Lung Nodule Detection in CT Scans via Image Processing

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***Abstract*— Biomedical image processing is essential in modern diagnostics, using techniques like CT scans to help detect diseases. Early lung cancer diagnosis relies on detecting lung nodules. This paper presents a MATLAB-based GUI designed to detect lung nodules by enhancing images, reducing noise, and using edge detection to process CT scan images. The tool segments possible nodules with morphological operations and automatically labels and outlines detected areas. This user-friendly tool effectively identifies nodules, supporting early diagnosis with a low rate of false positives.**

Keywords— Computed Tomography , Nodule Detection, Canny Edge Detection , Noise Reduction , Otsu's -Thresholding .

INTRODUCTION

Lung cancer is one of the most common cancers worldwide, leading to a high number of deaths each year. Detecting lung cancer early is essential to improve the chances of successful treatment, making early diagnostic tools critical for patient care. Lung nodules, which are small, round growths in the lung tissue, can indicate the presence of cancer.

However, it's important to note that not all nodules are cancerous. They can be classified into two types:

1. **Benign Nodule**: This is a non-cancerous nodule, usually less than 3 cm in diameter.

2. **Lung Mass**: This is a larger nodule, more than 3 cm in diameter, which has a higher likelihood of being cancerous.

To support early diagnosis, imaging techniques like CT scans and X-rays are widely used because they provide clear, high-resolution views of lung structures. CT scans use narrow-width beams of X-rays to give more detailed information than standard X-rays, creating cross-sectional images that allow clinicians to examine the lungs layer by layer.

A **low-dose CT (LDCT)** scan is especially useful for spotting small nodules and tracking their growth patterns over time. LDCT uses only about one-fifth of the radiation of a regular CT scan, making it safer. This scan provides a 3D image of the lungs, helping detect smaller nodules that can be monitored for any changes in size, as larger nodules are more likely to be cancerous

Manually analysing CT scan images can be difficult, time-consuming, and may vary between different radiologists. This has led to the development of automated image analysis techniques and *Computer-Aided Diagnosis (CAD)* systems, which are valuable tools for radiologists, helping to improve accuracy and consistency in detecting nodules.

In this study, we present a **MATLAB-based Graphical User Interface (GUI)** to assist in lung nodule detection in CT scan images. The GUI includes various image processing techniques, such as image enhancement, noise reduction, edge detection, and segmentation, to simplify the identification of nodules and increase diagnostic accuracy.

This GUI-based tool integrates several important techniques to improve detection accuracy. The tool's main components include *image enhancement* and *noise reduction, which make the nodules clearer by adjusting contrast and removing noise that might interfere with detection. The **Canny edge detection algorithm* is used to outline the edges of nodules by detecting sudden changes in intensity, known for its accuracy in finding fine details.

For binarization, **Otsu's thresholding method** is applied. This method automatically separates pixels into two classes, foreground and background, and in this case, separates lung nodules from surrounding tissues by converting the grayscale image into a clear black-and-white format. Finally, **morphological operations** like opening and closing are used to refine the segmentation, effectively separating nodules from remaining noise in the image.

A. Literature Survey

The Paper [5] discusses three segmentation algorithms: threshold-based, edge-based, and region-based, concluding that region-based segmentation produces the most effective results.

The Paper [6]. provides a comparative study focused on region-based segmentation techniques, offering an objective evaluation of different region-based segmentation methods.

The Paper [7]. Describes a two-phase pre-processing method applied to various CT and MRI images of the brain, thorax, and abdomen. This pre-processing step removes irrelevant portions from images, significantly minimizing the risk of over-segmentation during the segmentation process.

B. Motivation and justification

Various preprocessing filters have been developed with the primary objective of enhancing specific features within medical images while simultaneously suppressing or removing noise, artifacts, and other unwanted elements that may obscure critical information. These preprocessing techniques play a pivotal role in improving the visibility and accuracy of targeted features, such as lung nodules, which are essential in diagnostic imaging. By refining the quality of the input images, these filters make it easier for segmentation algorithms to differentiate between healthy tissues and potential abnormalities.

