Medical Imaging Project

CT Lung Image Segmentation using ITK

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Introduction

- Lungs, vital for respiration, are a focal point in global health, contributing to numerous diseases and millions of deaths annually

- Quantitative analysis of pulmonary abnormalities requires accurate lung segmentation before deploying additional tools for analysis

- Segmentation techniques enable precise disease detection, treatment planning, and follow-up assessments

- ITK's algorithms enhance accuracy, speed, and reproducibility, providing invaluable insights into pulmonary health and pathology

Methods:

Three segmentation algorithms available in ITK:

- Thresholding
- Region Growing
- K-means Clustering

Dataset

- Chest CT dataset publicly available on Kaggle
- First 5 subjects

Thresholding

Thresholding in Image Processing

- **Definition:** Setting a threshold or range of values to classify pixels based on intensity or other features.
- **Application:** Often used in medical image segmentation to isolate specific structures or tissues from the background.

Lung Segmentation

- **Objective:** Create a binary mask isolating the lungs from surrounding structures based on intensity levels.
- **Utilized Techniques:** Binary Thresholding, Otsu Multiple Thresholds, and Huang Thresholding.
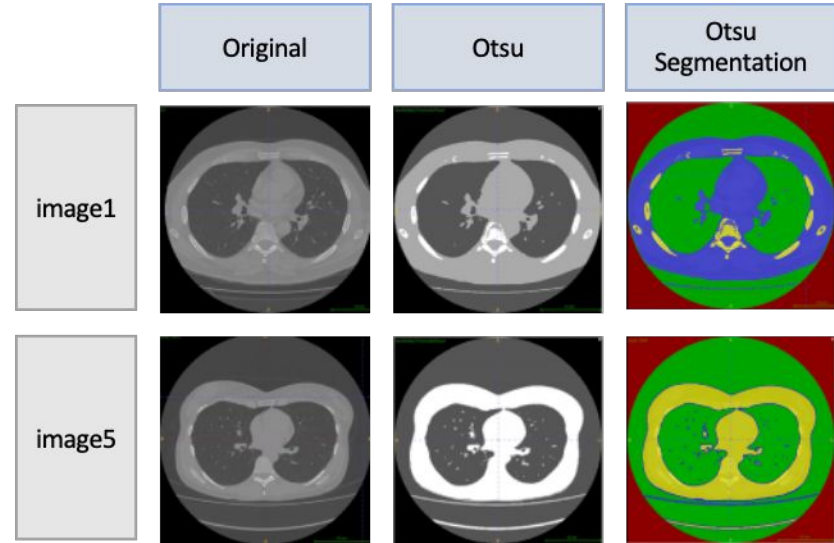
Thresholding

Preprocessing:

Gaussian Smoothing:

- **Purpose**: Reduce noise and ensure a smoother intensity distribution.
- **Implementation**: Used SmoothingRecursiveGaussianImageFilter.
- **Parameter**: Sigma value set to 1.0 (adjustable based on image characteristics).

Thresholding: Otsu Multiple Thresholds

- **Algorithm:** Determines optimal intensity thresholds based on image histogram.
- **ITK Filter**: OtsuMultipleThresholdsImageFilter.
- **Parameters**:
  - Number of Histogram Bins: 256.
  - Number of Thresholds: 3 (adjustable).
 - Label Offset: 1 (adjustable).

