Segmentation Of Lungs from Chest X-Rays

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Abstract → *In this project, we aim to segment the lung regions from the chest x-ray images using fundamental Digital Image Processing techniques such as Spatial Processing, Image Filtering, Guided Thresholding, Connected Component Labeling and Binary Morphological Operations.*

INTRODUCTION

In medical imaging, even though CTR and MRI technologies provide much more accurate information on patients compared to X-ray images, X-ray imaging is much faster and lower budget for many applications and expose patients to much less radiation. Therefore, medical doctors often rely on X-ray images. Computer Aided Segmentation of chest X-rays – if accurate- save medical doctors effort and time.

In this project our methodology is to segment the chest x-ray image by pre-process the x-ray image by Median Filter to reduce the granular noise-which may be apparent on tuberculosis infected patients- then apply CLAHE (Clip Limited Adaptive Histogram Equalization) to enhance the x-ray images contrast, thresholding the image by applying Otsu's Thresholding Method and apply a series of recursive Binary Morphological Operations guided by a Connected Component Labeling algorithm -which separates the left and right lung regions and guide Binary Morphological Operations to work on them separately- to obtain the segmented Lung regions, and finally apply a Connected Component Labeling algorithm based hole filling algorithm to fill the holes which may be apparent inside the lung regions.

TECHNIQUES

Geometric Transformation

A simple resizing of the original x- ray image is carried out to fix the size of the image by 512 by 512 pixels to limit the amount of processing power used on each image. After the segmentation process is finalized, the resulting image is converted back to original dimensions.

Kernel Concept

For the explanation of some of the Spatial Processing Techniques, it is useful to first go over the concept of a Window or Kernel.

Simply put, a kernel is an array of pixel values extracted from the image we wish to apply Spatial Processing Techniques. Usually (but not necessarily) the size of the kernel is smaller than the image of interest. We apply the kernel by overlaying the kernel to some region of the image, extracting the values that overlay from the original image, apply the Spatial Processing on the resulting array, assign the resulting value to pixel in original image which overlayed with the center of the kernel, iteratively re-apply the process to process all the elements of the original image.

Median Filtering

Median filtering works with the kernel concept, median value in the kernel extracted from the original image is assigned to the center. Usually used to reduce the Salt/Pepper noise in the image.

Gaussian Filtering

Gaussian Filtering or Gaussian Blurring is equivalent to Low-Pass filtering the image in frequency domain, but we use the impulse response of the Low-Pass Gaussian filter and use it as a kernel. Since the kernel is symmetric (Figure 1), correlating the image with the kernel is equivalent to convolving the image with the kernel.

$$\frac{1}{16}\begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix}$$

Figure 1: *3x3 Gaussian Kernel[1]*

Histogram Equalization

The Histogram equalization is the process of calculating the intensity distribution of the image to obtain how many of a pixel value is apparent in the image, calculate the Cumulative Distribution Function of the intensity distribution (CDF) and re-mapping the intensity distribution to the CDF to obtain contrast-wise enhanced image.

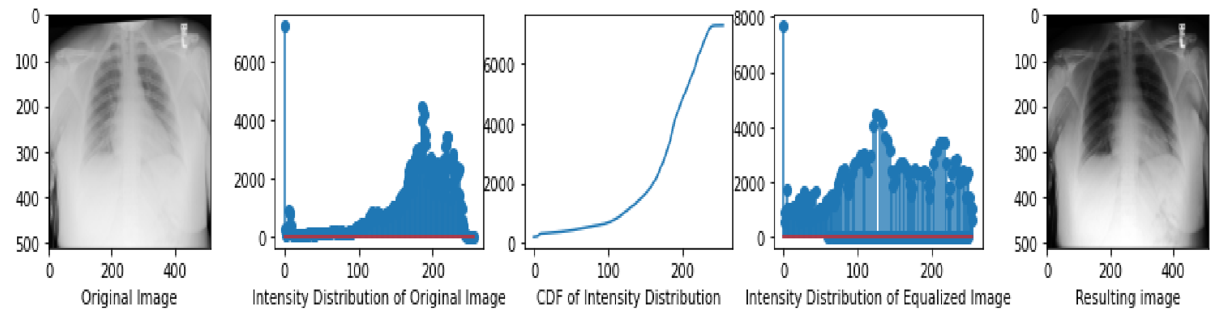


Figure 2: *<u>Histogram Equalization Process</u>*

Clip Limited Adaptive Histogram Equalization (CLAHE)

