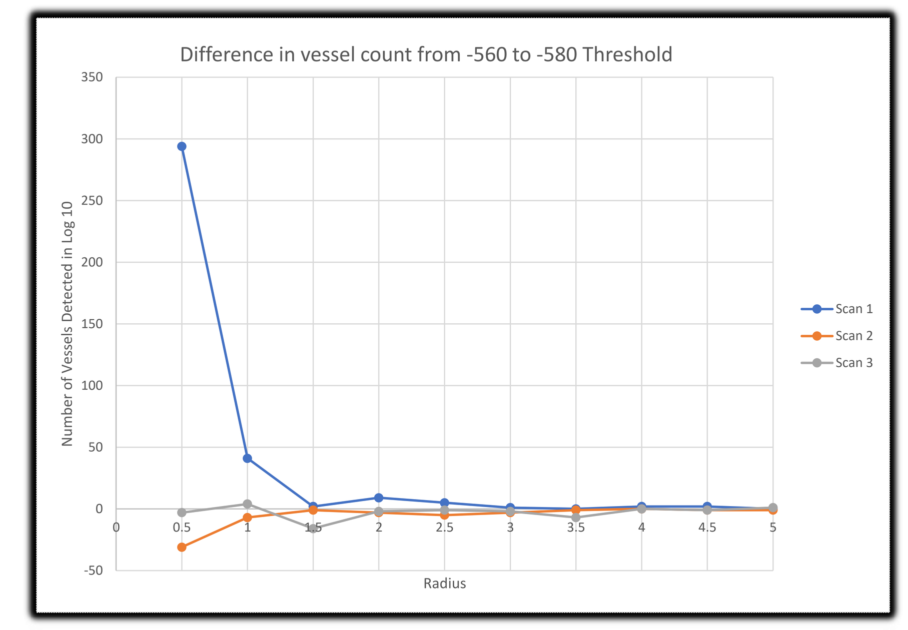


Figure 12: Plot shows multiple scans overlapped to highlight differences in vessel counts at -560 and -580 thresholds. When comparing multiple scans, parameters played a significant role in the number of vessels observed at varying thresholds.

V. CONCLUSIONS AND DISCUSSION POINTS

- Overall, there is a large trend towards increasing lung vessel count during lung segmentation while lowering the threshold. This makes sense as at lower Hounsfield unit thresholds, the code allows for more lenient vessel detection via a lower pixel intensity requirement.
- There were large differences when incorporating multiple scans with varying scan parameters. The differences in voxel size, slice thickness, and reconstruction filter need to be addressed for a quantitative comparison of metrics across individuals and over time.
- $a_0(s,t)$ was determined to be patient and time frame specific and can be solved for and used to obtain more accurate vessel counts.
- Despite changing the thresholds, the general trends stayed the same. The total number of branches appeared to decrease with increasing slice thickness and in-plane pixel size, and when using body filter vs. lung enhancement filter. More statistical data should be done to quantitively show the differences
- More advanced models are under development.

V. REFERENCES

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