Automatic Segmentation of Lung Nodule From CT Images Using Fuzzy C-Means Clustering Algorithm and Active Contour Model

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***Abstract*— Lung nodule segmentation is a major part in computer-aided diagnosis (CAD) system for lung cancer detection and diagnosis. The key issue in CAD of lung nodule is to correct and accelerate rapid segmentation of diseased tissue. This paper provides a novel approach method to segment the lung nodules using region based active contour model and Fuzzy C-Means clustering technique. Computed Tomography (CT) imaging is much efficient for lung cancer diagnosis and detection. Fuzzy c-means clustering algorithm (FCM) is sensitive to noise, local spatial information is often introduced to improve the robustness of the FCM algorithm for image segmentation. The methodology involves image acquisition, seeks the contour of the object using active contour model and segmentation of lung nodule is performing by using fuzzy c-means clustering algorithm. The experimental results of this method show that it is an effective algorithm and produces highest accuracy in the segmentation of lung nodules.**

Keywords— Fuzzy c-means clustering (FCM), Computed Tomography (CT), Active Contour Model (ACM).

I. Introduction

Lung cancer is the leading cause of cancer death and the second most diagnosed cancer in both men and women in the world. Compare to other diseases, cancer tends to have high death rate and treatment of cancer is effective only on its early stage. As world Health Organization publication, 9.6 million deaths in 2018. Lung cancer will become the biggest threat to human health. Lung nodules are most common form of early lung cancer. To improve the true positive rate of lung nodules, CT images are used for the auxiliary diagnosis of lung nodules. If the cancer can be detected on its early stage, then there is a good chance of survival of the patient. Usually Computed Tomography (CT) or Low-Dose Computed Tomography (LDCT) is used for early detection of cancer.

The majority lung cancer cases are diagnosed after a doctor requests testing for cancer based on a patient's medical history and the results of physical examination. Lung cancer is usually first observed through chest radiography or chest CT images, as tumor nodules. To confirm the diagnosis, the tumor cells of nodules have to be examined under microscope. The tumor cells are suctioned into the syringe by a biopsy, which is usually performed by bronchoscopy or CT-guided needle biopsy. CT image data shows an explosive growth trend, which is bound to lead missed diagnosis and misdiagnosis and increase the workload of doctors.

This field of research is called computer aided detection/diagnosis (CAD). CAD is used to provide technical support to medical staff during diagnosis and treatment. In the absence of a doctor, CAD allows for the identification and possible emergency treatment of life-threatening symptoms. The aim of this research work to develop a CAD system using CT images. This dissertation introduces the approaches of automated segmentation of lung nodules, further the detection of blobs touching the inner wall of the chest is very challenging task and time consuming to the particular complex architecture. Therefore, this work has the purpose of developing computer vision solution for automatically segment the lung nodules and to overcome the difficulties found in the earlier methods.

Recent researchers propose segmentation results with less accuracy which is undesirable for medical usage. In order to improve the accuracy of FCM image segmentation algorithm, the present work aims to propose a novel Fuzzy c-means clustering algorithm to improve the local area pixel adaptive degree. Fuzzy C-means Clustering (FCM) [4] is the most widely used image segmentation algorithm at present. The traditional fuzzy C-means clustering is very sensitive to noise, and does not consider the spatial positional relationship of pixels, and easily converges to local extremism.

II. Literature review

The challenges of CT image segmentations are rooted in the ambiguity and diversity of the visual textures encountered in input images. [1] Segmenting images accurately and effectively has always been important in the fields of image processing and computer vision. Traditional segmentation methods have difficulty meeting modern needs, such as, if a unified single threshold is used to separate the target from the background, the effect is not ideal in the threshold-based image segmentation method. [3] It is usually over-segmented and sensitive to noise in region-based image segmentation. [2] If the image segmentation algorithm is unsuitable, it will lead to poor-quality image segmentation.