For often cases, histogram equalization on its own is not enough to enhance the contrast of the image for the method of histogram equalization applies the remapping of the intensities according to global distribution of the intensities in the image. To avoid this, we use a technique called the Adaptive Histogram Equalization; In this technique we divide the image into smaller pieces called grids, apply Histogram equalization on each grid, re-combine the Histogram Equalized grids. In this technique, if there is noise in the original image, it would affect the equalization process of singular grids dramatically. To overcome this noise obstacle, we assign a clip limit to each intensity and distribute the values over the clipping threshold to each pixel in the grid. These processes combined are called the Clip Limited Histogram Equalization or CLAHE for short.

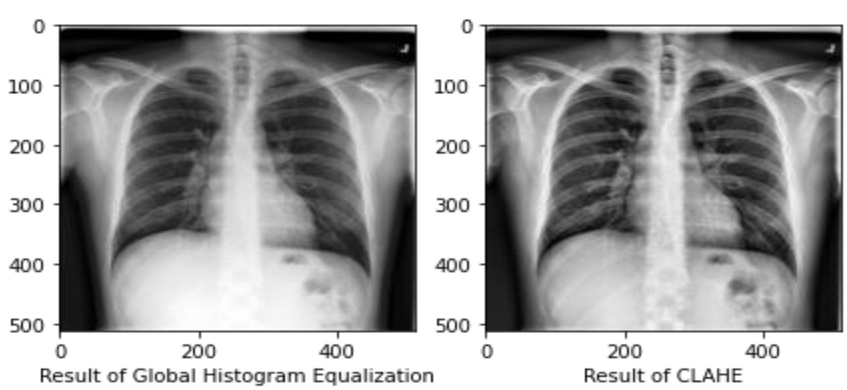


Figure 3: Global Histogram Equalization vs CLAHE

Thresholding

Thresholding is the process of binarizing the image by setting a value of threshold. Pixels with value under the thresholding value are set to zero and pixels with value over the thresholding value are set to a non-zero value.

Otsu’s Thresholding

Otsu’s method finds a local minimum of the intensity distribution function and separates the intensities into two regions. This local minimum value is then used as the thresholding value.

Binary Morphological Transformations

Just like Spatial Processing techniques, Morphological Transformations also use an element like kernels to perform operations. These elements are called Structuring Elements and play a crucial role in performing Morphological Transformations. Structuring elements have shapes and centers, and centers of a structuring elements vary the result of the operation dramatically but for the cases of this project all structuring elements have their centers at the center of their shape.

Erosion

For any position of Structuring element if every element of the structuring element fits inside of a BLOB (Binary Large Object), Center position of the structuring element in the original image is set to 1. Every position else is set to zero. This Operation shrinks BLOBS in image.

Dilation

For any position of Structuring element if any element of the structuring element fits inside of a BLOB (Binary Large Object), Center position of the structuring element in the original image is set to 1. Every position else is set to zero. This Operation enlarges BLOBS in image.

Opening

Erosion operation Followed by Dilation operation.

Closing

Dilation operation Followed by erosion operation.

Binary Component Labeling

Scanning the binary image for every pixel until an un-labeled pixel is found, label the pixel with an unused label (by assigning its value to a new unused value), check the neighboring pixels for connections (4 way or 8 way) if there is a neighboring pixel with non-zero value, assign the same label to the pixel, check until there is no un-labeled non-zero neighboring pixel to the labeled component, continue to scan the image until there is no un-labeled non-zero pixels.

ALGORITHM

The aim of the algorithm is to obtain lung regions from the input images in binary form (white for lungs, black for everything else). So, the center part of this algorithm would naturally be to thresholding the image. The first part of the algorithm is to process the original gray scale image in a way that the resulting image of the thresholding would contain the lung fields as accurately as possible. This part of the algorithm would have been different from –for example- fracture detection algorithm since we want to get rid of rib bones. But we do not want to get rid of all the bone structure for we need to obtain the borders of the lungs. In this part of the algorithm, lung regions are still black and treated as background so until we invert and label the resultant image of the thresholding, we need to use the dual of the Binary morphological Transformation we want to use (Erosion for dilation and Opening for Closing vice versa).

