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THE PERFORMANCE OF VARIOUS THRESHOLDING ALGORITHMS FOR SEGMENTATION OF BIOMEDICAL IMAGE

Manoj R. Tarambale[1] and Nitin S. Lingayat[2]

[1]Electrical HOD, Marathwada Mitra Mandal's College of Engineering,
Pune, Pin-411052, University of Pune, Maharashtra, India.
[2]Electrical HOD, DR. Babasaheb Ambedkar Technological University's Institute of Petrochemical Engineering, Lonere, Dist. Raigard, Maharashtra, India Pin–402103.

ABSTRACT

In biomedical image processing, segmentation is required for separating suspicious organ from the medical radiography. In segmentation techniques, thresholding is widely used because of its intuitive properties, simplicity of implementation and computational speed. Thresholding divided intensity of the image into two sub groups 0 or 255 for 8 bit image. Biomedical images contain complex anatomy which makes the segmentation task difficult. Various algorithms have been proposed to threshold the image. These algorithms take into consideration one or two properties of image for computing threshold. This paper contains performance comparison of various thresholding algorithms by applying on the chest radiograph (X-ray Image).

Keywords: Diagnosis, Feature, Global Thresholding, Segmentation, Transformation.

I. INTRODUCTION

Biomedical image processing is an emerging technology which is widely used for diagnosing suspicious diseases using medical radiography and computer aided diagnosis. In biomedical image processing, segmentation is done to separate suspicious region from the rest of the image. Feature extraction and classification results are totally depending upon how accurately the region is segmented.

Segmentation technique partitions an image into distinct regions containing each pixel with similar attributes. For meaningful and useful image analysis and interpretation, the regions should strongly relate to depict objects or features of interest. Meaningful segmentation is the first step from the low-level image processing for transforming a grayscale or colour image into one or more other images, to high-level image description in terms of features, objects, and scenes [1]. The success of image analysis depends on the reliability of segmentation, but an accurate partitioning of an image is generally a very challenging job. Segmentation is typically used to identify objects or other relevant information in digital images. There are many different ways to perform image segmentation includes-Thresholding, Color-based, Transform methods and Texture methods based. An effective approach to performing image segmentation includes using algorithms, tools, and a comprehensive environment for data analysis, visualization, and algorithm development.

In digital image processing, thresholding is a well-known technique for image segmentation. Thresholding is a segmentation technique which is widely used for separating solid region from the background, separating important area from the rest of the image or finding the edges of the image [2]. Because of its wide applicability to other areas of the digital image processing, quite a number of thresholding methods have been proposed over the years. Depending on the application, threshold algorithm is selected.

Thresholding technique produces segments having pixels with the similar intensities. Thresholding is a useful technique for establishing boundaries in images that contains solid objects resting on a contrasting background. There exit a large number of gray-level based segmentation methods using either global or local information. The thresholding technique requires that an object has homogenous intensity and background with a different intensity level [3]. To make segmentation more robust, the threshold should be automatically selected by the system. Knowledge about the objects, the application, and the environment should be used to choose the threshold automatically by seeing intensity characteristics of the objects, sizes of the objects, fractions of an image occupied by the objects and number of different types of objects appearing in an image.

II. GLOBAL THRESHOLDING

Global thresholding is the simplest and most widely used of all possible segmentation methods. Global thresholding consists of setting an intensity value (threshold) such that all pixels having intensity value below the threshold belong to one phase; the remainder belongs to the other. Global thresholding is as good as the degree of intensity separation between the two peaks in the image or the separation of light and dark regions in the image [4]. A histogram of the input image intensity should reveal two peaks, corresponding respectively to the signals from the background and the object [5], [6], [7].

If $p(x, y)$ is a threshold version of $w(x, y)$ at some global threshold T, When T is a constant applicable over an image, the process is referred to as global thresholding [8].

