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Analytical Study on Human Lung Lobe Segmentation Using Digital Image Processing Techniques

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Abstract : Medical Imaging is the technique that is used to create images of the human body or parts for clinical purpose. Lung lobewise analysis of pulmonary parenchyma is of diagnosing and monitoring pathologies. Segmentation of images has become important and effective tool for many technological applications like lung segmentation from CT scan images, medical imaging and many other post-processing techniques. This literature review attempts to provide overview of the most common segmentation techniques. Segmentation is automated analysis by delineating structures of interest and discriminating them from detailed review on lung lobe segmentation. In this paper, the review of segmentation of lung CT images, which can help radiologist in early diagnosing lung diseases like lung cancer.
Index Terms: Image segmentation, Image analysis, CT scan, Lung lobes, Fissures.

I. INTRODUCTION.

Human lungs are the organs of respiration and each lung consists of pulmonary lobes which are separated by the fissures. These fissures are divided into two types, namely major fissure and minor fissure. The lobes in the lungs are separated horizontally by a thin layer called minor fissure or horizontal fissure. The fissure that separates its own pleural cover of each lung is known as major fissure, and it is also known as oblique fissure. The pleurae are dual covered membrane structure that presented on each lung. The major fissures are frequently seen on the lateral view while the minor fissure seen on normal view of the lung. Moreover, lung consists of bronchial tree and vascular systems which execute relatively independent of each other. The general anatomy of the human lungs is illustrated in the figure1.

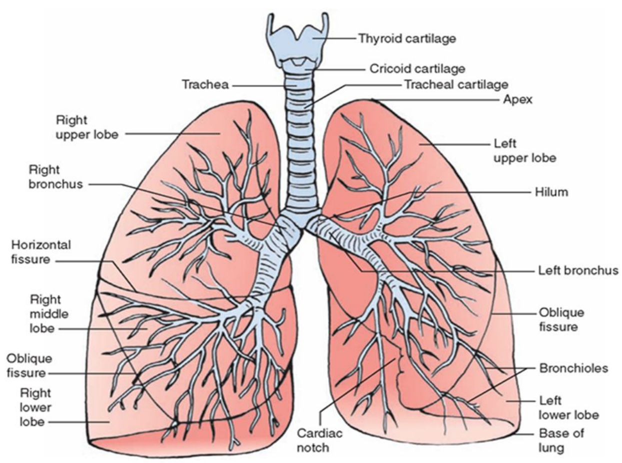

Fig.1. Anatomy of Lung

CT scan is more appropriate for showing the detailed information of the parts of human body and it is used for various applications such as detection, classification, etc. The analysis of lungs in CT image is used to detect the airway and the vessel present in the lungs [1]. The main purpose of segmenting the lobes in CT image is to find out any disease such as cancer, tumor are affected in the lungs since it is useful for surgical planning. Lobe Segmentation is useful for the radiologist to analyze the image and found out whether there is any disease affected in the lungs or not. Most of the authors have proposed a various methods such as Graph search algorithm [2], Artificial Neural Network, Multi-atlas approach, Iterative threshold [3] and [4], Selective and Iterative method for Performance level estimation, Watershed transformation method, for the lobe segmentation in CT images[5].

The concept of this paper is organized as follows. In Section 1, Introduction about lung anatomy is discussed. In Section 2 the literature review related to the proposed problems and methodsare presented. In Section 3 provides the conclusion about the lung related issues and problems.

II. LITERATURE REVIEW ON HUMAN LUNG LOBE SEGMENTATION METHODS

A. Image Segmentation

Image Segmentation is a primary process of image analysis in any situation. It is a process of sub dividing an image into constituents region or objects. The image segmentation techniques are Edge Based, Thresholding, Region Based and Clustering [6][7] [8].

