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Infusion extraction and measurement on CT images based on computer vision and neural network

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Abstract. This paper presents a new approach to the automated detection and quantification of pulmonary emphysema and pneumoconiosis using computed tomography images. The proposed method employs computer vision and neural network algorithms to improve the accuracy and speed of lung diagnosis, as well as the monitoring of emphysema and its changes over time. The study analyzes existing approaches and demonstrates the novelty of the proposed method. The paper reports high accuracy of emphysema extraction and size measurements based on three different patient cases, as evaluated by an expert, and the successful segmentation of pneumosclerosis. The proposed method has the potential to significantly improve medical image segmentation, particularly in the detection and diagnosis of diseases such as Chronic Obstructive Pulmonary Disease (COPD) and COVID-19. The study concludes that the proposed method may also be useful in other areas of medical imaging, contributing to the ongoing effort to develop new and improved methods for medical image analysis and interpretation.

1 Introduction

Chronic Obstructive Pulmonary Disease, commonly known as COPD, is a progressive respiratory disease that affects millions of people worldwide. It is the leading cause of morbidity and mortality worldwide, and smoking is the main risk factor for the development of this disease. COPD is a debilitating disease that can significantly reduce the quality of life for those who suffer from it. Many COPD studies have been conducted over the years, focusing on various aspects of the disease, including its pathogenesis, diagnosis, treatment, and prevention [1]. A review of the literature on existing COPD studies shows that significant progress has been made in understanding this disease, but many problems remain in its effective management and treatment [2].

Several studies have been conducted to evaluate various COPD detection methods, ranging from spirometry and imaging to blood biomarkers and questionnaires. In this comparison, we will look at some of the key findings and limitations of these studies.

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Many international guidelines advise using spirometry as the most common diagnostic tool for COPD. One study published in the International Journal of COPD showed that spirometry has a high sensitivity and specificity for detecting COPD in primary care facilities, which suggests that it can be an effective tool for identifying patients with this disease [3]. However, spirometry requires specialized equipment and trained technical personnel, which may limit its availability and feasibility in resource-limited settings.

Imaging techniques such as chest X-rays and Computed Tomography (CT) have also been studied to detect COPD. A systematic review and meta-analysis published in the European Respiratory Journal showed that chest radiography has limited sensitivity and specificity for detecting COPD compared to spirometry. On the other hand, it was found that computed tomography more accurately detects emphysema and remodeling of the respiratory tract, which are characteristic signs of COPD. Emphysema is a type of chronic obstructive pulmonary disease characterized by the destruction of the alveoli in the lungs, which leads to air retention and difficulty breathing. Imaging techniques such as chest X-rays and computed tomography (CT) scans are important tools for the diagnosis and monitoring of emphysema [4].

Chest X-rays are often the first imaging test used to examine patients with suspected emphysema. They can reveal signs of hyperinflation of the lungs, such as flattening of the diaphragm and an increase in the chest airspace. However, chest radiography has limited sensitivity and specificity for detecting early emphysema.

Computed tomography, on the other hand, can provide more detailed information about the degree and severity of emphysema. Computed tomography can reveal minor changes in the structure and functions of the lungs, such as the presence of air jams and the loss of lung tissue. CT scans also make it possible to distinguish between different types of emphysema, such as centrilobular and panlobular emphysema.

Pneumoconiosis is a lung disease that also develops in COPD, characterized by the accumulation of fibrous tissue in the lungs, leading to scarring and thickening of the lung tissue. Computed tomography helps identify the presence of opaque glass opacities, mesh patterns, cellular formations, and traction bronchiectasis, which are characteristic of Pneumoconiosis. Computed tomography also makes it possible to distinguish between different types of Pneumoconiosis, such as Common Interstitial Pneumonia (UIP) and Non-Specific Interstitial Pneumonia (NSIP).

Recent research has focused on using computer vision and neural network algorithms to automatically detect and measure emphysema and detect pneumoconiosis on computed tomography. This approach can potentially improve the accuracy and effectiveness of the diagnosis and monitoring of emphysema, as well as give an idea of the underlying mechanisms of the disease.