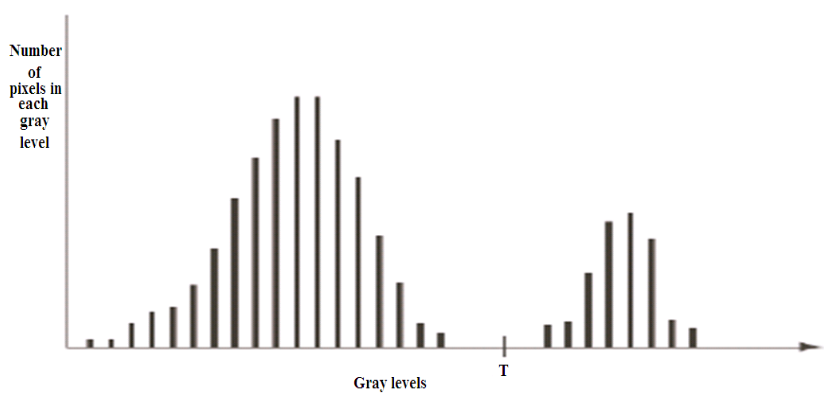

Figure 1(a): Intensity histogram with single threshold

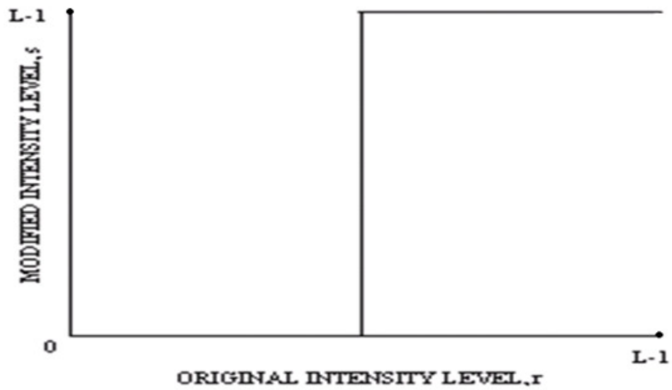

Figure 1(b): Single threshold transformation

$$p(x,y) = \begin{cases} L-1 & \text{if } \; w(x,y) \geq T \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

Where '*p(x,y)*' are the gray level of the pixel, '*T*' is the threshold and '*L-1*' is the max gray level of the image.

III. VARIABLE THRESHOLDING

When the value of threshold changes over an image, it is referred as variable thresholding. When intensity values are randomly distributed over the image, then the segmentation of a particular area is difficult by using single thresholding. Variable thresholding solves this problem [5], [6], [7]. In this technique two thresholds are used [9]. Variable thresholding is given by equation (2).

$$v(x,y) = \begin{bmatrix} a & \text{if } \; w(x,y) > T_2 \\ b & \text{if } \; T_1 < w(x,y) \leq T_2 \\ c & \text{if } \; w(x,y) \leq T_1 \end{bmatrix} \qquad (2)$$

Where a, b and c are any three distinct intensity values. T_1 and T_2 are the two thresholds and their value can be decided according to the area to be segmented. Transformation is shown in Fig.2 (b).

