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A Survey of Image Processing Techniques for Emphysema Detection

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ABSTRACT
The main reason behind pulmonary emphysema is mainly due to long-term smoking, and medical treatments are quite difficult. In worst cases, the structure of the lung can get damaged irreversibly. In this case, one of the most important parts is to detect the different stages of the diseases. This requires some well-trained radiologists to observe the changes in the CT scans of the patients over a period of time. But there is dearth of well trained radiologists worldwide. Hence, it would of great help if an accurate computer aided detection (CAD) system for emphysema is developed. Emphysema region classification from CT image is a time consuming process because there exists many sub-regions because of the huge size of CT image. There exists some sub-regions which contain no sign of Emphysema and the classification of these regions is meaningless. In order to speed up the process of classification, an algorithm has been proposed for selecting the Emphysema affected regions which is region of interest. Then only Emphysema affected region is used for classification instead of all of the sub-regions.

General Terms
Computer aided detection (CAD) system.

Keywords
CAD, CT, Emphysema, region of interest.

1. INTRODUCTION
Computed tomography (CT) scans are performed to find out the pathological changes of the tissues present in the body. CT scans generate a massive quantity of images for examining the pathological change of the tissues. Hence, radiologists get exhausted while diagnosing pathological changes by making use of a lot of CT images. Computer-aided detection (CAD) systems have come into use for speedy disease diagnosis and help the radiologists. For detection of lung diseases like emphysema, lung cancer, etc., CAD systems are extensively used nowadays by taking help of biomedical image processing.

In case of Emphysema detection, standard methodology has been adopted for detecting the Emphysema region in the CT image by classifying sub-regions to identify Emphysema or not. This methodology is quite time consuming because there exists a lot of sub-region which needs to be examined. There exists some sub-region which does not have any Emphysema and performing classification of these sub-regions is a waste of time. In order to reduce the classification time of Emphysema region, it is needed to delete some of the sub-regions that have no Emphysema.

Any sort of pathological change of the tissues can be known from the local texture and brightness differences in the CT images. The color intensity of the lung CT image can help us in Emphysema detection. Brightness in the lung region helps the radiologists to pre-determine Emphysema region. Fig. 1 depicts a CT lung image with emphysema. On close observation of the image, the emphysema affected region looks darker as compared to the normal region as well as its surface is smooth. Emphysema affected regions can be filtered by utilizing the brightness information of lung region.

In this study, a review of all those available techniques is done to find out the best available technique. Each of the techniques has some advantages as well as disadvantages. Based on this study, it can be determined which technique can be applied in which scenario to obtain the optimal result.

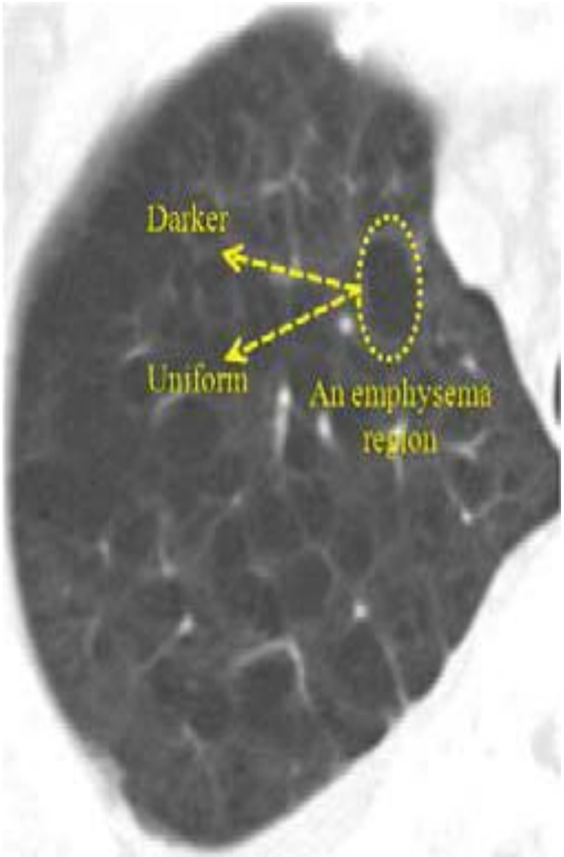

Figure 1: Emphysema affected CT Lung image Picture courtesy: [4]