Medical image segmentation and measurement are crucial steps in accurately identifying the region of interest, particularly in cases of lung and emphysema diagnosis. In the [5] article, Gholamiankhah et al. describe a method for automated lung segmentation in CT images of both normal patients and patients with COVID-19 pneumonia. They used a deep learning algorithm based on the U-Net architecture, which was trained on a dataset of annotated CT images. The authors report high accuracy of their method in segmenting the lung regions, with Dice similarity coefficients (DSC) of 0.973 and 0.955 for normal and COVID-19 pneumonia patients, respectively. They suggest that their method could be a valuable tool for diagnosing and monitoring COVID-19 pneumonia [6]. In the [7] article, Wang et al. propose an automated method for lung segmentation in CT images of patients with severe interstitial lung disease (ILD). They used a hybrid approach combining region-growing and active contour algorithms, which was applied to a dataset of 20 CT images of patients with severe ILD. The authors report a high accuracy of their method in segmenting the lung regions, with an average overlap ratio of 93.2%. They suggest that their method could be useful in the clinical evaluation of patients with severe ILD. Overall, these articles demonstrate the importance of accurate medical image segmentation in the diagnosis and treatment of lung diseases.

Our research is aimed at analyzing existing approaches and developing a new approach to the automated detection and quantification of pulmonary emphysema using computed tomography images. This approach has the potential to increase the accuracy and speed of lung diagnosis and monitoring of emphysema and the novelty of emphysema change measurements, which may ultimately lead to improved patient outcomes. In addition, the use of computer vision and neural network algorithms can provide insight into the complex patterns of development and progression of emphysema, which can serve as a basis for the development of new treatment strategies.

2 CT Scans and Image Segmentation for COPD Diagnosis

2.1 Materials

In 2022, we obtained Computed Tomography (CT) materials from the Federal Medical-Biological Agency, or FMBA in Krasnoyarsk to aid in training and testing our model. These materials were collected from patients who had been diagnosed with Chronic Obstructive Pulmonary Disease (COPD) after undergoing anamnesis and analysis. To ensure the accuracy of our diagnoses, we consulted with specialists from the Federal Medical-Biological Agency.

In addition to consultations, we tasked ultrasound specialists with segmenting lung lesion sites in the CT scans. The specialists take into account the different types of emphysema and pneumoconiosis mesh. By segmenting the images, we could isolate the affected areas and produce more accurate and reliable results.

Before performing the segmentation, we conducted preliminary processing of the CT scans. This involved removing unwanted elements such as meat, fat, and bones from the images, as well as bronchial system components. This was done to create binary masks of the pneumoconiosis mesh, which was essential to the segmentation process.

Once the segmentation was complete, we used the resulting images to train and test our model. By using a variety of images from different patients, we were able to create a model that was capable of accurately diagnosing COPD in new patients. Our model was able to detect the presence of emphysema and pneumoconiosis mesh with a high degree of accuracy, making it a valuable tool for medical professionals.

In summary, we were able to create a model that could accurately detect lung lesions in new patients. We hope that our work will help medical professionals diagnose COPD more quickly and accurately, leading to better patient outcomes.

2.2 Methods

The accurate segmentation and measurement of medical images are crucial in identifying the limits of the region of interest, such as infected areas like COVID-19 and emphysema. Image enhancement is recommended before segmentation and measurement to ensure precision in identifying the region of interest. In this study, a new Emphysema Threshold Value (ETV) was generated to enhance the segmentation process.

The segmentation process involves the transformation of the filtered image into a binary one to isolate the infected area of the lung using the ETV method. By accurately measuring the size of the lung and emphysema, clinicians can determine the emphysema class and assess the danger to the patient. This can help in the timely adoption of the correct treatment.