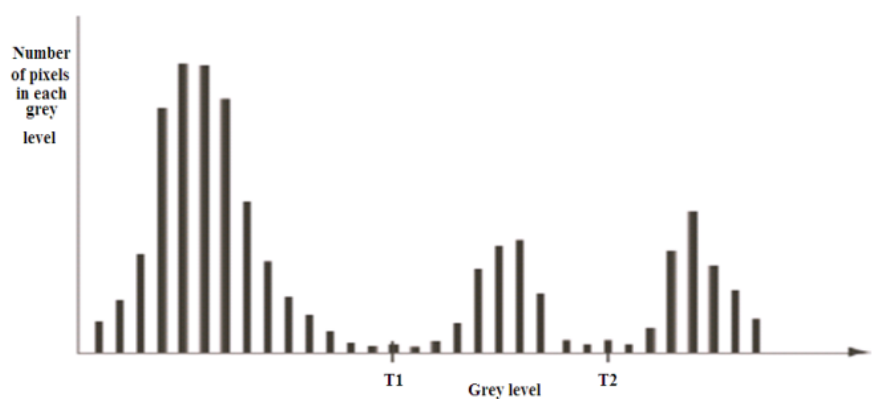

Figure 2(a): Intensity histogram with two thresholds

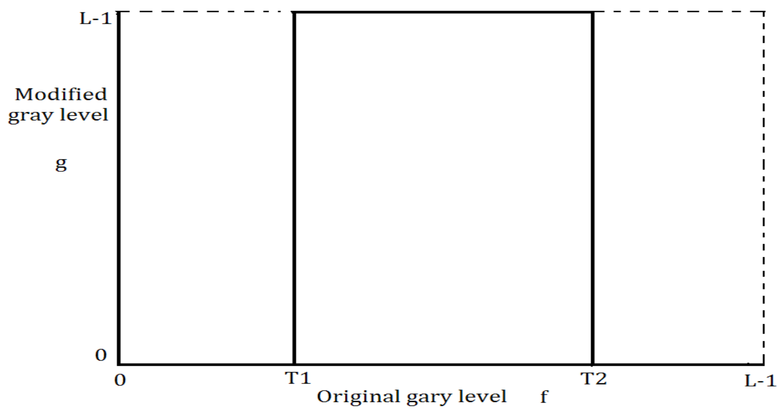

Figure 2(b): Variable thresholding transform

IV. THRESHOLDING WITH BACKGROUND

When thresholding is done it split the gray level into two parts. In this method background is completely lost. In some application, we not only need to enhance a band of grey levels but also need to retain the background. The transformation is shown Fig.3 and formulation for this in equation (2).

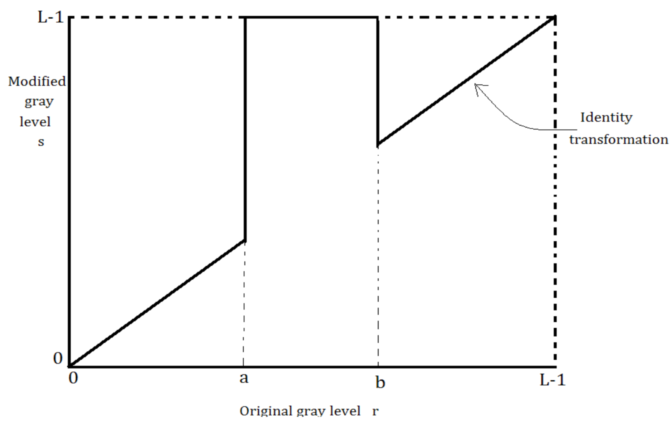

Figure 3: Thresholding with background transformation

$$b(x,y) = \begin{cases} L-1 & if \;\; a \geq w(x,y) \geq b \\ w(x,y) & otherwise \end{cases} \qquad (3)$$

Where 'L-1' is the maximum gray level, ' *w(x,y)*' is the original image grey level and '*b(x,y)*' is the modified grey level.

V. OSTU'S METHOD

This method is optimum in the sense that it maximizes the between class variance, a well-known measure used in the statistical discriminate analysis. The basic idea is that well-threshold classes should be distinct with respect to the intensity values of their pixels and conversely that a threshold giving the best separation between classes in terms of their intensity values would be the best threshold. In addition to its optimality, Ostu's method has the important property that it is based entirely on the computation performed on the histogram of an image, an easily obtainable 1-D array [7], [10], [11].