Marten et al. [4] evaluated the features such as nodule size, margin, position, matrix characteristics, vascular and pleural attachments with gold standard. Recent researchers used manually segmented lesion as the gold standard. Lung nodule identification is one of the most fundamental problems in medical image processing. Pulmonary nodules are small tissue in the lung and most of them are benign [5]. Tong et al. [6] used a three step process to detect lung nodules they was used an adaptive threshold algorithm to segment the lung region and then they were used Active Contour Model (ACM) to remove the lung vessel then Hessian matrix (selective shape filter) was used to detect the suspicious nodules.

Dehmeshki et al. [7] proposed volumetric measurement for the detection of lung nodule. Nithila, E.E. and Kumar [16] have proposed a level set function for the characterization of the image, and the energy function reaches the minimum, once the segmented contour meets the boundary of the lung nodule. Tong et al. [17] used a three step process to detect lung nodules. Firstly, an adaptive threshold algorithm was used to segment the lung region. A new region growing solution for lung nodule segmentation in combination of fuzzy connectivity, distance and intensity information as the growing mechanism and peripheral contrast as the halting criterion has been used. It was found that the proposed method is highly reproducible for various types of nodules from various data protocols.

The proposed methodology aims to segment the lung nodule automatically with the help of CT images. The novel fuzzy c-means clustering algorithm specifies the grayscale values of the pixels in the domain space by grayscale. The weights of different fuzzy factors are adaptively updated according to the characteristics of pixel points and the gray level fluctuations in the pixel domain.

III. METHODOLOGY

Automatic lung nodule detecting scheme using CT images helps the physicians to reduce the load of their work and to improve quality of detection. The proposed methodology focused on the detection of lung nodule consist of the CT lung acquisition and the segmentation of lung nodules. The main aim of this process is to segment the lung nodule after removing the portions that are part of the CT image other than lung lesion. Fig 1 shows the proposed methodology for segment the lung nodule.

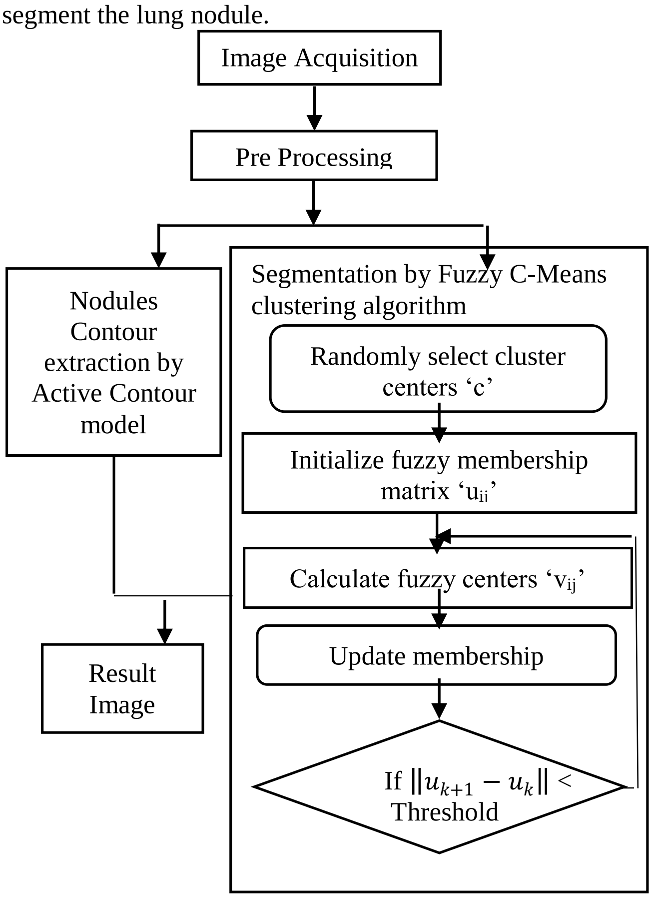

Fig. 1. Over view of the proposed Methodology

A. Image acquisition

In this research, CT images are used to segment the lung nodules. The main advantage of the computer tomography image is, it has Poisson noise and Speckle when compared to scan image and its better clarity, low noise, Salt and Pepper and distortion. The image needs pre-processing to remove the noises. The target dataset of lung nodule CT images is mainly from the database of the Lung Image Database Consortium (LIDC). We have selected 40 low-dose lung CT images from the LIDC database.