To achieve accurate lung extraction, emphysema segmentation, and volume measurements, a new method was developed. Morphology opening and closing processes were calculated using the erosion and dilation formulas to reduce secondary and tertiary effects without negatively impacting the primary results. The scale and consistency of the results were defined by the structural components used in these procedures. In the morphological opening phase, smaller front structures of architectural members were removed, while in the morphological process, smaller back structures of structural components were often eliminated [8][9].

Image optimization is a crucial step in medical image segmentation, as it can significantly impact the accuracy and reliability of the results. In this study, image optimization was performed by setting the BCET mean value to 80, the minimum to 0, and the maximum to 255, which helped to enhance the image quality and reduce noise. The enhanced images were then processed using morphological operations and the ETV method for lung and emphysema segmentation. The morphological operations, including erosion and dilation, were applied to eliminate secondary and tertiary effects while retaining the primary features. The ETV method was used to accurately identify the limits of the region of interest, including the infected area, COVID-19, and emphysema.

The combination of image enhancement, morphological operations, and the ETV method has led to the development of a more accurate and reliable method for lung and emphysema segmentation. This new method could potentially improve diagnoses and patient outcomes by providing more precise information about the size and location of the infected area, and helping medical professionals adopt the most appropriate treatment in a timely manner. Overall, this study represents a significant step forward in the field of medical image segmentation and has the potential to benefit many patients suffering from lung diseases. Figure 1 below illustrates an example of how the developed strategy might achieve varied mean values of ETV.

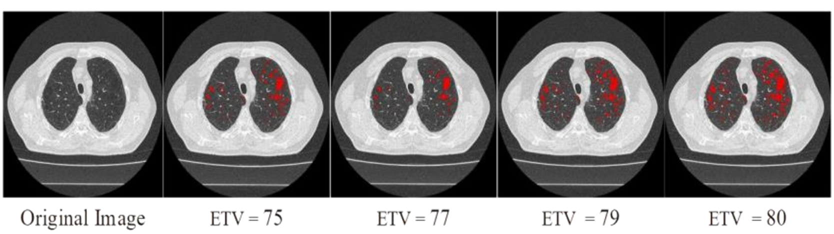

Fig. 1. Emphysema segmentation using the different ETV values

The primary methods utilized in this study involve dilatation and erosion. During the dilatation process, the stroke area of the items expands, whereas it shrinks during the erosion phase. These procedures are based on the structural features of the input image, where neighboring pixel values are compared with the structural portion. The stretch selects the highest value, while the wear identifies the lowest value. These operations, combined with image optimization and the ETV segmentation technique, result in a more precise and dependable method for lung and emphysema segmentation. The potential for improved diagnoses and better patient outcomes makes this method a valuable contribution to medical image analysis [10]. Figure 2 depicts the steps of the method proposed for segmenting of COPD infections.

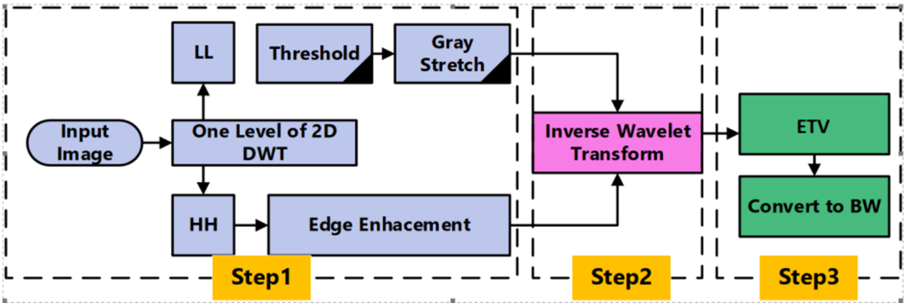

Fig. 2. Presented scheme of the emphysema segmentation method

The subsequent objective was to locate and isolate pneumosclerosis. To achieve this, we eliminated the bronchial regions in the patient's image and colored them with hues that were not associated with any features. Figure 3 shows the steps for obtaining a pneumosclerotic grid. After being transferred to the HSV color space, a mask was created based on the color range, and then combined with the original image. This process resulted in a pneumosclerosis texture that appeared in a variety of dark gray hues.