Between class variance

$$\sigma_B^2(k) = \frac{[m_G P_1(k) - m(k)]^2}{P_1(k)[1 - P_1(k)]} \quad (4)$$

Where m_G is the global intensity mean, $m(k)$ is the cumulative mean, $P_1(k)$ cumulative sums and

$$m_G = \sum_{i-0}^{L-1} ip_i \quad (5)$$

$$m(k) = \sum_{i-0}^{k} ip_i \quad (6)$$

$$P_1(k) = \sum_{i-0}^{k} p_i \quad (7)$$

p_i is calculated using equation

$$p_i = \frac{n_i}{MN} \quad (8)$$

Where n_i denotes the number of pixels with the intensity 'i' and 'MN' total number of pixels in the image.

The optimum threshold is the value k* that maximizes $\sigma_B^2(k)$:

$$\sigma_B^2(k^*) = \max_{0 \le k \le L-1} \sigma_B^2(k) \quad (9)$$

For finding k^*, all integer value of k are evaluate and select the value that yields the maximum $\sigma_B^2(k)$

Global variance σ_G^2

$$\sigma_G^2 = \sum_{i-0}^{L-1} (i - m_G)^2 p_i \quad (10)$$

Threshold at level k is given by

$$\eta = \frac{\sigma_B^2}{\sigma_G^2} \quad (11)$$

VI. SAUVOLA THRESHOLDING

In Sauvola's binarization method, the threshold $t(x, y)$ is computed using the mean $m(x, y)$ and standard deviation $s(x, y)$ of the pixel intensities in a $w \times w$ window centered around the pixel (x, y):

$$t(x, y) = m(x, y)\left[1 + k\left(\frac{s(x, y)}{R} - 1\right)\right] \qquad (12)$$

where R is the maximum value of the standard deviation ($R = 128$ for a grayscale document), and k is a parameter which takes positive values in the range(0.2, 0.5). The local mean $m(x, y)$ and standard deviation $s(x, y)$ adapt the value of the threshold according to the contrast in the local neighborhood of the pixel. When, there is high contrast in some region of the image, $s(x, y) \sim R$ which results in $t(x, y) \sim m(x, y)$. The parameter k controls the value of the threshold in the local window such that the higher the value of k, the lower the threshold from the local mean $m(x, y)$. However in order to compute the threshold $t(x, y)$, local mean and standard deviation have to be computed for each pixel [12].

VII. VARIABLE THRESHOLDING BY SUBDIVING IMAGE

In this approach image is subdivided into non-overlapping rectangles. This approach is used to compensate for non-uniformities in illumination and or reflectance. The rectangle is chosen small enough so that the illumination of each is approximately uniform. In this technique, all subdivided image are independently thresholded and again merging the entire subdivided threshold image to obtain full image.

VIII. RESULT AND DISCUSSION

For comparison purpose, we have taken a enhance image which is free from noise and illumination problem from reference database. All codes are implemented in MATLAB software. Described threshold algorithms are applied on the image and results of all algorithms are shown in the fig.4-fig.10.

