

Detection of Lung Cancer using Morphological Operations

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Abstract— Early detection of cancer is the most promising way to enhance a patient's chance for survival. This paper presents a Computer Aided Detection method in Computed Tomography (CT) images of lungs using mathematical morphological operations. The image is first preprocessed and the entire lung region is segmented from the CT images. Then by using morphological operations, the nodule region is segmented. The images are collected from Lung Image Database Consortium (LIDC) and also from reputed hospitals. The proposed method gives sensitivity of 88.24%, specificity of 93.33% and accuracy of 90.63%.

Keywords— Computer aided detection, computed tomography, segmentation, morphological operations.

1 INTRODUCTION

Lung cancer is one of the deadly diseases in the world [1]. The survival rate depends on the early detection and treatment of small and localized tumors. The patient survival rate is more when lung cancer is detected in the early stage [2]. Computer-aided diagnosis (CAD) system can be defined as a diagnosis made by a radiologist where the output from a computerized analysis is considered as a second opinion in detecting lesions in the images. Computer-aided diagnosis assists radiologists in improving diagnostic accuracy. In this paper we present a computer aided detection method in Computed Tomography (CT) images of lungs using morphological operations.

First algorithm segments the lung lobes from the CT scan image. The second algorithm is to detect the well-circumscribed nodules and vascularized nodules. The third algorithm is to detect juxta-pleural nodules and pleural-tail nodules when the nodule is located outside pleural surface. The fourth algorithm is to detect juxta-pleural nodules and pleural-tail nodules when the nodule is located inside pleural surface. An image with well circumscribed nodule is shown in Figure 1 and with vascularized nodule is shown in Figure 2. An image with juxta pleural nodule located near the outside pleural surface is shown in Figure 3 and pleural tail nodule located near inside pleural surface is shown in Figure 4.

2 MATERIALS AND METHOD

The images are collected from a database of Lung Image Database Consortium (LIDC) and also from reputed hospitals. CT images of 120 patients are collected including both men and women. The average age of the patients considered is 64.2 years (age of the youngest patient is 18 years and the oldest patient is 85 years). The image is first preprocessed and the entire lung region is segmented from the CT images. Then by using morphological operations, the nodule region is segmented. The lung nodules are classified into four types based on the presence and location of cancer part as Well-circumscribed nodules, Vascularized nodules, Juxta-pleural nodules and Pleural-tail nodules [3]. Four algorithms are proposed for segmentation of nodules from the images.

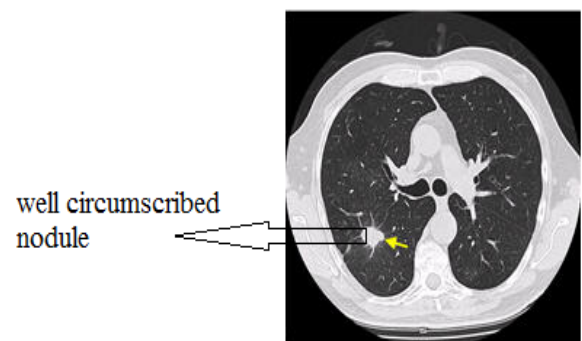


Figure 1: Well circumscribed nodule

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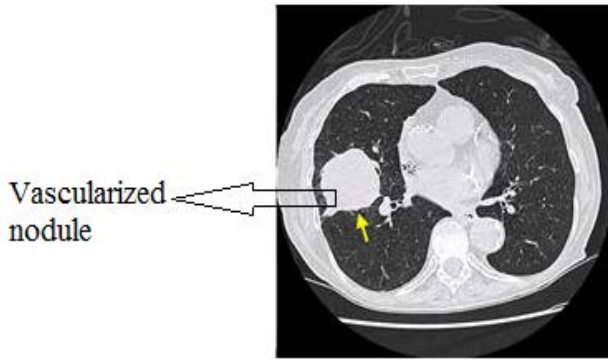