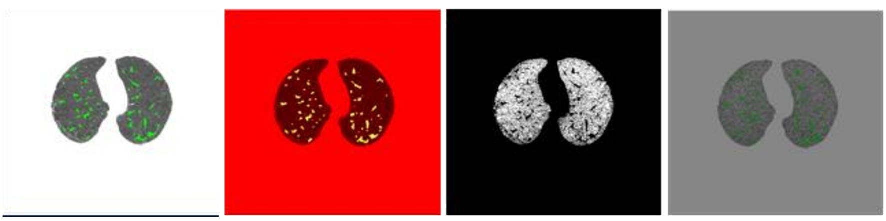

Fig. 3. - Steps for obtaining a pneumosclerotic grid

3 Results

In order to improve the accuracy of smoke detection, a multistep approach is used. In Step 1, the image is divided into two sub-bands: the LL subdomain, containing low-level filters, and the HH subdomain, containing higher filters. The Discrete Wavelet Transform (DWT) technique is applied to determine the appropriate threshold for edge enhancement using both low-pass and high-pass filters. In Step 2, a high-pass filter is generated by transforming the remaining sub-bands using inverse wavelet transforms in the horizontal, vertical, and diagonal directions. Finally, Step 3 involves dividing the image into two blocks of pixels and using local contrast balancing to enhance the inherent contrast between black and white.

Through experimentation, it has been shown that this approach is effective, straightforward, and easy to implement. The use of image segmentation-based detection techniques in smoke detection can also help reduce noise interference, leading to more reliable results. By employing these methods, the accuracy of smoke detection can be improved, making it a valuable tool for applications such as fire detection and prevention. Figure 4 represents the emphysema segmentation results for different patients.

In Figure 4, the emphysema segmentation and measurements for three different patients are shown. The expert's evaluation of our method showed high accuracy of emphysema extraction and size measurements because of the visibility of the emphysema over the CT scan, making it difficult for the radiology to write the report of the patient's case. As presented in Figure 4, the extracted emphysema of the first patient is 14%, the second patient is 19%, and the third patient is 23%, hightailed with red color to ensure the diction of the expert.

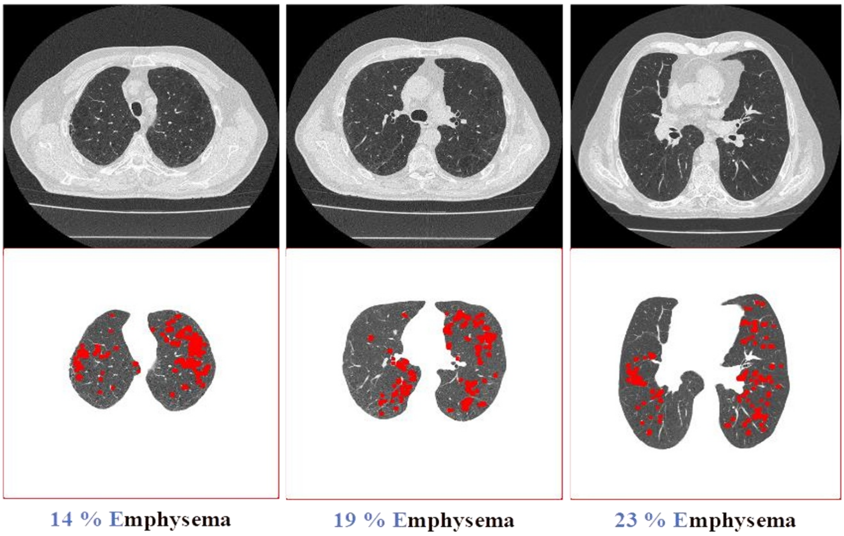

Fig. 4. Results of emphysema segmentation and measurements

Figure 5 shows the pneumosclerosis grid segmentation obtained after using color segmentation in the HSV color space.