JiantaoPuet al. described a shape analysis strategy to facilitate automated medical image segmentation and applied it to segmentation of human lung [9]. The shape "Break-and-Repair" strategy consists of three main stages. Modeling extracts the raw Regions of interests (ROIs) and represents as a surface model. In the break stage the problematic regions were identified and removed. In the repair stage, the remaining incomplete regions were fitted. An efficient mesh simplification algorithm was applied to reduce the computation cost and the method demonstrates the accuracy and robustness.G. Amalorpavamet al.developed analysis of digital images using morphological operations and the digital images were transformed into different forms [10]. The mathematical morphological techniques are dilation, erosion, opening and closing operation, hit-or-miss operation and thinning. This approach does not support all types of scan images. AlirezaSepasMoghaddamet al. have presented a novel hybrid image segmentation method [11]. Their objective was to utilize the efficiency of PSO and k-mean methods under the supervision of learning automata. Particle Swarm Optimization (PSO) was based on population and random search k-means is a local search algorithm, it performs exploitation with lower computational complexity and higher speed. Each particle has been equipped with learning automata. The experiments were conducted on 12 standard test grayscale images with size of 512 X 512. Their experimental result was also compared with ten other state of the art algorithms. This method produced result with improved accuracy but the method was not automatic.ZulaikhaBeeviet al.have presented Robust Segmentation Approach for Noisy Medical Images using Fuzzy Clustering with spatial probability [12]. The renowned unsupervised clustering method, Fuzzy C-Means (FCM) algorithm was extensively used in medical image segmentation and it is an effective approach for the segmentation of noisy medical images. In Histogram based Fuzzy C-Means clustering algorithm, the spatial probability of the neighboring pixels are integrated in the objective function of FCM to improve the robustness. This method attains reliable segmentation accuracy despite of noise levels and was more efficient and robust against noise when compared to FCM. The segmentation accuracy was 94%, but it was not a faster method.Chunming Li et al. presented a level set method for image segmentation in the presence of intensity in homogeneities with application to MRI [13].

A novel region-based method was used for image segmentation. A local intensity clustering property of the image intensities were derived first and a local clustering criteria function for the image intensities were defined. This algorithm has been validated on synthetic images and real images and the method is more robust, faster and accurate than Piecewise smooth (PS) model. Salem Saleh Al-amriet al. presented Image Segmentation by using Threshold Techniques [14]. It includes five threshold methods such as Mean method, P-tile method, Histogram Dependent Technique (HDT), Edge Maximization Technique (EMT) and Visual Technique. They were compared with threshold segmentation. This requirement based on some knowledge about the intensity characteristics of the objects, sizes of the objects, fractions of the image occupied by the objects and the number of different types of objects appearing in the images.

O. Michaelovichet al. reported Image Segmentation Using Active Contours Driven by Battacharrya Gradient Flow which described the problem of image segmentation by means of active contours [15]. The methodology was viewed as a generalization of the segmentation methods, in which active counters maximize the difference between a finite number of empirical moments of the "inside" and "outside "distributions and this algorithm was found more convenient for image segmentation from a practical perspective and to decompose an image into a number of its fragments. Segmenting the image into two segments namely foreground and background were not specified in the algorithm.Nassir Salman et al.presented Image segmentation and edge detection based on Chan-Vese algorithm [16].

The regions were detected using K-means fuzzy. Their boundaries were decided based on curve evolution technique to isolate and extract individual components from a medical image by chan - vese and level set approaches. The final output was the region which has closed boundary per actual region in the image and segmented map. This method produced good result when detecting the object. But they used the grey scale image for analysis.A.S.Pednekar*et al.* presented Image Segmentation based on fuzzy connectedness using dynamic weights [17]. They described a modification and extension of previously published image segmentation algorithms based on fuzzy connectedness by providing a method, called fuzzy connectedness using dynamic weights to introduce directional sensitivity to the homogeneity based component and to dynamically adjust the linear weights in the functional form of fuzzy connectedness.DenizAykac*et al.* reported Segmentation and Analysis of the Human Airway Tree from Three-Dimensional X-Ray CT Images [18]. Airway segmentation was used to identify the airway lumen in the CT images and Airway tree segmentation was performed manually by image analyst, but the complexity of the tree makes manual segmentation tedious and extremely time-consuming. The algorithm used grayscale morphological reconstruction to identify candidate airways on CT slices and then reconstruct a connected 3D airway. The method used a combination of grayscale morphological reconstruction, bounded space dilation and region connectivity to identify and reconstruct the 3D airway tree. Sang Cheol Park *et al.* developed a Computer Aided Detection Scheme for Pulmonary Embolism (PE) detection [19]. This method includes five basic steps. Lung Segmentation step includes 2D based adaptive threshold segmentation and 3D based region growing process. To detect and extract 2D Pulmonary Embolism (PE), tobogganing algorithm was used. Then the feature was extracted and the Artificial Neural Network was used to reduce the false positive. A multi feature based K-nearest neighbor has been used for positive or negative classification.