Figure 2: Vascularized nodule

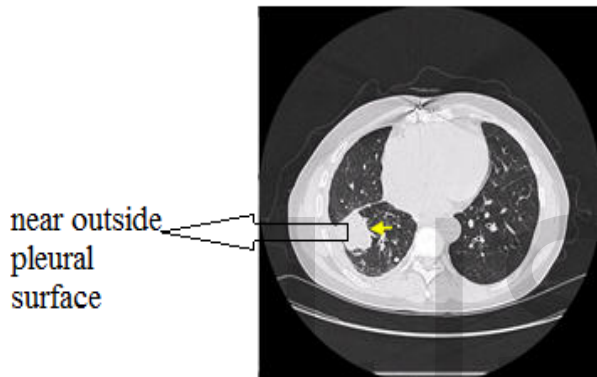


Figure 3: Juxta pleural nodule located near the outside pleural surface

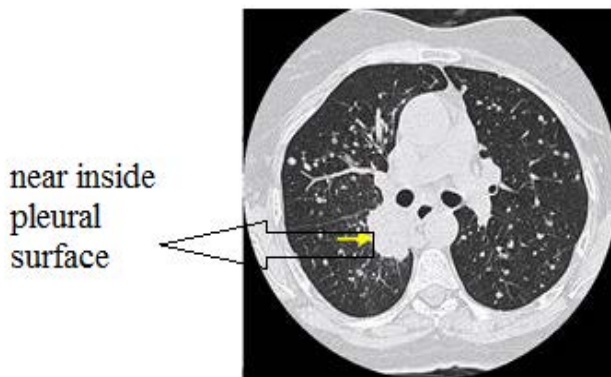


Figure 4: Pleural tail nodule located near inside pleural surface

3 ALGORITHM 1: SEGMENTATION OF LUNG LOBES

The entire lung is segmented from the CT images using mathematical morphological operations. The algorithm 1 is to segment the lung lobes from the CT image. The morphological operations are tools for extracting image components that are useful in the representation and description of the region shape. The gray scale image is first converted to binary image. All the pixels in the input image with a luminance greater than a threshold level is replaced with value '1' and all pixel values with a luminance less than threshold level is replaced with value '0'. The threshold level is calculated by Otsu method [4]. Otsu's method is used to automatically perform histogram based image thresholding. The algorithm assumes that the image to be threshold contains two classes of pixels (e.g. foreground and back ground) then calculates the optimum threshold separating those two classes so that their combined spread is minimal [5]. The Otsu method chooses the threshold level to minimize the intra class variance of the black and white pixels. The morphological opening operation is performed to the binary image with a structuring element [6]. Opening removes small objects from the foreground of an image, placing them in the background. Opening is the dilation of the erosion of a set A by a structuring element B. In mathematical morphology, a structuring element is a shape, used to probe or interact with a given image, with the purpose of drawing conclusions on how this shape fits or misses the shapes in the image [7]. The morphological opening operation is performed to the binary image with following three structuring elements. The three structuring elements are

1. SE1 is disk with radius 1
2. SE2 is line of length 2 degree 0
3. SE3 is line of length 2 degree 90.

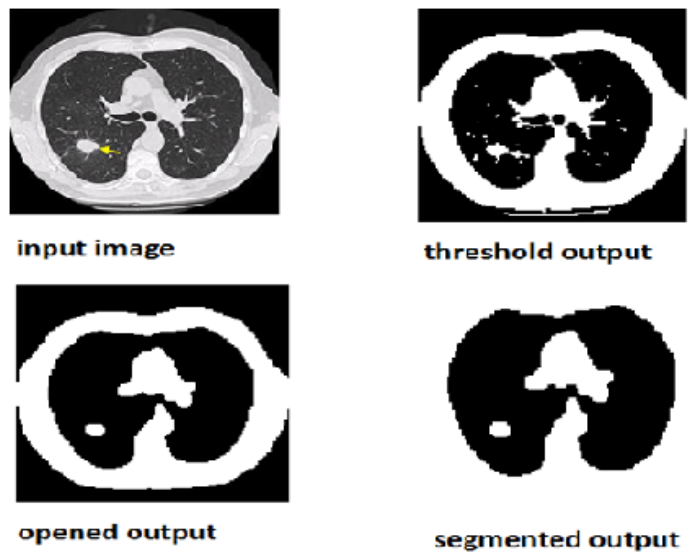


Figure 5: Steps in segmentation of lung lobes

A new structuring element is created using the above three structuring elements. The structuring element is located at the

origin [8]. The image is then inverted and clear border operation is performed. The clear border operation suppresses structures that are lighter than their surroundings and that are connected to the border of the image. The steps in segmentation of lung lobes are shown in Figure 5.

