

# An Effective Segmentation Approach for Lung CT Images Using Histogram Thresholding with EMD Refinement

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**Abstract** Image segmentation is an important step in extracting information from medical images. Segmentation of pulmonary chest computed tomography (CT) images is a precursor to most pulmonary image analysis. The purpose of lung segmentation is to separate the voxels corresponding to lung tissue from the surrounding anatomy. This paper presents an automated CT lung image segmentation. The approach utilizes histogram-based thresholding with Earth Mover's Distance (HTEMED)-based refinement methods. The final segmented output is further refined by morphological operators. The performance of HTEMED is compared with Otsu's, K-Means, and histogram thresholding using fuzzy measures.

**Keywords** Computed tomography · Lung nodule · Earth mover's distance · Histogram thresholding

## Introduction

Image segmentation is important for isolating and extracting details of an image. Many image segmentation methods have been proposed by early researchers. This process partitions the image into different meaningful regions with homogeneous characteristics [1]. Segmentation has been used in the past for quantification of

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tissue volumes, computer integrated surgery, reconstruction of volume of medical image slices. Chest CT image helps in evaluating the stages of the unwanted material growth in lung. This process has been used for the diagnosis of various pulmonary diseases (lung cancer, tuberculosis, and pulmonary embolism (PE)). This paper presents four stages for achieving effective segmentation of CT lung image.

*Stage 1:* The left and right lung of the CT image is segmented using fuzzy logic.

*Stage 2:* Apply EMD for refinement of segmented image. *Stage 3:* Apply morphological operation in order to obtain the correctly segmented right and left lung image. *Stage 4:* Performance comparison is presented.

The remaining sections of this paper are organized as follows. Section “[Related Works](#)” presents an overview of existing lung segmentation methods. Section “[Materials and Methods](#)” explains the proposed methodology in detail. Section “[Segmentation Based on Fuzzy Logic](#)” depicts the experimental results, and Sect. “[Refinement Process](#)” provides the conclusions on this work and suggests some possible future enhancements.

## Related Works

Armato and Sensakovic [2] proposed an accurate lung region segmentation procedure called a multilevel thresholding for identifying the regions of interest (ROI) lung nodule. 5–17 % of the lung nodules are undetected by their approach.

Segmentation of lung high resolution CT (HRCT) images using a pixel-based approach was suggested by Garnavi et al. [3]. These authors have used global-threshold segmentation, mathematical morphology, edge detection, noise reduction, and geometrical computations to achieve the defined ROIs.

Ye et al. [4] presented a CAD method for detecting both solid nodules and ground-glass opacity nodules in the lung image. A fuzzy-based thresholding approach is used to segment the lung region. Their method results in fast computation.

Zheng et al. [5] proposed a method for segmenting the lung region by an adaptive threshold based on value distributions. Component analysis and gray-level thresholding are used to segment the lung volume.

Sang et al. [6] proposed a CAD-based lung segmentation algorithm to segment a 3-D lung. Their algorithm searches for suspicious PE regions.

From the literature mentioned, there is still a requirement for improving segmentation of lung in a CT image in terms of fast computation and improved segmentation accuracy.

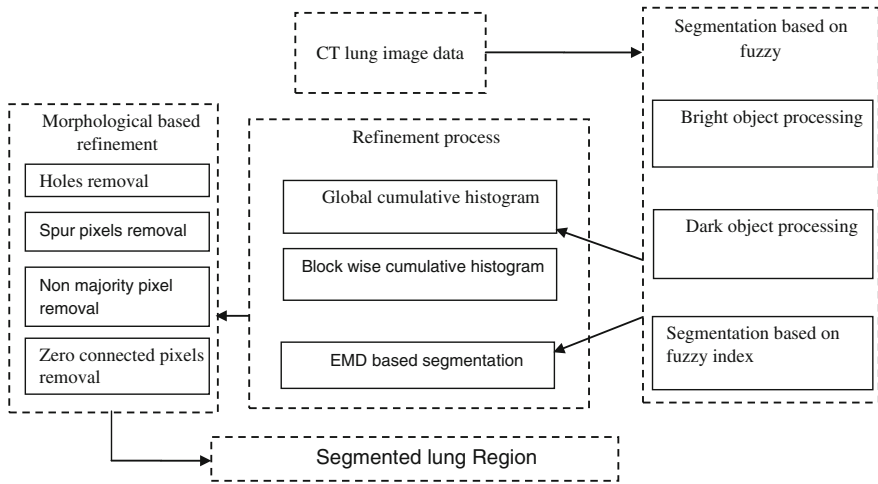


Fig. 1 Block diagram of the proposed system

## Materials and Methods

Figure 1 is the prototype for the proposed system of pulmonary Lung region segmentation on CT Image which consists of four stages: (1) segmentation based on fuzzy (2) refinement based on EMD (3) morphological-based refinement, and (4) comparison of segmentation performance.