B. Lung Segmentation

Pulmonary segmentation of lungs from chest CT images is useful in diagnosis of abnormalities and surgery planning. Lobe segmentation is carried out by edge tracking and region filling algorithms to differentiate the segments. The method is evaluated on chest CT images of normal and abnormal cases[20].

Mythily. A et al. reported a method to segment and classify Lung Tumors using Chest CT images [21]. Adaptive threshold algorithm was used for segmentation, Gray Level Co-occurrence Matrix (GLCM) to extract the features from segmented images and Support Vector Machine (SVM) classifier for classification using Optimal Separating Hyperplane (OSH). This method was used to detect benign and malignant tumour for treatment planning. The computation take more time and this method may not distinguish the shading of the real images.Trang K. Le et al. described Segmentation of Lung Vessels together with Nodules in CT Images [22]. This algorithm combines morphology and Level set method. By using this algorithm, weak vessels, and weak junctions of vessels were detected. To find the strong vessels, high intensity and middle level intensity were used. This method is not suitable for large size images.

PanfangHuaet al. presented Segmentation of Pathological and diseased Lung tissue in CT images using Graph search algorithm [23]. An automatic algorithm was proposed for pathological lung CT image segmentation that used a graph search driven by a cost function combining the Intensity - Based lung presegmentation, gradient, boundary smoothness,rib information sensitivity, specificity and Hausdorff distance were calculated to evaluate the method. The analysis shown that lung segmentation framework performs better than the intensity only method. The sensitivity of the graph search-based method was 7.71%. RuiShenet al. proposed an automated segmentation technique to detect Tuberculosis (TB) cavities automatically by using hybrid knowledge based Bayesian classification approach from Chest Radio Graphs (CXRs) for which Gradient inverse coefficient of variation and circularity measure were applied using optimal thresholds in a Bayesian classification technique [24]. TB cavities were either confirmed or excluded. This method was not dealt with automatic lung field segmentation technique.Panayiotis D. Korfiatiset al. reported a Texture based Identification and Characterization of Interstitial Pneumonia (IP) pattern in Lung Multi-detector CT using computer aided scheme [25]. This method includes robust vessel-tree segmentation method to obtain the Lung parenchyma (LP) volume, the identified vessel tree volume is removed from Lung-field (LF), K-NN voxel classification and 3-D co-occurrence analysis were followed to identify and characterize the patterns. This method did not deal with lung lobe segmentation.Michael W.Graham et al. proposed Automatic airway tree segmentation [26]. The segmentation includes conservative segmentation, Airway segment definition, Airway segment connection and global graph-partitioning algorithm required 3minutes on average to complete segmentation process. From analysis, thick-slice scan those employing 3-10mm thick section were unsuitable for robust definite of peripheral airways.Lin-Yu Tseng et al. presented an Adaptive Thresholding Method for Automatic Lung Segmentation in CT Images [27]. The lung segmentation technique consists of eight steps that determines the threshold for each CT slice in a patient stack and automatically does the lung segmentation. This method found a good threshold for each slice and the segmentation accuracy was improved by using the threshold.Eva M. van Rikxootet al. reported Lung segmentation based on region growing method using fissure segmentation and a lung segmentation to segment the lobes using a voxel classification approach [28]. This method was evaluated on 100 low-dose CT scans obtained from a lung cancer screening trial and compared to estimate both inter observer and intra observer agreement. The merit of this method was that it increased the segmentation accuracy (77%) to a significant level and the demerit was that it performed better for the left lung than for the right lung and the lobe segmentation with in- complete fissures was often incorrect.Lu Menget al. presented Interactive Lung Segmentation Algorithm for CT Chest Images