2. RELATED WORKS
Texture descriptors have been used for detecting abnormal regions of lung CT images by Liang et al. [1] and Peng et al. [2] as depicted in Fig. 2. To locate the Emphysema region from the CT image of lung, the contrast of the input image is corrected using gamma correction. Otsu method [3] is used for obtaining the binary image. They used morphology and region growing methodology to remove the noise present in the image and also the lung vessels were deleted to get the lung region without any type of vessels.

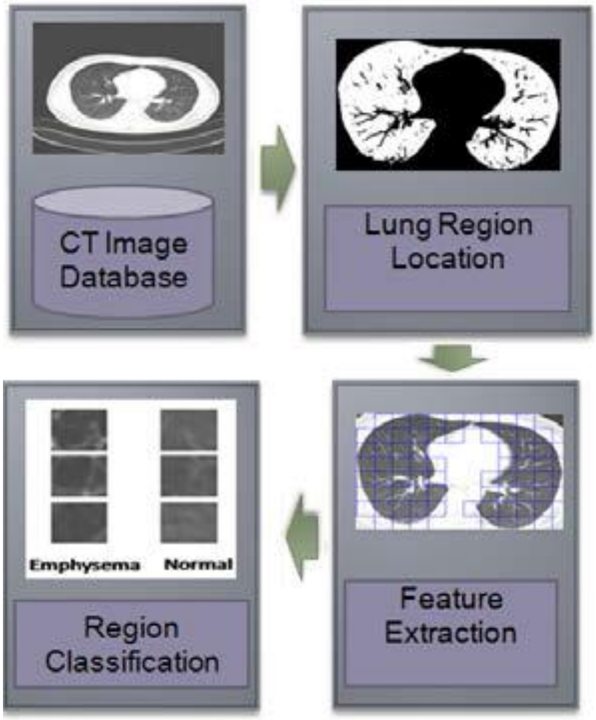

Figure.2: Emphysema Region Classification Scheme Picture courtesy: [4]

KHAIRUL et al. [4] used feature extraction for Emphysema detection. Here, the texture feature of each sub-region is separated from the lung image. The texture feature is extracted using the texture descriptors. This methodology is a time consuming procedure as there exists a lot of sub-region which need to be classified. There is certain sub-region which may not contain any Emphysema at all and the classification of the sub-regions is meaningless and so they removed those regions to speed up the Emphysema region detection process. Finally they used the resultant features are in order to detect whether it contains emphysema or not for region classification process.

EMAM et al. [5] analyzed digital data as obtained from the CT scan for Emphysema detection. This methodology is objective in nature and, hence, not dependent on interpreter bias. There exist two computerized methodologies for detecting emphysema. Low Attenuation Areas (LAA) present in the CT image is considered as a characteristic of emphysema. One approach detects areas of low attenuation depending on a range of density indices or a single density index threshold. So, all the areas whose densities are less than the threshold value (e.g.,910 Hounsfield Units (HU) or falling within a specified range of densities or the lowest fifth percentile of the histogram) are known to be emphysematous. For emphysematous subjects, the lowest fifth percentile of the histograms shows a good correlation with respect to the surface area of walls of distal air spaces per unit lung volume [6, 7].Now, the second methodology computes the mean lung density as an important characteristic of emphysema. Both of these techniques have achieved good correlation as compared with some of the pulmonary function tests [7].

For pattern identification in a medical image, Pramod k singh [8] used texture as one of the important characteristics. Gray scale combined with texture information play an important role in HRCT image analysis. Reeves et al.[5] proposed a methodology of texture characterization for JPEG compressed images. They considered the DCT block size in their work as 8x8. Then segmentation of regions in JPEG images using region growing and unsupervised classification [9, 10] is carried out. Their work of emphysema detection is on the similar lines as that of Reaves et al. but it is different on two basic aspects. First of all, they used the standard deviations and statistical mean of the DCT coefficients of a 2x2 block as compared to some neighboring 2x2 blocks. For 8x8 block, JPEG image is transformed to 2x2 JPEG image. Secondly, a set of concept rules are used for detecting emphysematous patterns; and these rules are utilized for the classification of each 2x2 JPEG image block depending on derived features. The accuracy of detection of emphysema Containing images and patients are nearly more than 96% if the window size is chosen as 16x16.