Thresholding: Binary Thresholding

- **Approach**: Simple intensity-based segmentation.
- **ITK Filter:** BinaryThresholdImageFilter.
- **Parameters:**
    - Lower Threshold:- 1030.
    - Upper Threshold: -648.
    - Inside Value: 300.
    - Outside Value: 10.
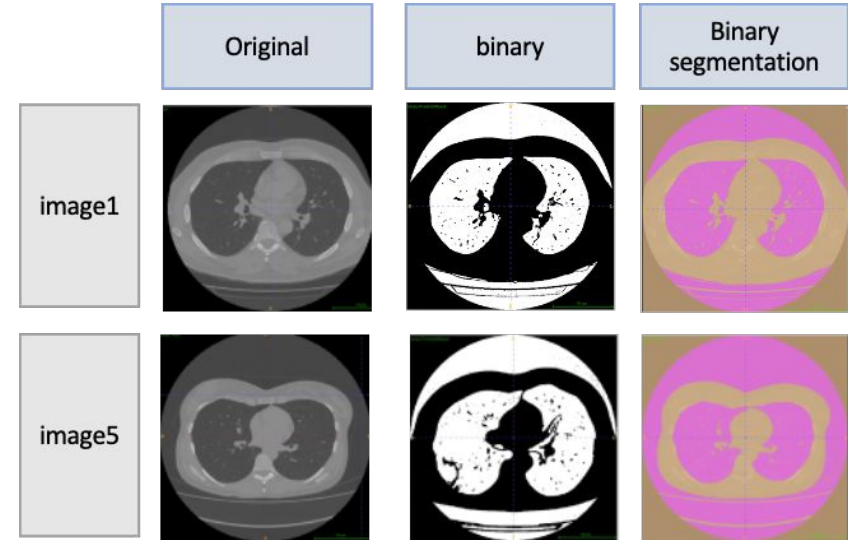
Thresholding: Huang Thresholding

- **Method**: This filter creates a binary thresholded image that separates an image into foreground and background components. The filter computes the threshold using the HuangThresholdCalculator and applies that threshold to the input image using the BinaryThresholdImageFilter.
- **ITK Filter**: HuangThresholdImageFilter.
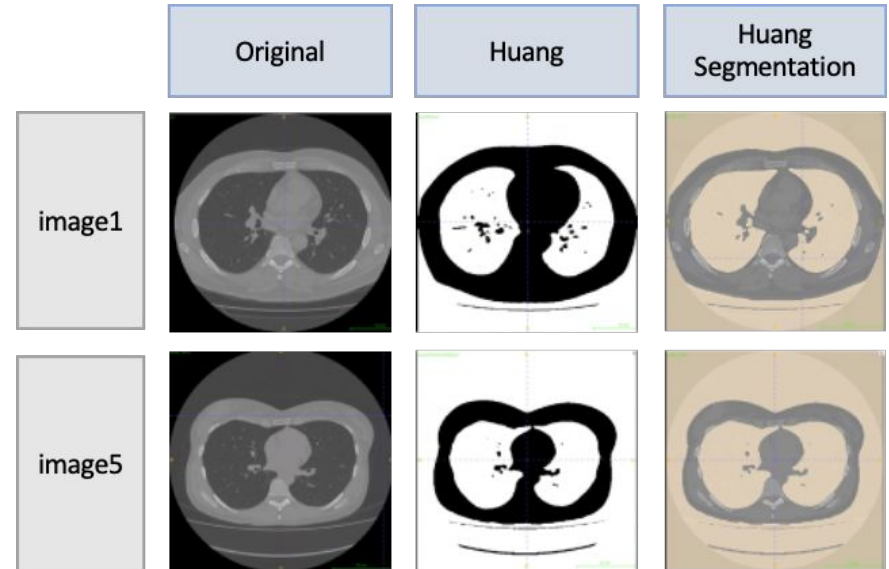
Region Growing

## Region Growing in Image Processing

- **Definition:** Start from a seed region that is considered to be inside the object to be segmented. The pixels neighboring this region are evaluated to determine if they should also be considered part of the object
- **Application**: Often used as an effective approach for image segmentation

Lung Segmentation

- **Objective:** Segment lung region using seed points in that area
- **Preprocessing:** Gaussian Smoothing
- **Seed points and Thresholding values:** Slicer
- **Approaches:** ITK's **itkConnectedThresholdImageFilter**, **itkConfidenceConnectedImageFilter**