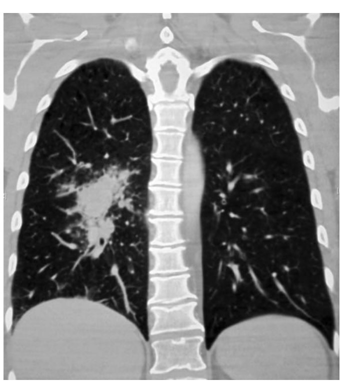

Figure 4: Original image

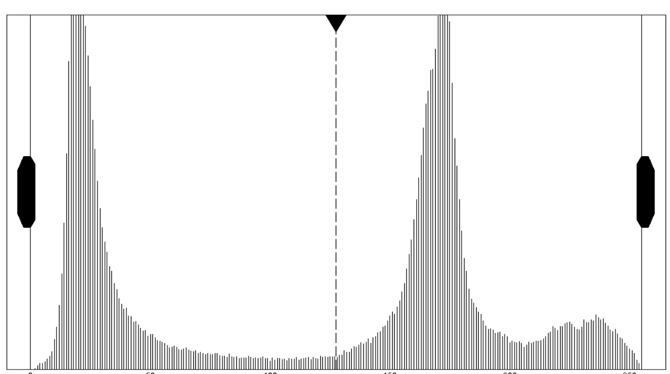

Figure 5: Original image histogram

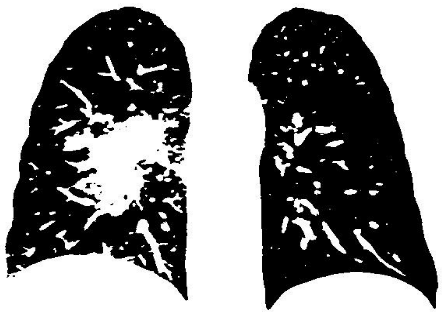

Figure 6(a): Global threshold (T=50)

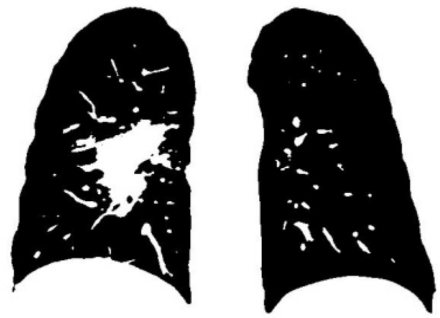

Figure 6(b): Global threshold (T=100)

Figure 6(c): Global threshold (T=150)

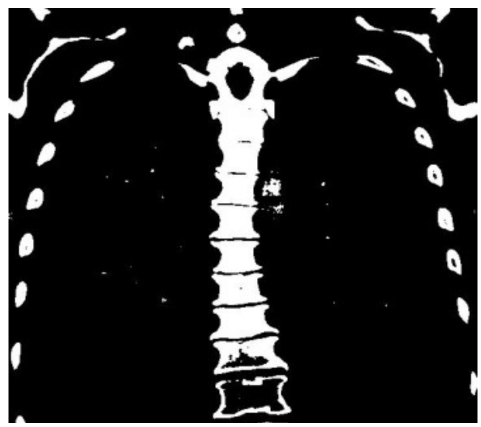

Figure 6(d): Global threshold (T=200)

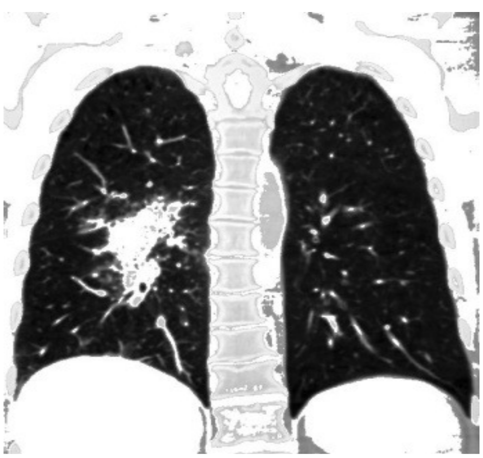

Figure 7: Variable Thresholding with background

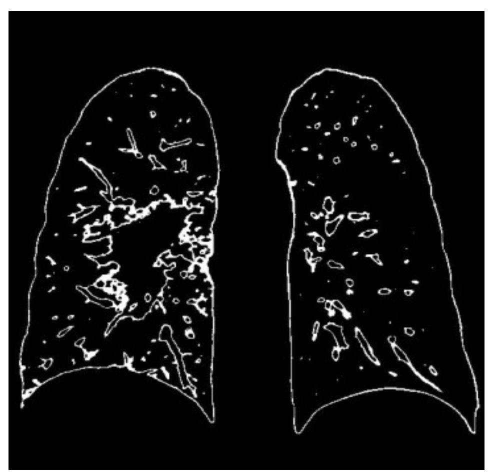

Figure 8(a): Variable thresholding (T1=50, T2=100)