In this study, Harvey et. al [11] took the CT image of lung inflation and compared it with the histologic estimates of surface area. In this way they developed prediction equations that allow lung surface to volume ratio and surface area can be predicted from an observation of the CT scan. The result of this study shows that mild emphysema occurs when there is an increase in lung volume as well as reduction in surface to volume ratio. In case of severe emphysema, the surface area and tissue weight decreases. When the CT predicted surface to volume ratio gets correlated with histology, and then both predicted as well as measured surface areas gets correlated with the diffusing capacity. Hence, it can be concluded that the CT analysis can be used for finding out the progression of emphysematous lung destruction in patients. Moreover, they can be used to assess the impact of both surgical and medical treatments for emphysema.

Takeshi et. al [12] adapted an automated detection approach in order to find out the ratio of the pulmonary emphysema regions to the lung volume region. It is used for detecting the rate of lesion development utilizing 3D chest CT images. Earlier, the degree of the disease was found manually by well-trained radiologists after seeing the hard copy of the CT scan report, as the quantitative analysis of the ratio (abnormal region volume / whole lung volume) was not performed. The emphysema areas were detected by the presence of low attenuation areas (LAA) on CT scans. Their methodology was based on computing the ratio between the region extraction of LAA and volume measurement of the whole lung area except the bronchus regions. They undertook 32 cases (15 normal and 17 abnormal) which had been already diagnosed by radiologists prior to the study. With respect to the results of this approach, the ratio in all normal cases were less than 0.02, and in abnormal cases, it ranged from 0.01 to 0.26. All the abnormal cases were classified depending upon the degree of the diseases into three categories (moderate, intermediate, and severe).

Renuka et. al [13] developed a texture-based adaptive multiple feature method (AMFM) for calculating pulmonary parenchyma from computed tomography (CT) images. This methodology utilizes fractal texture as well as multiple statistical features. This AMFM was compared with two previously published methods, such as, lowest fifth percentile of the histogram (HIST) and the mean lung density (MLD). First of all, the ability of these approaches to find subtle differences in ventral–dorsal lung density gradient in the prone normal lung was observed. Second, their different approaches to distinguish between normal and emphysematous lung slices were also compared. Lastly, comparison between normal and emphysematous regions were carried out by dividing the lungs in the CT slices into six equal regions, from ventral to dorsal, and then each region is analyzed separately. The results reveal that the AMFM could distinguish the ventral from the dorsal which is about one-third of the normal prone lung with a 89.8% accuracy, in comparison to an accuracy of 74.6% with the MLD and 64.4% accuracy were obtained with the HIST methods. The normal and emphysematous slices were detected with 100.0% accuracy using the AMFM as compared to an accuracy of 97.4% and 94.7% using the HIST and MLD methods, respectively. The regional emphysematous and normal tissues were detected with an accuracy of 89.9%, 97.9% and 99.1% with the MLD, AMFM and HIST methods, respectively.

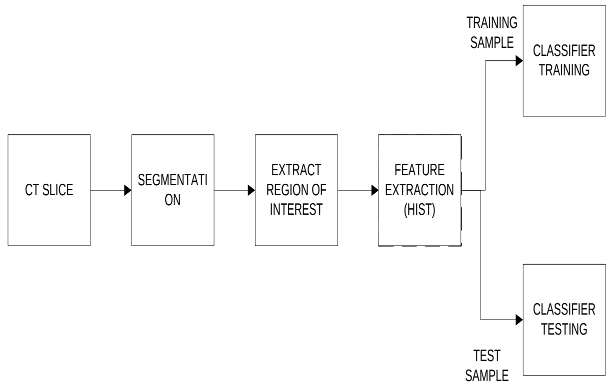

Figure 3: Flowchart showing HIST method Picture courtesy: [13]