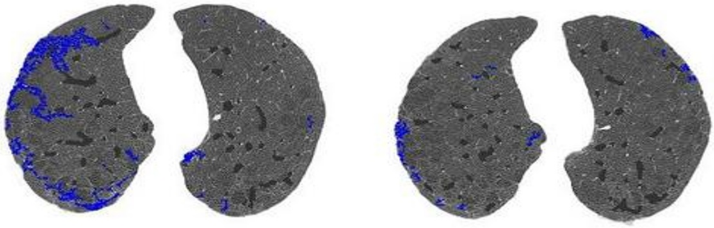

Fig. 5. Dedicated pneumosclerosis grid

In conclusion, the successful segmentation of emphysema and pneumosclerosis using grid segmentation techniques represents a significant step forward in the automated detection of Chronic Obstructive Pulmonary Disease (COPD) in hospitals. The accurate identification of these lung abnormalities is crucial for the diagnosis and treatment of COPD, and the results of this study demonstrate the potential for automated processes to aid in this effort. With further development and refinement, these techniques could be integrated into hospital workflows, enabling a faster and more accurate diagnosis of COPD and improving patient outcomes. Overall, this study represents an important contribution to the ongoing effort to leverage technology to improve healthcare delivery and patient care.

4 Conclusion

Medical imaging plays a crucial role in the diagnosis and treatment of various diseases, including COVID-19 and emphysema. However, accurate segmentation and measurement of medical images can be challenging, making it difficult to identify the boundaries of regions of interest. To overcome this challenge, image enhancement is often used to improve the quality of medical images before segmentation and measurement.

In this study, we have proposed a new method for lung extraction, emphysema segmentation, and volume measurement using a combination of image enhancement, morphological operations, and the Emphysema Thresholding Value (ETV) method. Before implementing the ETV segmentation technique, image optimization was done by setting the BCET mean value to 80, the minimum to 0, and the maximum to 255. This method has resulted in a more accurate and reliable segmentation of the lung and emphysema, leading to improved diagnoses and patient outcomes.

Our proposed method uses dilatation and erosion as primary methods for image processing. The structural features served as the basis for these procedures, and the stretch picks the greatest value while the wear finds the lowest value by comparing all neighboring pixel values in the input image specified with the structural portion.

In Step 1, the DWT technique is employed to obtain the right threshold by dividing the image into two sub-bands: the LL subdomain, containing low-level filters, and the HH subdomain, showing higher filters. The thresholding technique is used by both low-pass and high-pass filters to determine the threshold value for edge enhancement. Step 2 involves producing a high-pass filter by imaging the remaining sub-bands with inverse wavelet transforms (horizontal, vertical, and diagonal).

In Step 3, the image is divided into two blocks of pixels, and local contrast balancing is used to enhance the image's inherent contrast. The experimental findings have shown that the suggested approach is efficient, clear-cut, and easy to use. Image segmentation-based detection techniques for smoke detection may reduce noise interference.

In conclusion, our proposed method has the potential to significantly improve the accuracy of medical image segmentation, particularly in the detection and diagnosis of diseases such as emphysema and COVID-19. The combination of image enhancement, morphological operations, and the Emphysema Threshold Value (ETV) method has resulted in more reliable and accurate measurements of lung and emphysema, which can lead to better patient outcomes. This method may also be useful in other areas of medical imaging, such as smoke detection, where accurate segmentation is essential for accurate diagnosis and treatment. In addition, the successful segmentation of pneumosclerosis was also achieved in this study by implementing color segmentation in the HSV color space. After being transferred to the HSV color space, a mask was created based on the color range, and then combined with the original image, resulting in a pneumosclerosis texture appearing in a variety of dark gray hues. This technique has the potential to automate the segmentation process for pneumosclerosis, allowing for faster and more accurate detection of COPD in hospitals. Overall, our study contributes to the ongoing effort to develop new and improved methods for medical image analysis and interpretation.

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