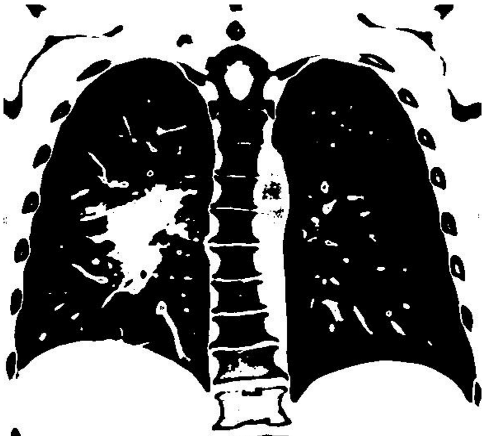

Figure 8(b): Variable thresholding (T1=100, T2=200)

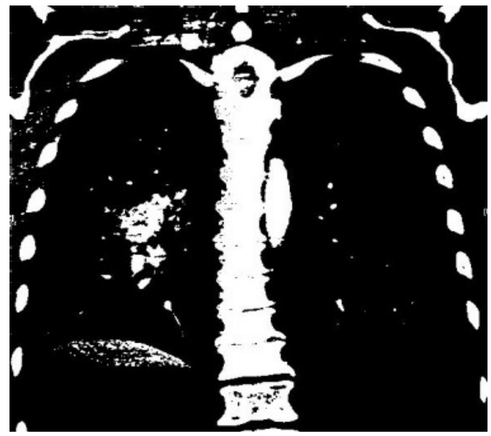

Figure 8(c): Variable thresholding (T1=180, T2=255)