Region Growing: Connected Threshold Filter

- **Approach:** The connected threshold filter labels pixels with a replace value that are connected to an initial seed and lie within a lower and upper threshold range.
- **Parameters:**
  - Seed point
  - Lower threshold
  - Upper threshold
  - Replace value
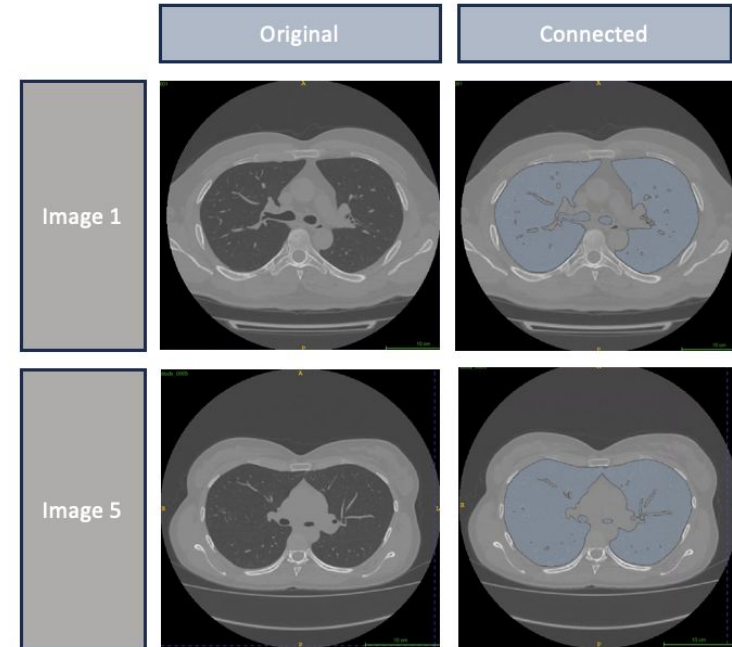
Region Growing: Confidence Connected Image Filter

- **Approach:**
  - The confidence-connected filter identifies a pixel set consistent with seed point statistics. Mean and variance are calculated in a neighborhood, and connected pixels within the confidence interval (controlled by "Multiplier") are grouped.
  - The segmentation recalculates mean and standard deviation using all pixels from the previous segmentation, not just the neighborhood of the seed point. The refined estimates are then used to update the segmentation.
  - The process repeated for the specified number of iterations
- **Parameters:**
  - Seed point
  - Replace value
  - Multiplier
  - Number of Iterations

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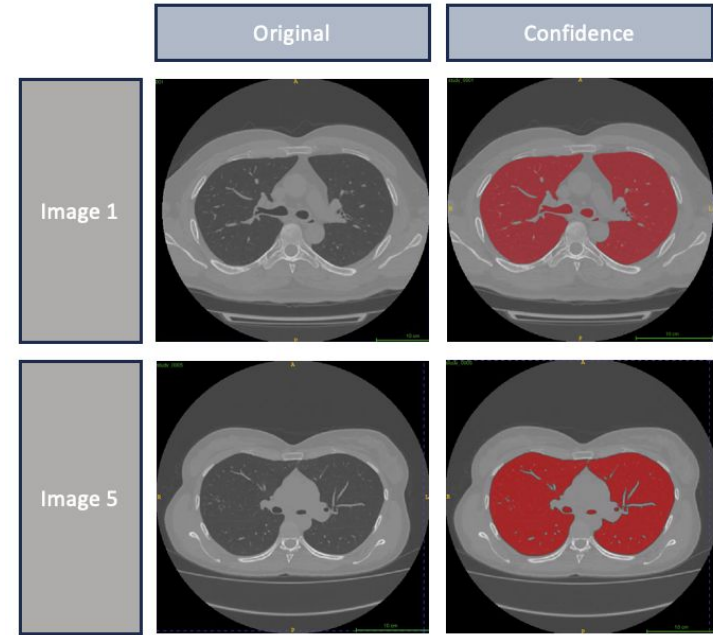
Clustering

## Clustering in Image Processing

- **Definition:** Categorizing pixels or regions into clusters based on their intensity, color, or other relevant attributes
- **Application**: Identify distinct groups of pixels that may represent different tissues or structures within an image to separate lung tissue from other structures in CT images

Lung Segmentation

- **Objective:** Segment lung region using clustering
- **Preprocessing:** K-means++ algorithm for initialization
- **Post-processing:** Re-labeled components and rescaled intensity of the image
- **Approach:** ITK's **itkScalarImageKmeansImageFilter**