Based on Live-Wire Model and Snake Model [29]. Computer-Aided Diagnosis system (CAD) was based on image processing and Lung parenchyma segmentation was the key part to this system. Key slices of lung parenchyma in serial CT images were selected and then the lung's contours in key slices by Live-Wire model were drawn to get the lung's contours in other slices by contour interpolation and finally segment lung's accurate contours in all slices by Snake model and manual modification. The results shown that this method was able to segment the lung parenchyma in serial CT images quickly and accurately with few manual operations.Giorgio De Nunzioet al. reported An Innovative Lung Segmentation Algorithm in CT Images with Accurate Delimitation of the HilusPulmonis which described a new segmentation method for the delimitation of the lung parenchyma in thorax Computed-Tomography (CT) datasets [30]. A threshold that discriminates the (low-density) lung parenchyma from other tissues was calculated and 3D Region Growing (RG) was then applied to the CT volume. Wave front simulation was applied for external bronchi extraction and fusion was detected by examining the mask M' in the junction regions. Then a seed point was located in each lung, RG is applied and the lungs were reconstructed. Two masks, ML and MR were thus obtained. Then lung cavities were filled due to isolated internal nodules and concavities originated from internal vessels and juxta pleural nodules. The lung masks cover the pulmonary parenchyma and all the lung nodule types, internal blood vessels, and internal airways. Finally the lung segmentation process is completed.

M. ArfanJaffaret al. presented GA and Morphology based automated Segmentation of Lungs from CT scan Images [31]. The goal of segmentation was to simplify or change the representation of an image into something that was more meaningful and easier to analyze. This method was able to perform fully automatic segmentation of CT scanned lung images which could be used as a basic building block for a computer aided diagnosis systems. It does not require any human expert intervention, nor any a prior information about the input image but doesn't provide three dimensional information. Cherry Ballanganet al. reported Lung Segmentation and Tumor Detection from CT Thorax Volumes of FDGPET-CT Scans by Template Registration and Incorporation of Functional Information [32]. PET-CT using FDG was accepted as the best method to stage non-small cell lung cancer (NSCLC). This method was successful to segment the lungs and detect NSCLC tumors of varying sizes and locations. It doesn't provide 3D information.Asem M. Ali et al. presented A Novel Frame work for Accurate Lung Segmentation Using Graph cuts that separates the lung tissues from the surrounding anatomical structures appearing in the chest CT scans [33]. Experiments shown that the developed technique segments CT lung images more accurately than other known algorithms. It gives minimum, optimal segmentation energy for all segmented images. It doesn't provide 3D information.RushinShojaiiet al. reported Automatic Honeycomb Lung Segmentation in Pediatric CT Images [34]. This method was based on wavelet transform and intensity similarities which focus on the honeycomb texture in lung tissue. The drawback of this technique was that although it detects all honeycomb areas, the boundary of the segmented abnormal area was not accurate.

D. Muhammad Noorul Mubarak et al. presented a Hybrid region growing algorithm for medical image segmentation [35]. The improved Harris Corner detects theory for maintaining the distance vector between the seed pixel and maintain minimum distance between seed pixels. A new uncertainty theory called cloud model computing (CMC) to realize automatic and adaptive segmentation threshold selection. The method was tested for segmentation on X-Rays, CT scan and MR images. ArfanJaffaret al. presented Genetic Fuzzy Based Automatic Lungs Segmentation from CT Scan Images for lungs [36]. A fully automatic unsupervised strategy has been developed for the segmentation of lungs. A fully histogram based image filtering technique has been used to remove the noise, which preserves the image details for low as well as highly corrupted images. This technique was used for finding the optimal and dynamic threshold values. It does not support incomplete fissures. OmidTalakoubet al. presented Lung Segmentation in Pulmonary CT Images Using Wavelet Transform [37]. Types of CAD schemes were developed for detection and/or characterization of various lesions for variety of imaging modalities, including conventional projection radiography, Computer Tomography (CT), Magnetic Resonance Imaging (MRI) and Ultrasound. A database containing 330 DICOM images randomly chosen from randomly selected patients were evaluated using this method.

Hye Suk Kim et al. presented Automatic Lung Segmentation in CT Images using Anisotropic Diffusion and Morphology Operation that segments the right and left lung [38]. The proposed method eliminates the tasks of finding an optimal threshold and separating the attached left and right lungs. The experimental results shown that this method improved the speed, robustness and accuracy as well as the reduction of over-segmentation to perform the anisotropic diffusion. The demerit of the method is that vascular tree segmentation was not included.Margarida Silveiraet al. reported Automatic segmentation of the lungs using robust level sets which was based on the use of a robust geometric active contour that is initialized around the lungs, automatically splits in two and performs outlier rejection during the curve evolution [39]. The performance of the proposed method was analyzed by the input data consisting of stacks of chest CT slices with X-ray attenuation ranging from -1024 to 3071 Hounsfield units, corresponding to a 12 bit quantization. The demerit of their method is that the segmentation of fissure was not included. Nisar Ahmed Memonet al. reported Deficiencies of Lung Segmentation Techniques using CT Scan Images for CAD; it includes the implementation thresholding and region growing algorithm, the thresholding and morphology algorithm and the thresholding and Ball algorithm [40]. By analysis, thresholding and region growing algorithm leads to inaccurate diagnosis of disease, the limitation of the thresholding and morphology algorithm has fixed object size. It takes more processing time and it includes unnecessary areas of lung regions.Ingrid Sluimeret al.Ginneken described Automated Segmentation of the Pathological Lung in CT and the performance of the method was compared with a conventional, user interactive and voxel classification method [41]. No statistical difference in performance was found between voxel classification and the registration method which consumed 10 min only for $1/8^{th}$ part of the voxel classification.