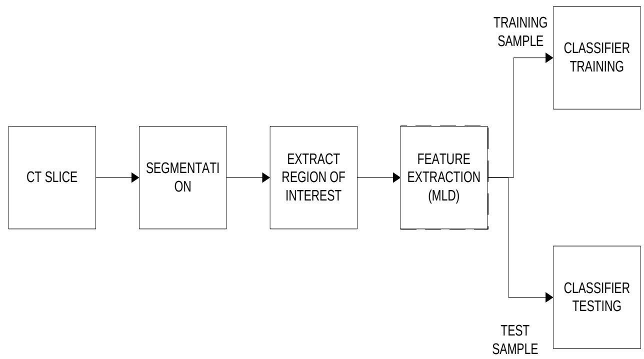

Figure 4: Flowchart showing MLD method Picture courtesy: [13]

Mithun et. al [14] developed an automated texture-based system depending on co-training. It has the capability of achieving multiple levels of emphysema extraction in high-resolution computed tomography (HRCT) images. Co-training is a semi-supervised approach which is used to improve the performance of classifiers that are trained with very few labeled examples. It utilizes a vast pool of unseen example scenarios over two disjoint feature sets known as views. There is also a scope which allows examples labeled by experts can be incorporated within the system in an incremental manner. The results obtained in this study were also compared with ‘‘density mask’’, which is a standard approach utilized for emphysema detection in the field of medical image analysis and other computerized techniques. This new approach can be used to classify diffuse regions of emphysema starting from a bullous setting. The classifiers are built at different iterations which show an interesting correlation in between different levels of emphysema, which deserves more research. The methodologies used in this paper automate the recognition process. They also help radiologists in the emphysema detection by providing accurate severity calculation from each HRCT scan. This can be obtained by minimum anatomical knowledge. For automated emphysema detection in lung images, a common methodology known as ‘‘density mask’’ is applied to perform thresholding of the image. Moreover, a fixed threshold results in unsatisfactory results as and when the degree of emphysema is low. In this study, we are estimating the degree of emphysema which has not been previously addressed. There are certain computerized techniques for classifying emphysema by using texture and machine learning approaches with a reasonable accuracy percentage. In case of a supervised learning framework, the system is provided with examples which belong to more than one class. All the examples are marked with respect to their membership in any one of the classes. Machine learning systems utilize a general description for the classes from these examples. In case of HRCT setting, labeling is a very time consuming as well as expensive process since it requires expert effort. Hence, it is much advantageous for the unlabelled data as much as possible.

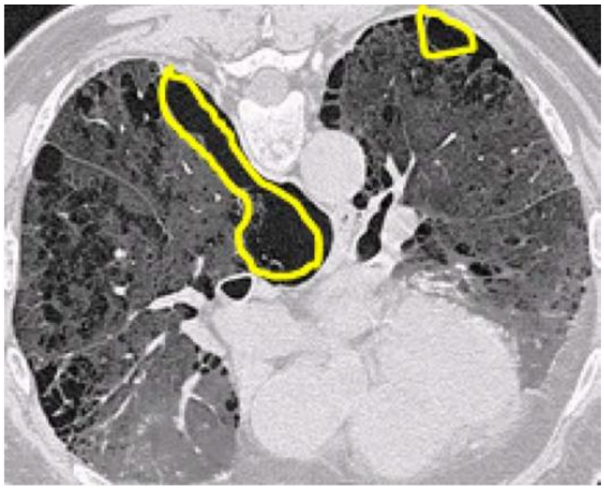

Figure 5: A HRCT scan image showing emphysema. The regions outlined denote emphysema. Picture Courtesy: [14]

Emphysema is a lung disease which can be recognized by its alveolar wall destruction property, which results in the increase of gas exchange spaces without any type of fibrosis. Emphysema is a chronic obstructive pulmonary disease (COPD), resulting in a 3.5% of total deaths worldwide. A technique known as Alveolar regeneration is working on the animal models and has the potential for clinical treatment if emphysema is detected in an early-stage. However, current methodologies for detection of initial stage emphysema are not sensitive at all. In this study, Josette et. al [15] modeled early-stage human emphysema is in the elastase-treated animals. Here, an *in vivo* imaging methodology is used for distinguishing emphysematous and normal rat lungs by calculating the apparent diffusion coefficient (ADC) of hyperpolarized 3He by utilizing the magnetic resonance imaging technique. This study reveals that the ADC is quite larger in case of elastase-treated rats, which indicates an alveolar expansion.