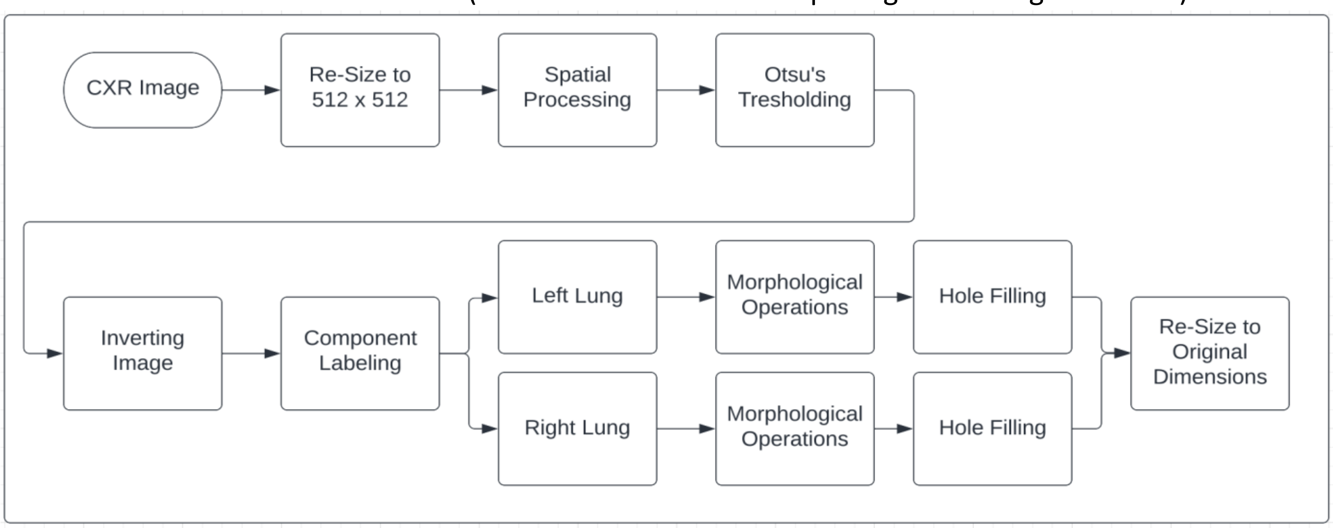


Figure 4: *General Outline of the Algorithm*

After the binary labeling process, with use of a predetermined seed location, left and right lung BLOBS are determined. An algorithm checks if the BLOBS are connected to the corners of the image, if the BLOBS are connected to the corners of the image, closing operation is applied to the image and checked again, if the BLOBS are still connected to the corners of the image, size of the elliptical structuring element is increased, and the image is subjected to the Closing operation again. This Process is repeated until the BLOBS are Separated from the corners. To obtain better accuracy, This Process is applied to the Left and Right Lung Blobs separately. After this process, a connected component-based hole filling algorithm is applied to the Lung Blobs and the lungs are re-combined in a singular image. This image is then resized into the original input dimensions.

Spatial Processing

As discussed before, in spatial processing, we need to obtain an image with good enough definition to determine the borders of lung with accuracy, but we also need to get rid of the rib bones. So, the Spatial Processing algorithm has been mostly trial and error.