S.G. Armatoet al. presented Automated lung segmentation for thoracic CT which described the importance of accurate segmentation as a preprocessing step in a CAD scheme [42]. In a nodule detection setting 5% –17% of the lung nodules in their test data was missed due to the preprocessing segmentation, depending on whether or not the segmentation algorithm was adapted specifically to the nodule detection task. Nilanjan Ray et al. described an Active contour model to merge multiple contours within homogeneous Image Region using hyperpolarized helium-3 to study the lung functionality [43]. The Generalized gradient vector flow (GRVF) was applied to develop geometric contour and Pratt's figure of Merit (FOM) was utilized to emphasize the effectiveness. This method was matched to the problem of delineating of lung cavity. Dirk Bartzet al. presented Hybrid Segmentation and Exploration of the Human Lungs which was based on a pipeline of three segmentation stages to extract the lower airways down to the seventh generation of the bronchi [44]. In the first stage, standard 3D region growing methods are used to segment the trachea and central and to complete the upper and central branches, 2D wave propagation was initiated. User interaction was limited to the specification of a seed point inside the easily detectable trachea at the upper end of the lower airways. Similarly, the complementary vascular tree of the lungs could be segmented. This method requires much iteration to complete the segmentation process.Shiying Hu et al. described a fully automatic method to identify the lungs in three dimensional (3-D) pulmonary X-Ray CT images using an optimal gray level thresholding to extract the lung region from CT images [45]. Dynamic programming was applied to separate left and right lungs and to improve the results. The segmentation process requires 3-4min for data set.Linda. A et al. proposed Segmentation of pulmonary lobes using marker based watershed algorithm [46]. Wiener filter was used to remove noise from the CT lung image. The adaptive threshold method was used to segment the fissure based on the internal and external marker. Internal marker was used to obtain lines and External marker to extract the region from the CT lung image which is used for surgical planning of treating lung disease.

N. Selvarasuet al. reported Euclidean distance based color image segmentation of abnormality detection from pseudo color thermographs [47].In these thermographs are acquired for the whole body or the region of interest. They analyzed the feature extraction algorithm for abnormality detection. This method discussed about the detecting and monitoring of diseases in the human body part.

C. Lung Lobe Segmentation

The lungs are divided into lobes and the physical boundaries between the lobes anre the lobar fissures. The lobes are further divided into segments. Fissure is a physical boundary between two segments. The left lung is divided into two lobes, an upper lobe and a lower lobe. The right lung is divided into three lobes, upper, middle and lower lobes.

B. van Ginnekenet al. have reported robust segmentation and anatomical labeling of the airway tree from thoracic CT scans [48]. The segmentation of the airway tree was used to approximate the lobe borders. The airways are automatically segmented and this method provides the anatomical labels for airway branches up to segmental level. These anatomical labels were transformed into lobar labels and the complete tree was relabeled by assigning to each airway segment the label of the lobar segment. Using these labeled airways, the lobes were approximated and lobar boundaries were extracted as those voxels. This method produced robust segmentation but takes more time. N. Blessy Tamil Ponmalaret al. proposed an Enhanced Framework for Automated Segmentation of the Pulmonary Lobes from Chest CT Scans using Level Set Approach and was tested on nine pulmonary CT scanned images [49]. The advantage of using level sets for image segmentation yield a nice representation of regions and their boundaries on the pixel grid without the need of complex data structures. The level set approach produced accurate result than watershed approach. The drawback of the system was that it didn't provide additional information about lung lobe image.T. Manikandanet al. described a Study of Different Chest CT Scan Image Segmentation for Pulmonary Lobes. Pulmonary function tests (PFT) metrics are used for performing analysis [50]. The method was evaluated by using Assessing Segmentation Accuracy (ASA), Best Match Displacement (BMD), A Pulmonary Function Tests (PFT) and Mean Squared Error (MSE).