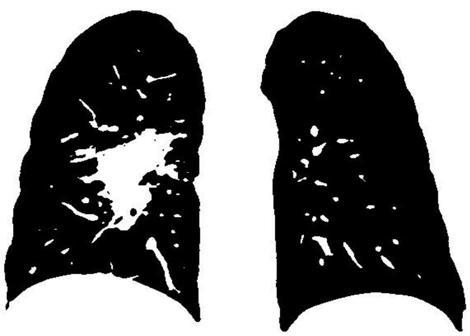

Figure 9: Otsu's thresholding

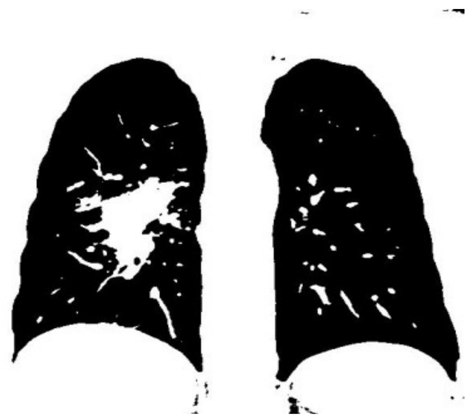

Figure 10: Sauvola thresholding

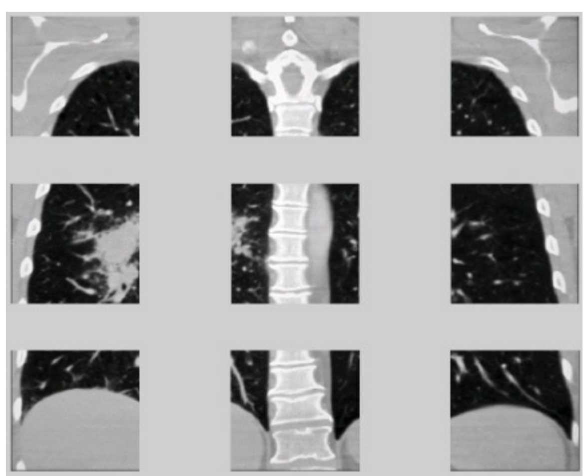

Figure 11: Image subdivision

Figure 12(a): Threshold subdivided image

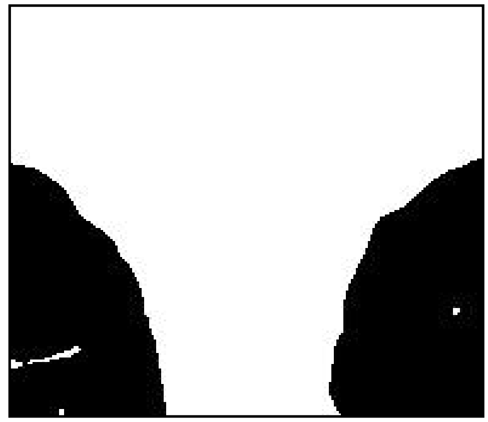

Figure 12(b): Threshold subdivided image

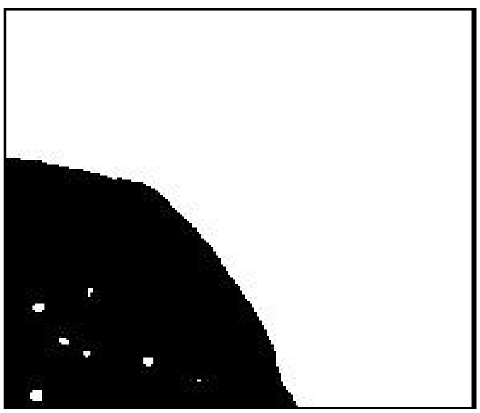

Figure 12(c): Threshold subdivided image

Figure 12(d): Threshold subdivided image

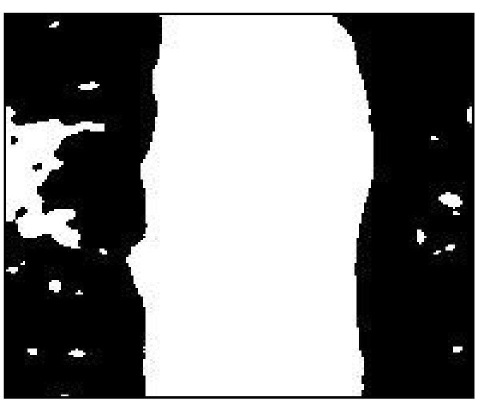

Figure 12(e): Threshold subdivided image

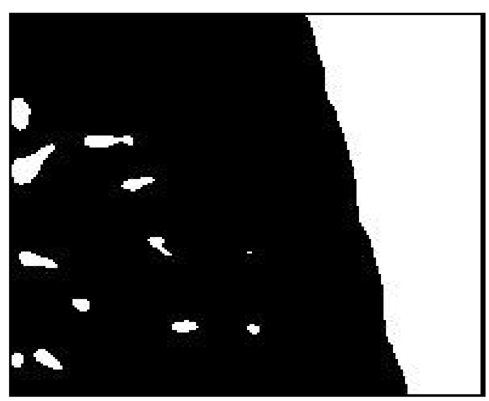

Figure 12(f): Threshold subdivided image

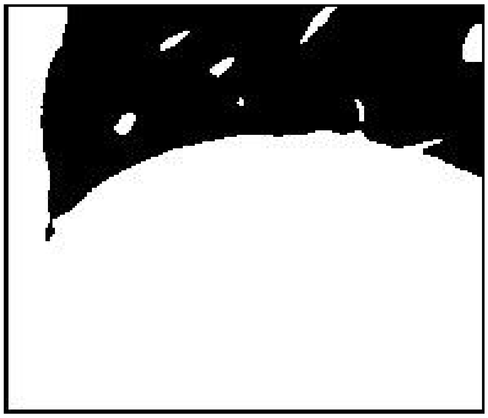

Figure 12 (g): Threshold subdivided image

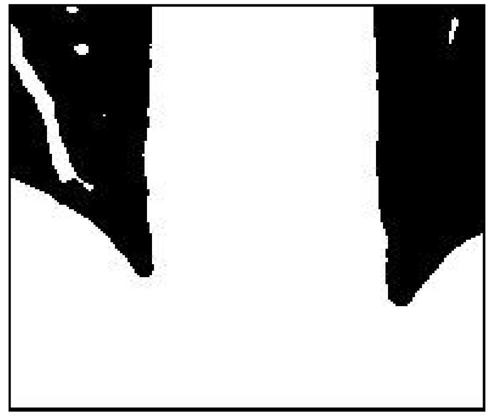

Figure 12(h): Threshold subdivided image

Figure 12(i): Threshold subdivided image

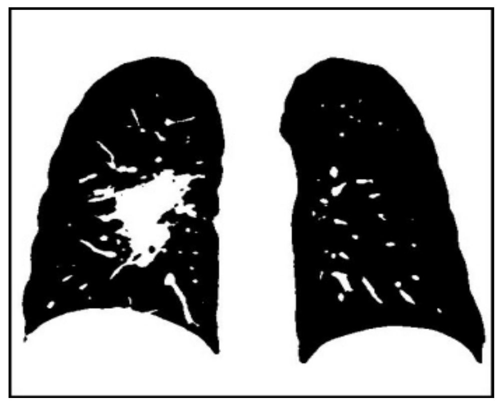

Figure 13: Merge image

Global thresholding in Fig.6 (a)-Fig6 (d) shows the result for different threshold value. For T=50, 100, 150 and 200 image get over or lower segmented by missing some important area and boundary in the image. Fig. 7 shows that segmented image retains back ground of the original image, only the interested area pixels are segmented. Variable thresholding Fig.8 (a) –Fig.8(c) shows a segmented area as per threshold limit. At T1-50 and T2 -100 boundary of the image is segmented. In Fig.8 (b) and Fig.8(c) shows the segmentation of hard and soft region of the image. The Ostu's and Sauvol thresholding techniques automatically calculating the threshold. By using this threshold, result is obtained to the expected level as shown in Fig.9-Fig.10. In Fig.11, image is subdivided into nine equal parts. This method is useful for segmenting image having different intensity levels. In this method, threshold is computed by taking into consideration of the subdivided image pixel not by considering the pixel value of the entire image. Because of this, image is properly segmented. In Fig.12 (a)-Fig.12 (i), Effect of segmentation is shown. Threshold subdivided images are merged and result is shown in Fig.13.