In this study, Lauge et. al [16] aimed at improving the quantitative measures for computed tomography (CT) images of the emphysema affected lungs. In the earlier adopted standard methods, such as the relative area of emphysema (RA), depends upon a single intensity threshold on individual pixels, thus overlooking any type of interrelations that exists in between the pixels. Here, texture analysis plays an important role as it takes into account the local structure around the pixels. This study represents a texture based classification system for emphysema quantification in CT images. The degree of emphysema severity can be found out by fusing the pixel posterior probabilities output by a classifier. Here, local binary patterns (LBP) are utilized as the texture features. LBP and intensity histograms are combined for characterizing the regions of interest (ROIs). Then, classification is performed using a nearest neighbor classifier with a histogram having dissimilarity measure as the distance. The study achieved 95.2% classification accuracy. The test was carried out on a set of 168 manually annotated ROIs, which consists of the three classes: centrilobular emphysema, paraseptal emphysema and normal tissue. The measurement of emphysema severity was in good arrangement with a pulmonary function test (PFT) which achieves correlation coefficients in 39 subjects. The results obtained in this study were compared to RA as well as to a Gaussian filter bank. The texture-based measures correlated much well with PFT as compared to RA.

Table 1. Review table stated year wise

Sl no.	Author	Paper title	Year	Remarks
1	Muzzamil *et al.*	Accelerating Emphysema diagnosis on lung CT images using Emphysema pre-detection method [4]	2013	Used feature extraction for Emphysema detection. Here, the texture feature of each sub-region is separated from the lung image. The texture feature is extracted using the texture descriptors. This methodology is a time consuming procedure as there exists a lot of sub-region which need to be classified. There is certain sub-region which may not contain any Emphysema at all and the classification of the sub-regions is meaningless and so they removed those regions to speed up the Emphysema region detection process. Finally they used the resultant features are in order to detect whether it contains emphysema or not for region classification process.
2	EMAM *et al.*	Characterization of Lung's Emphysema Distribution: Numerical Assessment of Disease Development [5]	2010	Analyzed digital data as obtained from the CT scan for Emphysema detection. This methodology is objective in nature and, hence, not dependent on interpreter bias. There exist two computerized methodologies for detecting emphysema. Low Attenuation Areas (LAA) present in the CT image is considered as a characteristic of emphysema. One approach detects areas of low attenuation depending on a range of density indices or a single density index threshold. So, all the areas whose densities are less than the threshold value (e.g., 910 Hounsfield Units (HU) or falling within a specified range of densities or the lowest fifth percentile of the histogram) are known to be emphysematous. For emphysematous subjects, the lowest fifth percentile of the histograms shows a good correlation with respect to the surface area of walls of distal air spaces per unit lung volume
3	Sørensen *et al.*	Quantitative Analysis of Pulmonary EmphysemaUsing Local Binary Patterns [16]	2010	Proposed a method aimed at improving the quantitative measures for computed tomography (CT) images of the emphysema affected lungs. In the earlier adopted standard methods, such as the relative area of emphysema (RA), depends upon a single intensity threshold on individual pixels, thus overlooking any type of interrelations that exists in between the pixels. Here, texture analysis plays an important role as it takes into account the local structure around the pixels. This study represents a texture based classification system for emphysema quantification in CT images. The degree of emphysema severity can be found out by fusing the pixel posterior probabilities output by a classifier. Here, local binary patterns (LBP) are utilized as the texture features. LBP and intensity histograms are combined for characterizing the regions of interest (ROIs). Then, classification is performed using a nearest neighbor classifier with a histogram having dissimilarity measure as the distance. The study achieved 95.2% classification accuracy. The test was carried out on a set of 168 manually annotated ROIs, which consists of the three classes: centrilobular emphysema, paraseptal emphysema and normal tissue. The measurement of emphysema severity was in good arrangement with a pulmonary function test (PFT) which achieves correlation coefficients in 39 subjects. The results obtained in this study were compared to RA as well as to a Gaussian filter bank. The texture-based measures