HarshaBodheyet al. developed a fully automatic lobe segmentation approach to accurately segment the lung parenchyma of lung CT images, which help radiologist in early diagnosing of lung diseases like lung tumor [51]. The advantage of the system was that it did not require any prior information about the image.Kalyani. G. Kohaleet al. presented Segmentation of Lungs Lobes and made clear distinction between Bening and Malignant Nodules by using of Massive Training Artificial Neural Network for Surgical Preplanning [52]. This method has two phases such as adaptive fissure sweeping to find fissure region and wavelet transform to identify the fissure location and curvature within this region. Massive Training artificial neural network (MTANN) is used for enhancement of actual lesions for distinction between benign and malignant nodules that include Training of MTANN, Multiple MTANN and Integration ANN then provide the output. Their algorithm correctly identified 100% of malignant nodules as malignant, whereas 48% of benign nodules were identified correctly as benign. So the algorithm might be useful in assisting radiologists in the diagnosis of lung nodules in LDCT. The simulation results produced an accuracy of 76.7% - 94.8%. It reduces the computation time and complexity. E.M. van Rikxoortet al. presented an automatic segmentation on Lung Lobes from thoracic CT scans [53]. The algorithm was especially designed to be robust against incomplete fissures. The algorithm was evaluated on 55 volumetric chest CT scans provided by the Lobe and Lung Analysis (LOLA11) challenge. The results shown that the methods perform well on most of the time but there were several scans for which the methods failed. The main reasons for the failures in the lung segmentation were that the method was not able to include some severe abnormalities at the lung border.
S. Sridhar et al. presented Segmentation of lung lobes and nodules in CT Images [54]. They have developed a segmentation system in order to assist the surgeons to remove the portion of lung for the treatment of certain illness such as lung cancer and tumors and used modified adaptive fissure sweep and adaptive thresholding to segment lung lobes and nodule. The analysis of the algorithm was made on 20 set of images and it took around 15 to 25 minutes to analyze the clinical CT images whereas the run time of segmentation algorithm was only 3 minutes. The demerit of the algorithm was that it didn't focus on the horizontal fissures.Eva M. van Rikxoortet al. presented Automatic Segmentation of Pulmonary Lobes Robust against Incomplete Fissures which was based on a multi atlas approach [55]. It is a fully automatic lobe segmentation method that employs the fissures, the lungs, the bronchial tree and shape information to define the lobe borders in a multiatlas based setup. The method was especially designed to be robust against incomplete fissures and was evaluated on two test sets of 120 scans and shown to perform well in the presence of incomplete fissures. The fissure segmentation is the most computationally expensive part of the algorithm.JiantaoPuet al. presented pulmonary lobe segmentation in CT examinations using implicit surface fitting that was capable of handling incomplete fissures [56]. Adaptive Border Marching Algorithm lung segmentation was applied to detect pulmonary fissures by combining computational geometry approaches with statistical analysis. No anatomical information was used for the extension of the fissures. This method was evaluated on 65 CT scans by visual inspection of two radiologists using a five point score. The results shown that 50.8% of the segmentations rated as good or excellent by both observers. It was not specified how many of the 65 CT scans used for evaluation contained incomplete fissures.
Qiao Wei et al. described Segmentation of Lung Lobes in High-Resolution Isotropic CT Images [57]. Modern multislice computed tomography (CT) scanner produces isotropic CT images with a thickness of 0.6mm. These CT images offer detailed information of lung cavities, which could be used for better surgical planning of treating lung cancer. The major challenge for developing surgical planning system is the automatic segmentation of lung lobes by identifying the lobar fissures. The algorithm yielded an accuracy of 76.7% - 94.8% for localizing the fissure regions in clinical CT images with a thickness of 2.5mm – 7.0mm the algorithm has low computational requirement of about 5 minutes for segmenting and visualizing both the lungs, making the algorithm attractive for clinical use. The merit of the method was low computational requirements and the demerit of this method was the lobe segmentation algorithm produced the lowest accuracies when the fissures were in the superior of the lungs and horizontal fissure segmentation was not included.