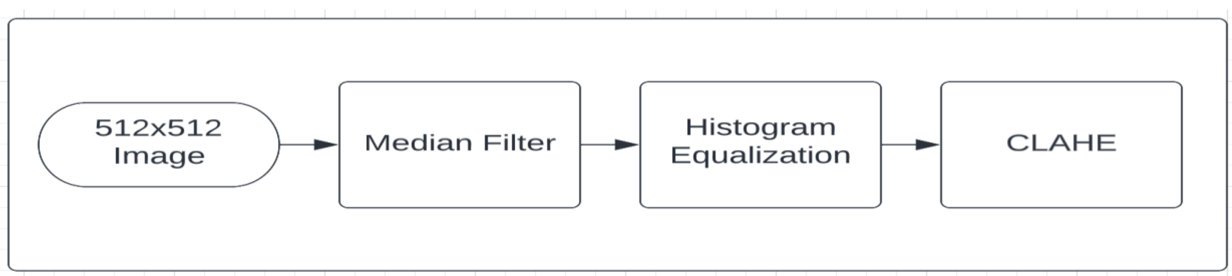


Figure 5: *Spatial Processing Diagram*

Corner Separation Algorithm

After the thresholding of image, in some cases, because of the definition of collarbone in the image, lung regions are connected to background of the image. To overcome this an algorithm is developed to iteratively apply closing operation with bigger structuring element to the image until the borders of Lungs are separated. In the Code implementation, separation function takes the output of thresholding and performs the morphological operation and checks for background connection by inverting and labeling in each iteration. So, the function applies Opening operation in each iteration. In figure 8 there is the right lung region connected to the background and right lung region separated after the structuring element with the size of 16x16 is applied.

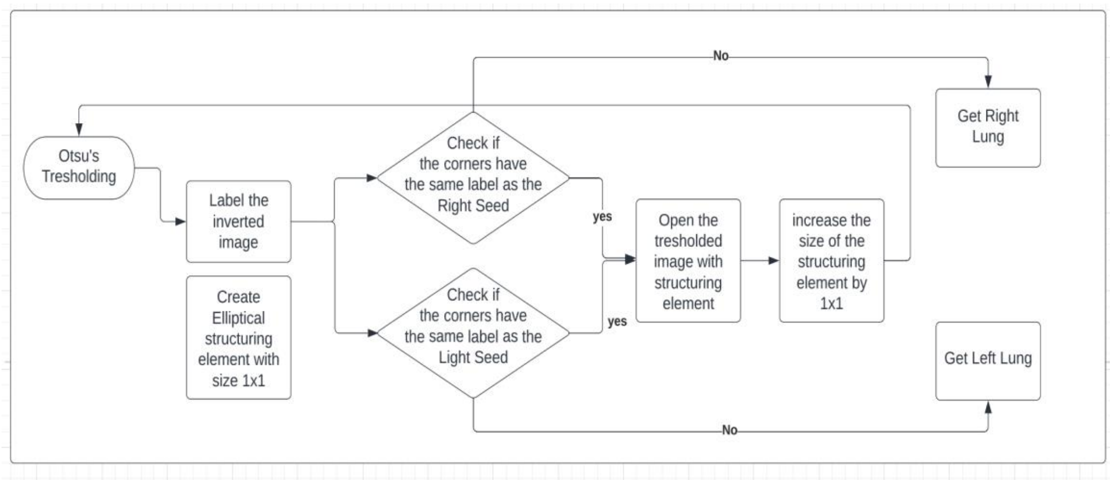


Figure 7: *Corner Separation Algorithm*

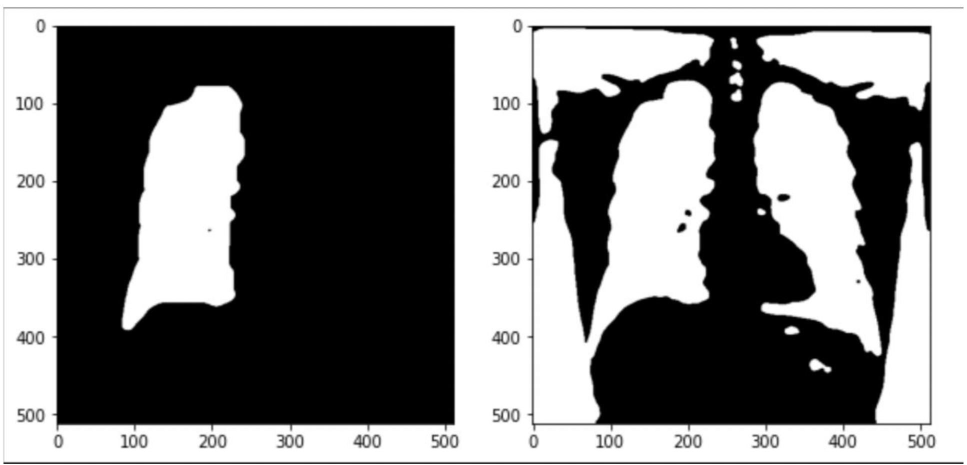


Figure 8: *Inverted Binarized image and the Right Lung Region After the Separation Algorithm*

Re-Obtaining the Shape

After the corner separation, most of the time the shape of the lung is distorted (Figure 7). To re-obtain the original shape, output of corner separation algorithm is dilated with the same structuring element used in the opening operation and logical and operation is performed between inverted binarized image and the dilated image.