4 ALGORITHM 2: SEGMENTATION OF WELL-CIRCUMSCRIBED AND VASCULARIZED NODULES

The second algorithm is to segment the well-circumscribed and vascularized nodules from the lung lobe which is the output of the first algorithm. In this the output of the first algorithm is performed clear border operation [9]. Then that output is morphologically opened, where it removes all connected components less than 500 pixels. The criteria 500 pixels are considered because if it is greater than 500, then the entire lungs is also removed. If it is less than 500 pixels, then all nodules present in the lungs will be considered. Finally, the morphologically opened output is performed Exclusive OR operation with clear border output. Then the exclusive OR operation gives the final segmented output. The input and the final segmented image are shown in Figure 6. The algorithm 2 is not able to detect the nodules which are located near the pleural surface.

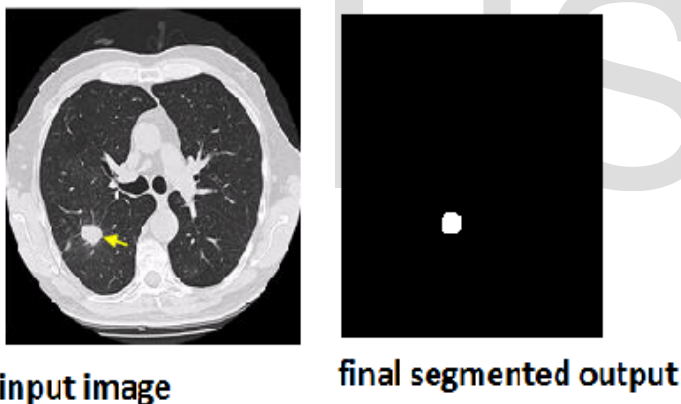


Figure 6: Input image and final segmented image

5 ALGORITHM 3: SEGMENTATION OF JUXTA PLEURAL NODULE LOCATED NEAR THE OUTSIDE PLEURAL SURFACE

The segmented image from the first algorithm is split into two halves. The right half of the lung is flipped into the left side. Then following operations are performed on each half of the image separately. In each row of the image, the first appearance of '1' value is noted down as a vector (say A). The difference between the adjacent values of vector A is calculated and stored in vector B. The maximum value of vector B is noted as maxB. If $\text{maxB} < 7$ it is found that there is no cancer nodule present in the image. If $\text{maxB} > 7$, then cancer nodule is present in the image. The position where $\text{maxB} = 7$ in the vector B is considered as a starting point for segmentation. The values in B after $\text{maxB} = 7$

are taken as another vector C. The maximum value of C is found and its position is located. This position is taken as the ending point. The starting and the ending point is connected and filled. The fill operation fills the region which is selected by holes or zeros. The two halves are again combined. This combined image is Exclusive-ORed with the original image to obtain the cancerous part. The outputs of various steps in segmentation of nodules near outside of pleural surface are shown in Figure 7. The algorithm 3 is able to detect the nodules present near outside pleural surface but not able to detect the nodules near inside pleural surface.