				correlated much well with PFT as compared to RA.
4	Peng *et al.*	Speeded Up Feature Extraction for CT image Based on Integral Image Technique [2]	2009	Proposed a method to locate the Emphysema region from the CT image of lung, the contrast of the input image is corrected using gamma correction
5	Mohanalin *et al.*	Tsallis Entropy based Microcalcification Segmentation [6] 3.	2009	Introduced a methodology which computes the mean lung density as an important characteristic of emphysema. Both of these techniques have achieved good correlation as compared with some of the pulmonary function tests
6	Liang *et al.*	A Neural Network based Computer-Aided Diagnosis of Emphysema using CT Lung Images[1]	2007	Introduce a method in which texture descriptors have been used for detecting abnormal regions of lung CT images
7	Prasad *et al.*	Multi-level classification of emphysema in HRCT lung images[14]	2007	Developed an automated texture-based system depending on co-training. It has the capability of achieving multiple levels of emphysema extraction in high-resolution computed tomography (HRCT) images. Co-training is a semi-supervised approach which is used to improve the performance of classifiers that are trained with very few labeled examples. It utilizes a vast pool of unseen example scenarios over two disjoint feature sets known as views. There is also a scope which allows examples labeled by experts can be incorporated within the system in an incremental manner.
8	Singh *et al.*	Emphysema detection in JPEG compressed HRCT lung Images[8]	2005	Used texture as one of the important characteristics. Gray scale combined with texture information play an important role in HRCT image analysis
9	Singh *et al.*	Segmentation of JPEG Compressed Medical Images[10]	2004	Proposed a method which considered the DCT block size in their work as 8x8. Then segmentation of regions in JPEG images using region growing and unsupervised classificatio is carried out. Their work of emphysema detection is on the similar lines as that of Reaves et al. but it is different on two basic aspects. First of all, they used the standard deviations and statistical mean of the DCT coefficients of a 2x2 block as compared to some neighboring 2x2 blocks. For 8x8 block, JPEG image is transformed to 2x2 JPEG image. Secondly, a set of concept rules are used for detecting emphysematous patterns; and these rules are utilized for the classification of each 2x2 JPEG image block depending on derived features. The accuracy of detection of emphysema Containing images and patients are nearly more than 96% if the window size is chosen as 16x16.
10	Hara *et al.*	Automated Detection System for Pulmonary Emphysema on3D Chest Images[12]	2004	Adapted an automated detection approach in order to find out the ratio of the pulmonary emphysema regions to the lung volume region. It is used for detecting the rate of lesion development utilizing 3D chest CT images. Earlier, the degree of the disease was found manually by well-trained radiologists after seeing the hard copy of the CT scan report, as the quantitative analysis of the ratio (abnormal region volume / whole lung volume) was not performed. The emphysema areas were detected by the presence of low attenuation areas (LAA) on CT scans. Their methodology was based on computing the ratio between the region extraction of LAA and volume measurement of the whole lung area except the bronchus regions. They undertook 32 cases (15 normal and 17 abnormal) which had been already diagnosed by radiologists prior to the study. With respect to the results of this approach, the ratio in all normal cases were less than 0.02, and in abnormal cases, it ranged from 0.01 to 0.26. All the abnormal cases were classified depending upon the degree of the diseases into three categories (moderate, intermediate, and severe).