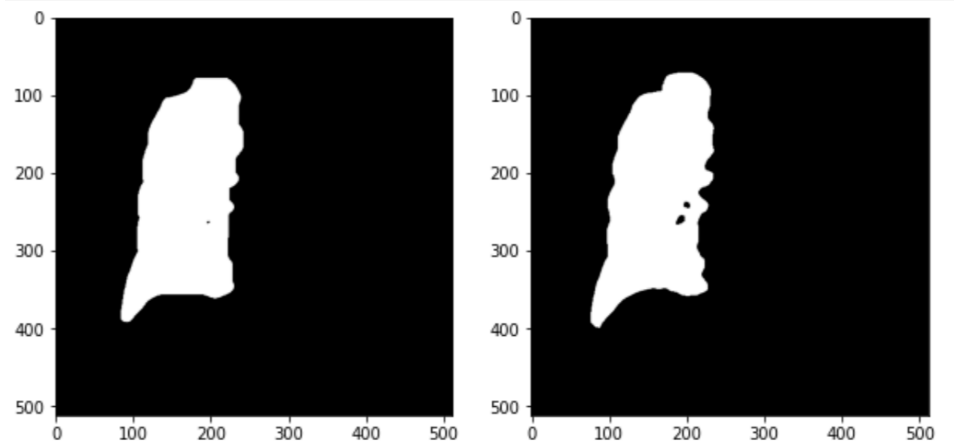


Figure 8: *Left: Output of Corner Separation Right: output of Shape Recovery algorithm*

Note that original holes that were apparent in the binarized image are inherited in the recovery of the shape.