Observation during the execution of the thresholding is that, we have considered only the intensity and not any relationships between the pixels. There is no guarantee that the pixels identified by the thresholding process are contiguous. We can easily include extraneous pixels those are not the part of desired region and we can just as easily miss isolated pixels within the region (especially near the boundaries of the region). These effects get worse as the noise gets worse, simply because it's more likely that pixel intensity doesn't represent the normal intensity in the region. The Ostu's method assumes that the histogram of the image is bimodal (i.e., two classes) and the method breaks down when the two classes are very unequal (i.e., the classes have very different sizes). In this case, σ_B^2 may have two maxima and the correct maximum is not necessary the global one. The selected threshold should correspond to a valley of the histogram and the method does not work well with variable illumination. Implementations of variable thresholding are difficult and computational time is also high as compare to other algorithm.

IX. CONCLUSION

Thresholding technique plays a vital role in the segmentation and is effective, if the correct threshold value is known. Thresholding technique is simple to implement and required less time to compute, makes it popular among the segmentation technique. Global thresholding works well, if image contain uniform gray level. For non uniform gray level, variable thresholding produce a good result. In subdivided image thresholding technique require a lot of analysis of the image for deciding threshold value. Image with different intensity value can easily and properly segmented by image subdivision method. Otsu's and Sauvola method works well for automated thresholding of the histogram in an image. Only noise and intensity problem produces a difficulty in thresholding the image. Therefore before doing thresholding image should be filtered and enhancement should be done.

X. ACKNOWLEDGMENT

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