MATERIALS AND METHODOLOGY

This project uses CT scan images of patients' lungs, providing detailed cross-sectional views that reveal the lung structure and highlight nodules, essential for detecting early-stage abnormalities. The GUI application is developed in MATLAB, utilizing its Image Processing Toolbox, which offers tools critical for this project, such as contrast adjustment, noise reduction, edge detection, morphological operations, and segmentation. Additionally, MATLAB's GUI-building features enhance user interaction, allowing for a seamless experience with the application

1. **Image Loading and Preprocessing :**

   The system begins by loading a CT scan image through a "Browse" option in the GUI, allowing users to select an image from their local device. To simplify processing and reduce computational load, the image is converted to grayscale if it is in RGB format.

The original lung ct image is shown below.Fig1

Fig1.Input lung CT image

2. **Image Enhancement and Contrast Adjustment :**

   Contrast adjustment is applied to improve the visibility of lung nodules, making them distinguishable from the surrounding tissues. MATLAB's imadjust function adjusts pixel intensity, enhancing potential nodules and differentiating them from bronchi and veins.

3. **Noise Reduction :**

   To eliminate noise that might interfere with accurate nodule detection, a median filter (medfilt2) is applied. This filter reduces small-scale noise without blurring edges, preserving nodule boundaries and ensuring that important structural details are maintained.

4. **Edge Detection :**

   The Canny edge detection algorithm is employed to identify the edges and boundaries within the CT scan. By detecting sharp intensity changes, this method helps outline the structural edges of lung nodules, which are critical for segmentation.

   It uses a multi-step process to detect edges while minimizing noise, algorithm of which can be summarized as :

   - ❖ Gaussian filter applied to smooth the image in order to remove the noise
   - ❖ The image gradient is calculated to find areas with sudden intensity changes. This involves computing the gradient in the x and y directions, typically using the Sobel operator
   - ❖ Non-Maximum Suppression: This step refines the edges by keeping only the local maxima in the direction of the gradient, thinning the edges to one pixel width.
   - ❖ Double Thresholding: Two thresholds (low and high) are applied to classify edges as strong, weak, or non-edges. Pixels with a gradient magnitude above the high threshold are marked as strong edges, while those between the thresholds are marked as weak edges.
   - ❖ Edge Tracking by Hysteresis: Weak edges connected to strong edges are retained, while isolated weak edges are discarded, resulting in the final edge-detected image.

The Canny edge detector finds sharp changes in brightness, which helps outline the edges of lung nodules. This is important for separating the nodules from nearby tissues. In MATLAB, the function for performing Canny edge detection is edge, used as

edges = edge(image, 'Canny')

Canny Edge Detection Image.Fig2

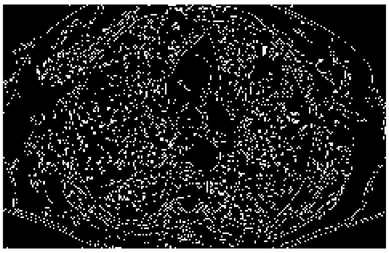

Fig2. Canny Edge Detection

5. **Image Binarization :**

   Binarization converts the grayscale image to a binary format, isolating areas of interest. Otsu's thresholding method (graythresh) determines an adaptive threshold, creating a clear separation between potential nodule regions and the background, simplifying subsequent analysis.

   Following are the steps used in the method :

   - ❖ Compute Histogram: Calculate the histogram of the grayscale image, which represents the frequency of each pixel intensity.
   - ❖ Calculate Probability: For each possible threshold value t (from 0 to 255 for an 8-bit image), calculate: The probability of each intensity level: P(i)=ni/N where ni is the number of pixels with intensity and N is the total number of pixels.
   - ❖ Calculate the cumulative sum, cumulative mean, global mean and intra class variance. The algorithm exhaustively searches for the threshold that minimizes the intra-class variance, defined as a weighted sum of variances of the two classes
   - ❖ Find Optimal Threshold: The optimal threshold t* is the value that maximizes the inter class varianceOtsu's thresholding can help automatically determine the threshold for segmenting lung nodules from surrounding tissues in CT images, enabling more accurate detection and analysis.