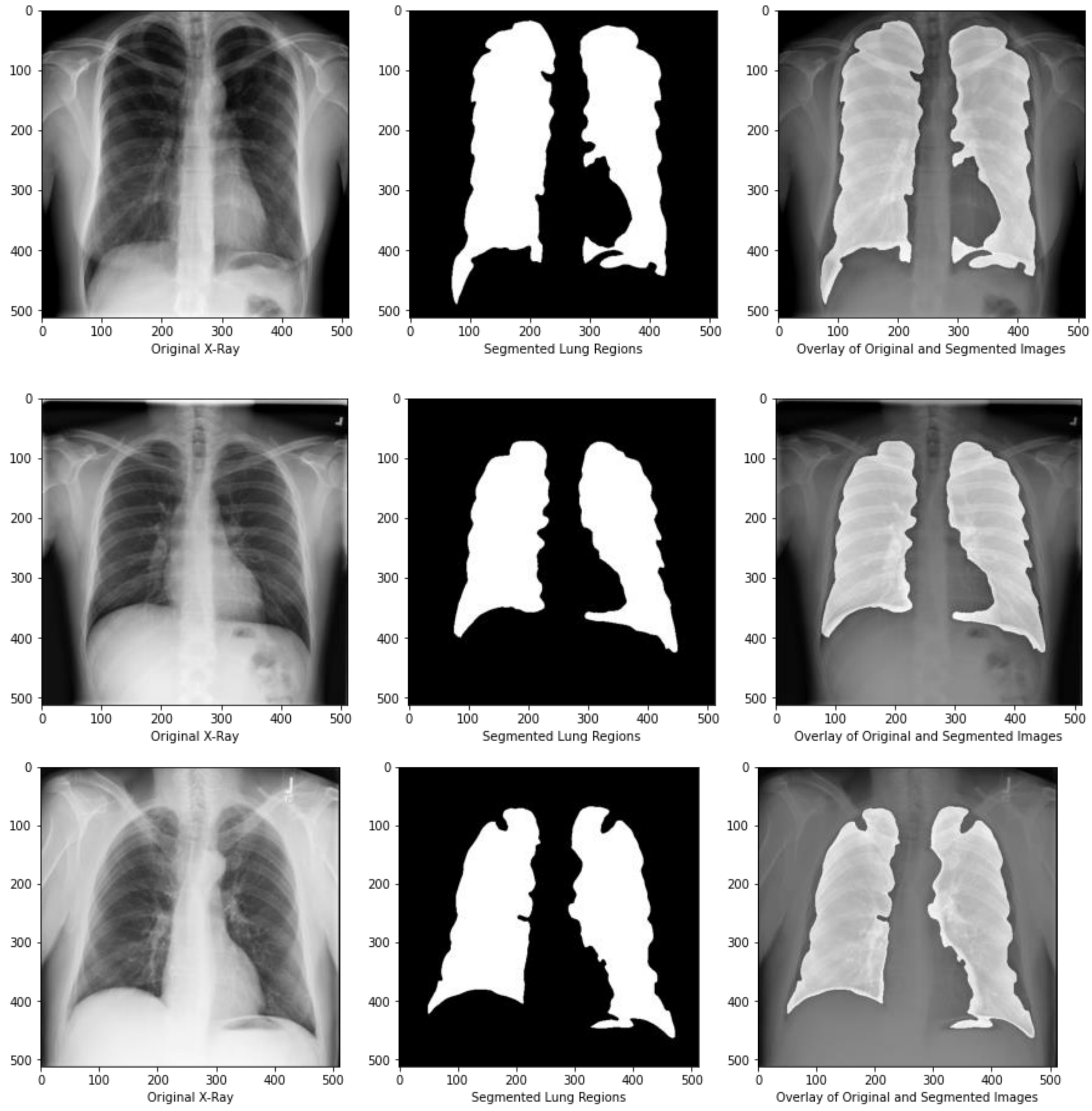
Hole Filling Algorithm

To fill the holes in segmented lung regions, first the image is inverted, then image is labeled. Since in inverted image background and holes become non-zero and the lung region becomes zero and the lung region contains the holes, when we apply the labeling algorithm background always takes the label of 1 and holes (if any apparent) take values greater than 1. Algorithm sets the values of any pixel with value greater than 1 then re-inverts the image.

Weak Points of the Algorithm

In the corner separation process, algorithms working is based on a predetermined magic number. Which may not result in any objects we are interested in (which often is the case for exceedingly small lungs). This case usually puts the program into long (But not infinite) Loop. Also, the separation of lungs from the background process checks the connection of lungs with the corner but for any reason if any interference occurs during the X-Ray imaging Process which makes the corners of the original image into a gray region, algorithm will fail to separate the background and the lung region.