### Segmentation Based on Fuzzy Logic

A fuzzy set is any set that allows its members to have different degree of membership, called membership function within the interval [0, 1]. Which can be mathematically expressed as  $\mu_A(x)$  which was assigned to each element on the set with in the same closed unit intervals [7]. Let  $X$  is the universal space and  $x$  is an element of the space  $X$ . A fuzzy set an in space  $X$  is defined as

$$A = \{\{x, A(x)\} | x \in X\}. \tag{3}$$

Where  $A(x)$  is the value of the function ‘A’ for element ‘x’. In this work, the ‘S’ function which denotes the set of brighter objects is used for modeling the membership function [7]. The  $S$  function can be defined as

$$\mu_{As}(x) = S(x; a, b, c) \tag{4}$$

$$S(x; a, b, c) = \begin{cases} 0 & x \leq a \\ 2 \left\{ \frac{(x-a)}{(c-a)} \right\}^2 & a \leq x \leq b \\ 1 - 2 \left\{ \frac{(x-a)}{(c-a)} \right\}^2 & b \leq x \leq c \\ 1 & b \geq c \end{cases} \tag{5}$$

The parameters ‘a’ and ‘c’ controls the ‘S’ function. The value of ‘b’ can be computed as  $b = (1/2)(a + c)$  which is called cross-over point. The mathematical function value of ‘b’ is 0.5 ( $\mu_{As}(b) = 0.5$ ).The Z-function, which is derived from the S-function represents the dark pixels is as follows:

$$\mu_{Az}(x) = Z(x; a, b, c) \tag{6}$$

$$= \begin{cases} 1 & x \leq a \\ 2 \left\{ \frac{(x-a)}{(b-a)} \right\}^2 & a \leq x \leq \frac{a+b}{2} \\ 1 - 2 \left\{ \frac{(x-b)}{(b-a)} \right\}^2 & \frac{a+b}{2} \leq x \leq c \\ 0 & x \geq b \end{cases} \tag{7}$$

### Refinement Process

Improving the quality of segmented output based on fuzzy methodology is carried in this stage. Histogram-based analysis was done in order to improve the segmented result. The segmented output has been further refined by EMD [8]-based refinement to reduce the issues in the existing methods. For dark and white objects, the refinement process is carried using the following steps:

- Step 1: Compute the inside and outside histogram ‘ $\alpha$ ’ and ‘ $\beta$ ’.
- Step 2: Compute the inside and outside cumulative sum ‘ $I_c$ ’, ‘ $O_c$ ’.

$$I_c(x_i) = \sum_{k=0}^i \alpha_k \tag{8}$$

$i \rightarrow 0$  to 255

$$O_c(x_i) = \sum_{k=0}^i \beta_k \tag{9}$$

Step 3: For all black and white pixels  $x$  in the fuzzy region, compute the block histogram ‘ $\gamma$ ’.

Step 4: For all black and white pixels, compute the foreground distance  $\delta_f$

$$\delta_f = \sum_{i=0}^{255} \text{abs} \left\{ \left( \sum_{k=0}^i \gamma_k \right) - \left( \sum_{k=0}^i \alpha_k \right) \right\} \quad (10)$$

where ‘ $\gamma_k$ ’ and ‘ $\alpha_k$ ’ are, respectively, the block histogram and inside histogram of white and dark objects.

The background distance ‘ $\delta_b$ ’ is as follows:

$$\delta_b = \sum_{i=0}^{255} \text{abs} \left\{ \left( \sum_{k=0}^i \gamma_k \right) - \left( \sum_{k=0}^i \beta_k \right) \right\} \quad (11)$$

Step 5: The membership value presents the state of final marked image as ‘1’ or ‘0’ based on the below condition.

$$\text{Membership value} = \begin{cases} 1 & \text{if } \delta_f(x_i) < \delta_b(x_i) \\ 0 & \text{else} \end{cases} \quad (12)$$

## Morphological-Based Refinement







We now use the morphological-based refinement for further improving the quality of initial refined output, which contains the holes, spur, non-majority pixels, and zero connective pixels. Predefined MATLAB morphological operators such as Fill, Majority, clean were used.

## Results and Discussion

In order to represent the performance of our proposed method, we have chosen 15 CT images from LIDC Lung database. A ground truth image has been generated manually for each image. The ground truth image was combined with its corresponding original image, to segment the CT lung image. The performance of our proposed segmentation method has been compared with other conventional segmentation algorithms like ‘Otsus’, ‘K-means clustering’, ‘Histogram thresholding using fuzzy measures (HDFM)’, ‘Log’, ‘Zerocross’, and ‘our earlier work using fuzzy logic’ [9]. The performance of individual methods over Lung image was carried out and the results of the techniques are depicted in Tables 1 and 2.

The segmentation accuracy  $A_s$  is computed using the following equation to evaluate the quality of the segmentation results:

**Table 1** Original results for four algorithms: Otsu’s technique, K-Means, histogram thresholding, fuzzy logic alone, and proposed method

<p>Original Image</p>  <p>Input image</p>	<p>Projection Image</p>  <p>Otsu's</p>	<p>Projection Image</p>  <p>K-means clustering</p>
<p>Projection Image</p>  <p>Histogram thresholding (HDFM)</p>	 <p>Our earlier work</p>	<p>Final Lung Segmented Image</p>  <p>Proposed method</p>

**Table 2** Comparison accuracy of Segmentation techniques

Algorithms	Number of objects	'Area'	'Solidity'	'Perimeter'	Accuracy of segmentation
Otsus	40	2,300	34.3	1903	60.0909
K-means	42	2,300	38.6	2103	62.8727
HDFM	54	2,166	40.1	2440	65.5964
Our earlier work using fuzzy logic	49	2,280	44.9	3036	84.7055
Fuzzy with HTEM	49	2,490	48	3078	87.9091

$$A_s = \frac{S_I}{O_I} * 100 \tag{4}$$

where  $S_I$  denotes the ratio between  $O_I$  and the number of objects presented in the segmented region.  $O_I$  denotes the total of solidity, Area and Perimeter of the pixels present in the unsegmented region.

## Conclusions

In this paper, we have proposed an automated Lung segmentation scheme based on fuzzy logic along with EMD-based refinement. The main advantage of this work is that it reduces false segmentation. From the experimentation results, it is proved that the proposed method ensures accuracy level of segmentation. Our method is useful in assisting for further diagnosis of Lung nodules in LDCT by reducing the mortality rate. Further works in this direction can be the application of a suitable classification algorithm for identification of Lung Nodules.

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