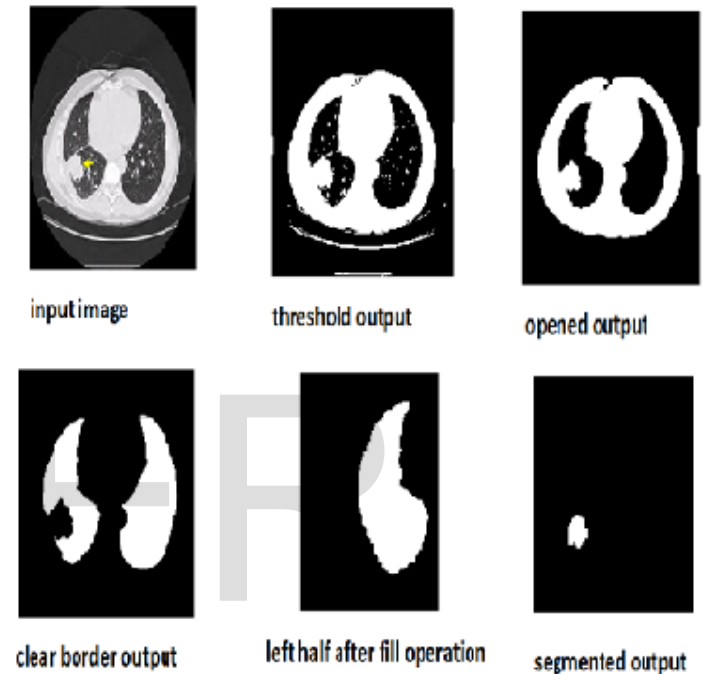


Figure 7: Segmentation of nodules near outside of pleural surface

6 ALGORITHM 4: SEGMENTATION OF JUXTA PLEURAL NODULE LOCATED NEAR THE INSIDE PLEURAL SURFACE

The segmented image from the first algorithm is split into two halves. The right half of the lung is flipped into the left side. Then following operations are performed on each half of the image separately. In each row of the image, the number of 1 present is stored as a vector D. The local minima's of D is calculated and stored as a vector say minD. The global minimum of D and its position is found out and stored as posD. Previous and next position to posD is noted as lowpos and highpos respectively. In each row of the image, the first instance of the appearance of 1 is noted down as a vector E. The maximum value of vector E is found as maxE. If the value maxE fall in between lowpos and highpos then there is a possibility of cancer nodule in the image. Otherwise there is no cancer near the inside of pleural surface. The lowpos and highpos are taken as the starting and ending point respective-

ly. The starting and the ending points are connected and filled with holes. The two halves are again combined. This combined image is Exclusive-ORed with the original image to segment the cancer nodule. The outputs of various steps in segmentation of nodules near inside of pleural surface are shown in Figure 8. The algorithm 4 is able to detect the nodules located near inside pleural surface. By combining algorithm 2, 3 and 4, nodules located in the center, near outside pleural surface and inside pleural surface can be segmented.

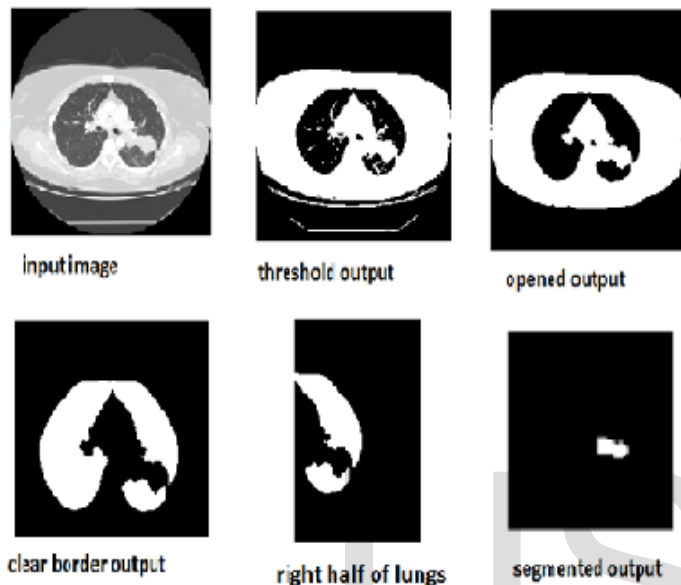


Figure 8: Segmentation of nodules near inside of pleural surface

7 EXPERIMENTAL RESULTS

The sensitivity, specificity and accuracy are calculated for the segmented images.

Sensitivity: It measures the proportion of actual positives which are correctly identified. That is the percentage of cancerous region correctly identified as cancerous region. The sensitivity obtained is 88.24%

$$Sensitivity = \frac{TP}{TP + FN}$$

True Positive: Cancer classified as cancer,
False Positive: Non cancer classified as cancer,
True Negative: Non cancer classified as non-cancer,
False Negative: Cancer classified as non-cancer

Specificity: It measures the proportion of negatives which are correctly identified. The percentage of non cancerous region correctly identified as non cancerous region. The specificity obtained is 93.33%

$$Specificity = \frac{TN}{TN + FP}$$

Accuracy: Accuracy is a statistical measure of how well a classifier correctly identifies or excludes a condition. The accuracy is the proportion of true results (both true positive and true negative) in the population. The accuracy obtained is 90.63%.

$$Accuracy = \frac{TP + TN}{TP + FN + TN + FP}$$

8 CONCLUSION

A computer aided segmentation of cancer region from the CT image of lungs is proposed. Morphological operations are used for segmentation. The proposed segmentation method gives accuracy of 90.63%. The false positives are mainly in the CT images where the cancer part is located near the pleural surface.

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