Clustering: K-Means

- **Approach:**
  - Given an input image with scalar values, it uses the K-Means statistical classifier in order to define labels for every pixel in the image
  - Segments the image by partitioning pixels into k clusters in which each pixel belongs to the cluster with the closest mean
- **Parameters:**
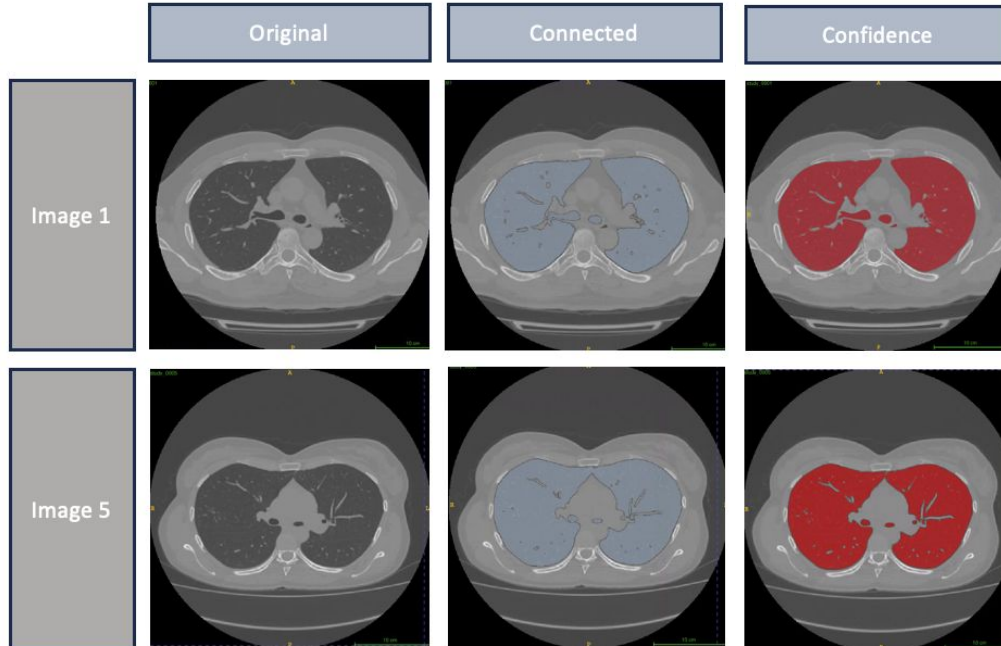 - Number of classes: 3 (led to the best results)
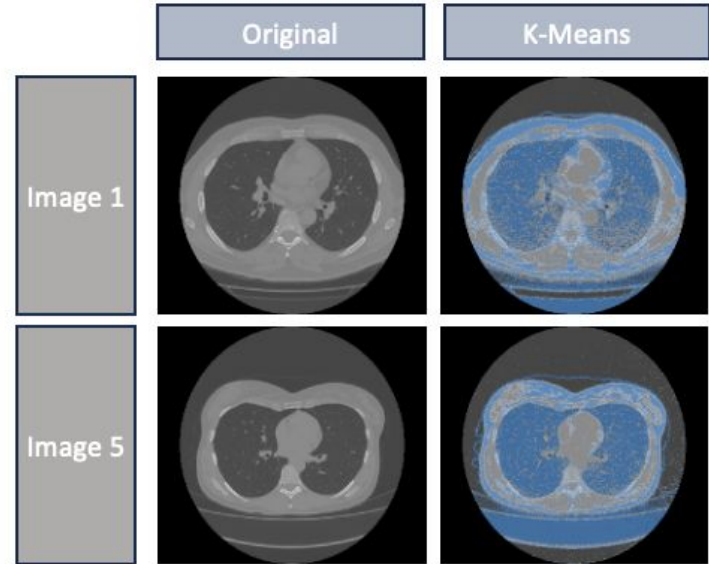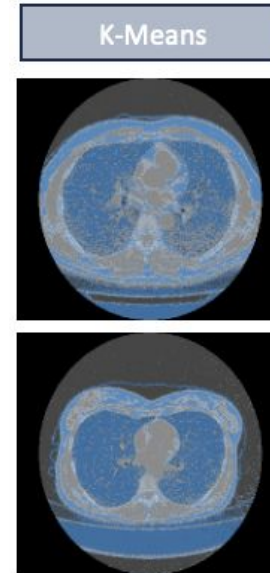
Summary of Results