RESULTS


Original X-Ray
Segmented Lung Regions
Overlay of Original and Segmented Images
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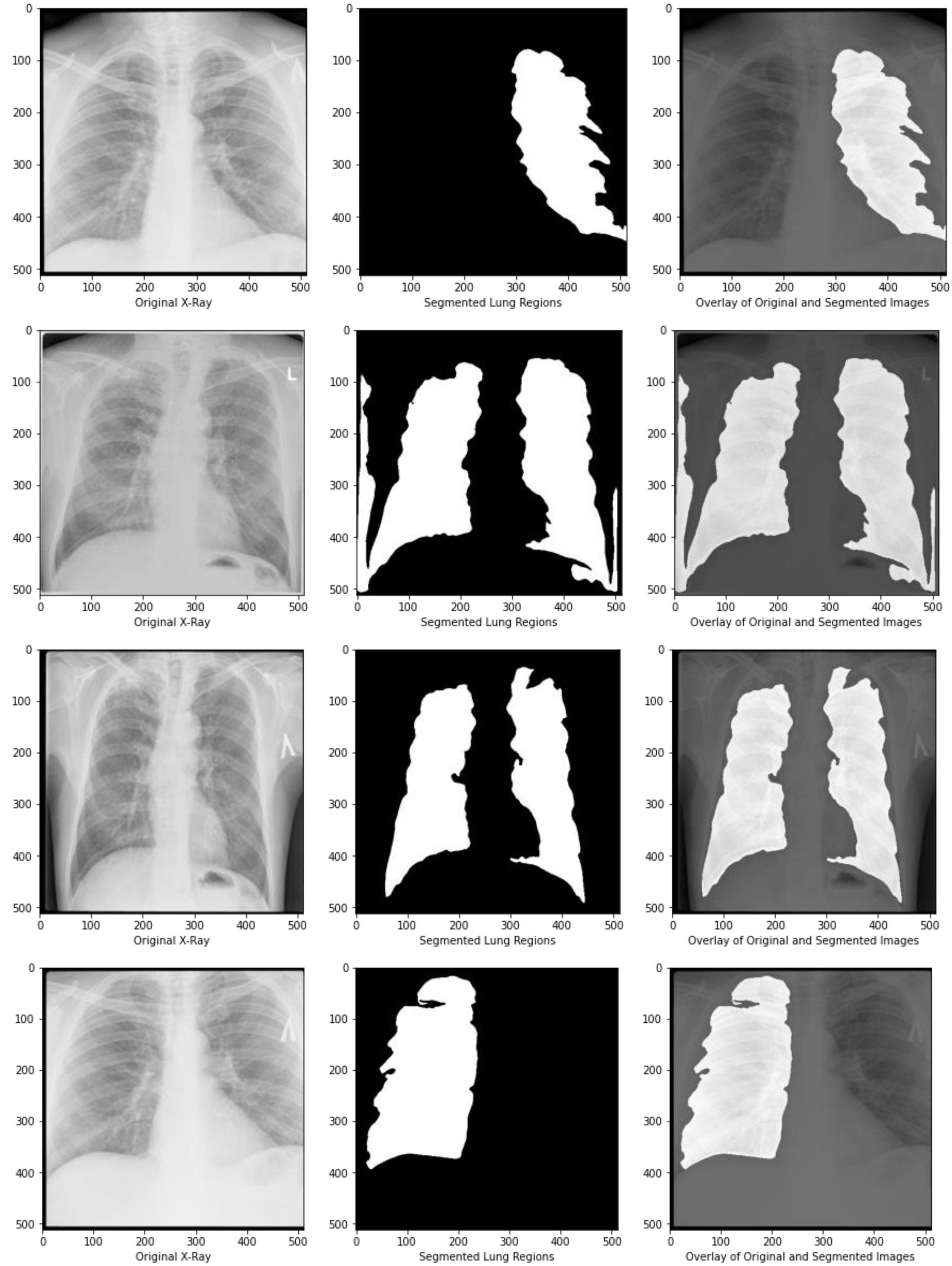
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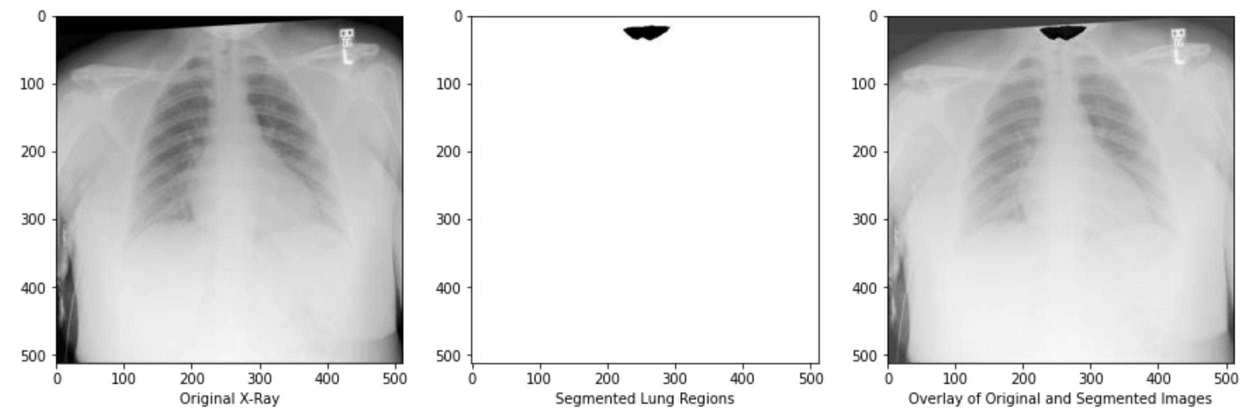

CONCLUSION

The algorithm is tested with a public dataset we found in web[2].We could not find CXR images with ground truth images of the Lung regions. So, this report lacks a decent evaluation of the working of the algorithm. But by inspection with bare eye, it is obvious that the algorithm does not output precise shapes of lung regions. Whether the area of the segmented image results in a decent result compared to the real area of the lung regions needs to be tested measured.

REFERENCES

[1] https://www.opencv-srf.com/2018/03/gaussian-blur.html

[2] https://www.kaggle.com/datasets/tawsifurrahman/tuberculosis-tb-chest-xray-dataset