B. Preprocessing

Pre-processing is the most important part to correct the different kind of errors in images before processing the methodology. It is needed in order to improve the quality of the image and make it available for next phases. The objective of this stage was to eliminate the mediastinum and thoracic wall and to separate the parenchyma using region based Active Contour Model (ACM).

C. Image Enhancement

Image enhancement is a preprocessing step in many image processing applications. The aim of this part is to improve the perception or interpretability of information in images for human viewers, or to provide better input for other automated image processing techniques. There are various reasons for poor quality of an image such as distortion being introduced by the imaging systems, lack of expertise of the operator or the adverse external conditions at the time of image acquisition.

Image enhancement includes intensity and contrast manipulation, edges sharpening, noise reduction and filtering, etc. Contrast Enhancement is focused on the problem of improving the contrast in an image to make various features more easily perceived. Contrast of an image is determined by its dynamic range, which is defined as the difference between lowest and highest intensity level. Contrast enhancement techniques have various application areas for enhancing the visual quality of low contrast images. Most of the contrast enhancement algorithms have been proposed over the years.

Mathematical morphology is a relatively new approach to image processing and analysis. The top hat transformation is used to improve the contrast of the images based on the shape and the size of the structuring element and it provides an excellent tool for extracting bright or dark features smaller than a given size from an uneven background. There are two variations of top hat transformation: white top hat and black top hat transformation.

The white top hat transformation helps to extract the white or bright features of the image smaller than the size of the structuring element. The black top hat transformation is used to extract the black or dark features of the image. The white top hat transform relies on the fact that by gray-scale opening, one can remove from an image the brighter areas, i.e. features that cannot hold the structuring element. Subtracting the opened image from the original one produces an image where the features that have been removed by opening are clearly visible.

A similar thing is true for closing operation also. It means that using a closing operation instead of an opening and subtracting the original image from the closed one helps to extract dark features from a brighter background. This is known as black top hat transformation opposed to white top hat transformation in case of opening.

Top-Hat transform is calculated by subtracting the opening of the original image from the image itself. The opening operator leaves background of the particular image; it is expected that Top-Hat transform removes the image background. This transform acts like a high-pass filter and extracts the bright areas of the image which are smaller than the mask.

D. Active Contour Model

In this section, a novel method for segmenting the lung nodules is presented. Firstly, lung nodule area is segmented by the active contour model is considered an optimizing method to determine the contour. After that, ROIs are detected using stochastic 2D features. Finally, detected nodules are used as the initial mask of active contour modeling for accurate contour extraction of nodules. The objective of reconstruction of lung nodule was to eliminate the thoracic and mediastinum wall and to separate the parenchyma using region based ACM. At each ACM evolution the convergence value is computed by summing the displacement of the curve along its length. The active contour is evolved for about 1000 iterations.

Active contour model is one of the techniques in segmentation which can be defined as the use of constraints for segregation of the pixel's region of interest from the CT image for more processing and analysis. Active contours are boundaries designed for the area of interest in an image. Contour is the main part in collection of points that undergoes interpolation process.

E. Fuzzy C-Means Clustering algorithm

Fuzzy clustering refers to the process of dividing a set of data into categories according to features without training samples. The fuzzy c-means clustering algorithm is a combination of fuzzy theory and cluster analysis. The FCM algorithm is a process of repeatedly modifying the cluster center and the membership matrix, so it is also called dynamic clustering. It is an unsupervised machine self-learning algorithm.