11	Feng *et al.*	Image Segmentation in CompressedDomain[9]	2003	Introduced a method to detect emphysema. It is different on two basic aspects. First of all, they used the standard deviations and statistical mean of the DCT coefficients of a 2x2 block as compared to some neighboring 2x2 blocks. For 8x8 block, JPEG image is transformed to 2x2 JPEG image. Secondly, a set of concept rules are used for detecting emphysematous patterns; and these rules are utilized for the classification of each 2x2 JPEG image block depending on derived features. The accuracy of detection of emphysema Containing images and patients are nearly more than 96% if the window size is chosen as 16x16.
12	Coxson *et al.*	A Quantification of the Lung Surface Area in Emphysema Using Computed Tomography[11]	1999	Proposed a method which took the CT image of lung inflation and compared it with the histologic estimates of surface area. In this way they developed prediction equations that allow lung surface to volume ratio and surface area can be predicted from an observation of the CT scan. The result of this study shows that mild emphysema occurs when there is an increase in lung volume as well as reduction in surface to volume ratio. In case of severe emphysema, the surface area and tissue weight decreases. When the CT predicted surface to volume ratio gets correlated with histology, and then both predicted as well as measured surface areas gets correlated with the diffusing capacity. Hence, it can be concluded that the CT analysis can be used for finding out the progression of emphysematous lung destruction in patients. Moreover, they can be used to assess the impact of both surgical and medical treatments for emphysema.
13	Uppaluri *et al.*	Quantification of Pulmonary Emphysema from Lung Computed Tomography Images[13]	1997	Developed a texture-based adaptive multiple feature method (AMFM) for calculating pulmonary parenchyma from computed tomography (CT) images. This methodology utilizes fractal texture as well as multiple statistical features. This AMFM was compared with two previously published methods, such as, lowest fifth percentile of the histogram (HIST) and the mean lung density (MLD). First of all, the ability of these approaches to find subtle differences in ventral–dorsal lung density gradient in the prone normal lung was observed. Second, their different approaches to distinguish between normal and emphysematous lung slices were also compared. Lastly, comparison between normal and emphysematous regions were carried out by dividing the lungs in the CT slices into six equal regions, from ventral to dorsal, and then each region is analyzed separately. The results reveal that the AMFM could distinguish the ventral from the dorsal which is about one-third of the normal prone lung with a 89.8% accuracy, in comparison to an accuracy of 74.6% with the MLD and 64.4% accuracy were obtained with the HIST methods. The normal and emphysematous slices were detected with 100.0% accuracy using the AMFM as compared to an accuracy of 97.4% and 94.7% using the HIST and MLD methods, respectively. The regional emphysematous and normal tissues were detected with an accuracy of 89.9%, 97.9% and 99.1% with the MLD, AMFM and HIST methods, respectively.
14	Otsu et al	A Threshold Selection Method from Gray-Level Histogram[3]	1979	Introduce a technique used for obtaining the binary image. They used morphology and region growing methodology to remove the noise present in the image and also the lung vessels were deleted to get the lung region without any type of vessels.
15	American Thoracic Society.	. Chronic bronchitis, asthma, and pulmonary emphysema: a statement by the committee on diagnostic standards for nontuberculous[7]	1962	Develop a methodology computes the mean lung density as an important characteristic of emphysema. Both of these techniques have achieved good correlation as compared with some of the pulmonary function tests

4. CONCLUSION

In this review paper, many works related to automated emphysema detection were studied. Different techniques used different approaches for emphysema detection. Among all of the techniques studied above, the text feature based adaptive multiple feature method achieved the highest accuracy.

Emphysema is one of the vital factors contributing to majority of lung diseases worldwide. So, there is a need for development of some inexpensive automated technique for accurate detection of different stages of emphysema. These techniques will be of great help in less developed countries where there is an acute shortage of radiologists. There have been several works done earlier in this field. In future, there arises a need to develop more accurate, robust as well as affordable automated techniques for emphysema detection so that the benefits are passed on the poorest of poor people. The current available techniques don't tell us about the degree of severity of the disease. It would be better if a proper automated classification system is developed in future which can analyze a patient's current state into mild, intermediate or severe.

Once emphysema is correctly diagnosed so proper medicine or surgery can be done in a timely manner to avoid death.

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