III. CONCLUSION

Segmentation of lobes from lung is very challenging task in CT scan images when abnormalities or anomalies are found in the lung images**.**This paper discusses the problems and specific issues in the segmentation of lung lobes segmentation methods. The review of the existing literature in the field of lung segmentation, lung lobe segmentation, lung fissure detection are discussed. It also discusses elaborate details of the characterstics of various methodologies and implementations of techniques used for lung lobe segmentation.

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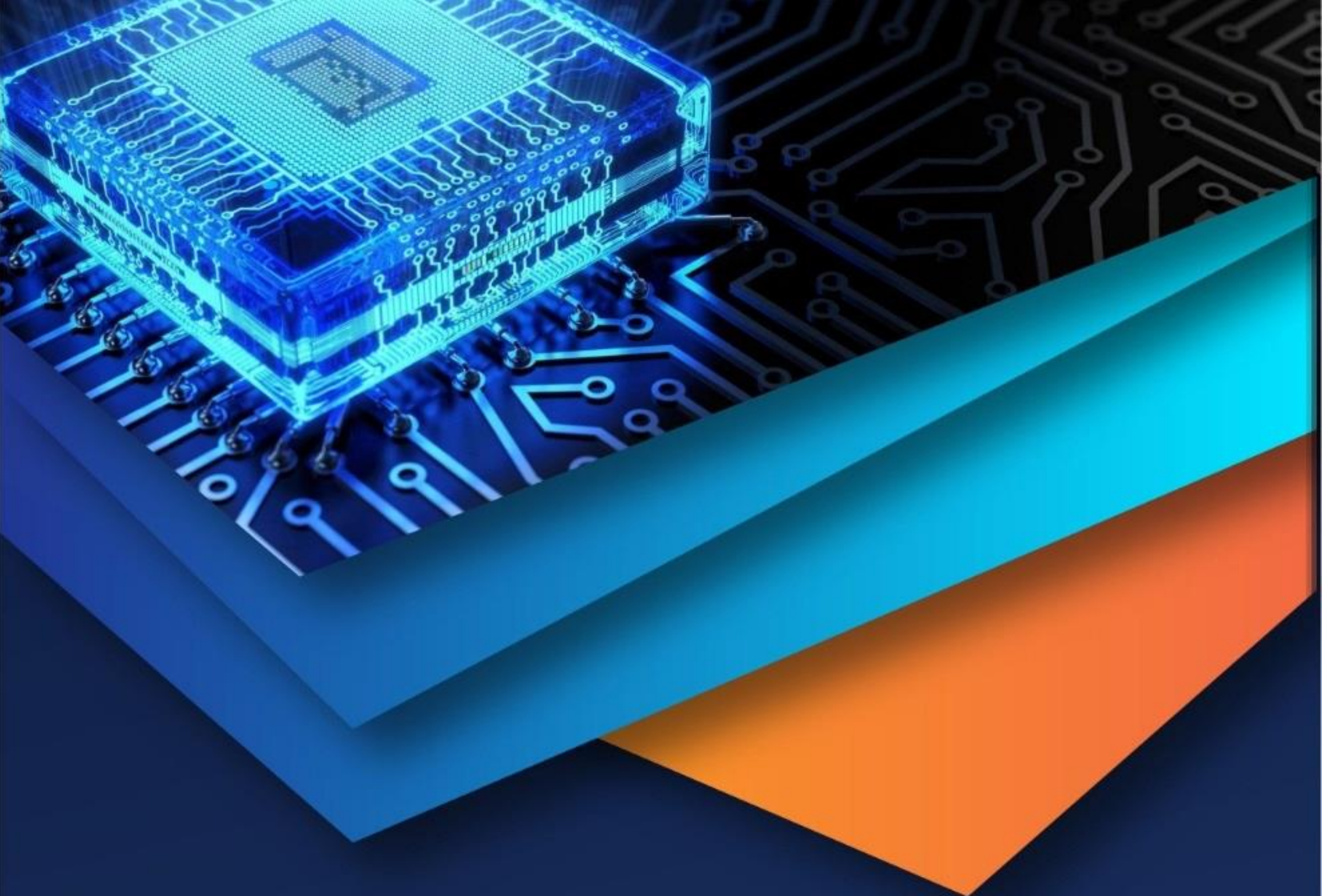

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