Clustering algorithms proposed region based segmentation by partitioning the CT image into sets or clusters of pixels that have strong similarity in the feature space. FCM is one of the most commonly used unsupervised clustering techniques in the field of segmentation of medical images. It is one method of clustering which allows one piece of data to belong two or more clusters. In hard clustering, data are divided into distinct clusters which allows that each data elements belongs to exactly one cluster. This can be used in many fields such as in feature extraction, pattern recognition and fuzzy identification. Here we proposed the 3-class FCM algorithm that is used to segment the region of interest from the reconstructed lung nodule. The region of interest contains blood vessels, nodules and bronchi. In order to separate nodule from these structures the methodology proposed ACM.

IV. RESULTS AND DISCUSSION

The proposed methodology uses LIDC dataset for the evaluation on Lung nodule CT images. The actual experiment of the segmentation effect is performed by Python. We selected 40 low-dose lung CT images from the LIDIC database. The result shows that our method has high accuracy. Figure-2 shows the time taken for the cluster process and BWarea.

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Image 1
Fuzzy time for cluster 2
0.26470398902893066 seconds
Bwarea : 861.0

Fuzzy time for cluster 3
0.4752671718597412 seconds
Bwarea : 750.25

Fuzzy time for cluster 6
2.3522820472717285 seconds
Bwarea : 331.0

Image 2
Fuzzy time for cluster 2
0.17145538330078125 seconds
Bwarea : 6723.0

Fuzzy time for cluster 3
0.7259571552276611 seconds
Bwarea : 6226.75

Fuzzy time for cluster 6
2.77434325218207 seconds
Bwarea : 3982.75

Image 3
Fuzzy time for cluster 2
0.15238022804260254 seconds
Bwarea : 10217.25

Fuzzy time for cluster 3
0.5023617744445801 seconds
Bwarea : 9816.0

Fuzzy time for cluster 6
2.128685235977173 seconds
Bwarea : 7220.0
```

Fig. 2. Fuzzy time for cluster process and BWarea.

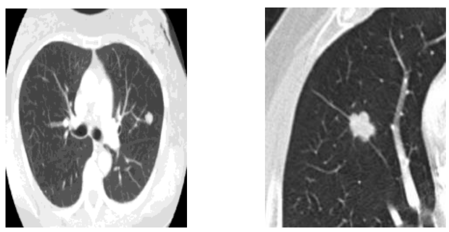

Fig. 3. lung nodule CT scan images

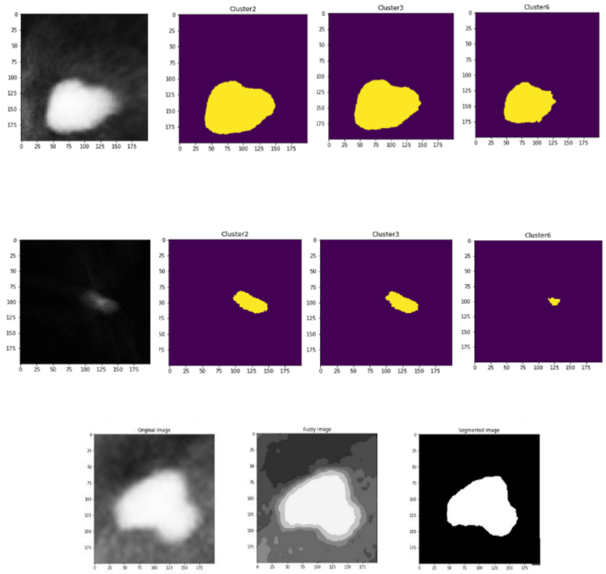

Fig. 3. Segmented images

V. CONCLUSION

Automatic segmentation using active contour model and fuzzy c-means clustering algorithm is effectively changed tissues fast and accurately. The proposed algorithm ACM and Fuzzy c-means clustering algorithm successfully segment the lung nodule from CT images. For lesion the average volume error obtained is 0.538%. The Coefficients of similarity, Root Mean Square Error, Spatial overlap, under over and average over segmentation ratios are 0.925, 0.09, 0.62, 0.012% and 0.78% respectively. The experimental results indicate that the proposed novel algorithm could segment the lung nodule with high accuracy and performs better than traditional segmentation, with decreased rate of errors and executive efficiencies.

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