Thresholding
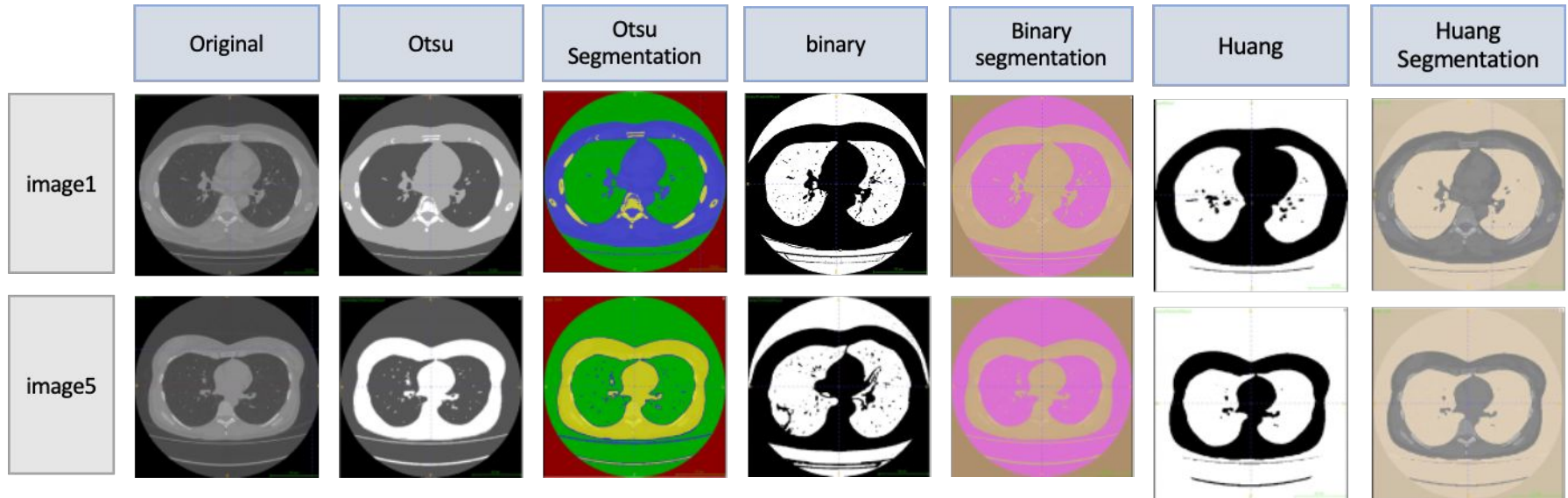
Summary of Results (cont'd)

Region Growing

Clustering

Discussion and Future Work

- **Visual Assessment:** No discernible difference observed between thresholding and region growing methods.
- **K-Means Sensitivity:** K-means clustering results may vary due to multiple factors, like initialization methods or the nature of the lung CT itself
- **Quantitative Comparison:** Ground truth is crucial for accurate and objective evaluation.
- **Future Consideration:** MSE calculation with a Ground Truth Image will provide a more rigorous assessment of segmentation methods.

References

- https://www.kaggle.com/datasets/metformin/chestctdataset/data
- GBD Chronic Respiratory Disease Collaborators. Prevalence and attributable health burden of chronic respiratory diseases, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet Respir Med. 2020;8(6):585-596. doi:10.1016/S2213-2600(20)30105-3
- ITK Region Growing Filters, https://itk.org/Doxygen/html/group__RegionGr
- owingSegmentation.html. Last accessed 9 Dec 2023
- 3. ITK BinaryThresholdImageFilter, https://itk.org/Doxygen/html/classitk_1_ 1BinaryThresholdImageFilter.html. Last accessed 9 Dec 2023
- https://itk.org/ITKSoftwareGuide/html/Book2/ITKSoftwareGuide-Book2ch4.html

Q&A