In MATLAB, Otsu's thresholding can be performed using the graythresh function, which calculates an optimal threshold level for converting a grayscale image to binary

```
threshold_level = graythresh(gray_img);
binary_img = imbinarize(gray_img, threshold_level);
```

Binarize Image Using Otsu thresholding.Fig3

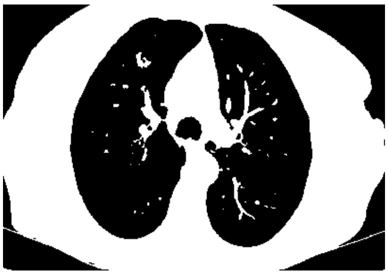

Fig3.Binary Image

6. **Morphological Processing :**
   Morphological operations are crucial for refining segmented images, particularly in lung nodule detection. One key operation is morphological opening, which involves erosion (this removes pixels from the edges of foreground objects, eliminating small noise and artifacts) and dilation (this restores the size of the remaining objects while keeping the noise removed). Opening was particularly used for noise reduction and enhancement of nodule regions . Lung nodules are typically round or oval in shape. A disk-shaped structuring element, thus, is well-suited to match these natural forms. Moreover, the radius of the disk can be easily adjusted to target specific sizes of noise or artifacts. For instance, if the expected nodules are small, a smaller disk can be used to avoid removing important features. Conversely, a larger disk can be applied to eliminate larger noise elements while still preserving the nodules' integrity.

7. **Region Labeling and Detection :**
   After segmentation, each connected region in the binary image is labeled using MATLAB's bwlabel and regionprops functions, which are essential for identifying individual lung nodules. The bwlabel function assigns unique labels to each connected component, enabling further analysis of each region. The regionprops function then calculates properties like area and bounding box, allowing for the filtering of small, insignificant regions that are unlikely to be nodules. By setting a minimum area threshold, the process reduces false positives and focuses on areas more likely to correspond to actual nodules. Subsequently, bounding boxes are drawn around these significant nodules on the original CT scan, enhancing visualization and making it easier for clinicians to assess their location and size. This labeling and visualization step is crucial for aiding medical professionals in diagnosis and treatment decisions, improving the overall effectiveness of the nodule detection system..

8. **Output Display and Analysis :**
   The final results are presented in a separate figure window, which displays the original image, enhanced, noise-reduced, edge-detected, and segmented versions of the image. The GUI provides an intuitive way for users to select and view each processing stage, while bounding boxes mark detected nodules on the original image, aiding medical professionals in determining if further evaluation is necessary.
   This methodology integrates image processing techniques within an accessible GUI framework, offering a practical tool for lung nodule detection that can assist in the early diagnosis of lung cancer in clinical settings.

Output Image Fig4

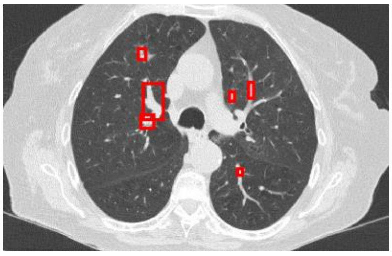

Fig4 Detected Lung Nodule

CONCLUSION AND SUMMARY

The MATLAB-based GUI for lung nodule detection provides an effective way to help doctors identify potential lung cancer early. By using various image processing techniques, such as enhancing contrast, reducing noise, detecting edges, and segmenting nodules, the tool simplifies the analysis of CT scan images. It employs Otsu’s thresholding and morphological operations to improve accuracy in detecting nodules. This automated method not only boosts diagnostic accuracy but also saves time and effort compared to manual image analysis. Ultimately, this tool can enhance early diagnosis and treatment planning for lung cancer, leading to better outcomes for patients.

In this report, we introduced a GUI designed for detecting lung nodules in CT scans. The system uses several image processing techniques to improve the images: it enhances contrast, filters out noise, detects edges, and segments nodules. The output includes processed images that show the original image, the enhanced image, the edges detected, and the isolated nodules in a binary format. By automating the detection process, this tool helps doctors make quicker and more accurate assessments, which is crucial for the early detection and treatment of lung cancer**.**

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