Study of Lung Segmentation techniques used in Pneumonia Disease Classification

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Abstract

The most common lung diseases are Asthma, Lung cancer, Pneumonia etc. Early diagnosis of lung diseases like pneumonia and cancer can be cured easily. Medical imaging like Chest X-ray (CXR) images or Computed Tomography (CT) is the most common ways to detect the disease. Computer Aided Diagnosis (CAD) refers to the mechanism developed by combining computers with medical science. For improving the efficiency of diagnosis, it is important to properly identify the lungs boundary from CXR images or from CT images. The algorithm developed to achieve it is known as segmentation and it is a most sought after step in diagnosing lung diseases. The approaches works well only if the lungs exhibit minimal or no pathologic conditions. Lung segmentation is a powerful tool in medical imaging. It can be used in quantification of lung disease progression, regression or stagnation, and change in the visual extent of disease over time is an important marker of response to therapy and a predictor of mortality.

Various approaches have been presented by researchers for segmenting lung from CXR or from CT image. The objective of the study is to investigate the latest segmentation techniques presented by researchers, their effectiveness in terms of accuracy achieved and finally find out the most effective method for segmentation.

Keywords : Pneumonia, Lung Segmentation, Quantitative Segmentation Model, Medical Imaging , Chronic Obstructive Pulmonary Disease

1. Introduction

Bronchitis, Asthma, Chronic Obstructive Pulmonary disease (COPD), Measles, Influenza, Lung Cancer, Pneumonia, COVID19 and other respiratory disorders are lung diseases that affect humans. Although clinical symptoms of these diseases differ slightly, however common signs are trouble in breathing, asphyxia like feeling, decreased ability to exercise, a stubborn un-healing cough, coughing up blood or coloured mucus, pain during expiration/inspiration (Bouazza et al. 2021). In recent times, medical imaging techniques like Magnetic Resonance Imaging (MRI), CT scan, X-Ray are some of the well-known imaging methods used in assessing lung functioning. Chest regions of patients affected with lung diseases are subject to scan under one of these scanning methods and radiologists identify regions affected by the disease using delineating annotations. These annotations help pulmonologists/thoracic surgeons to diagnose the patients, prediction of prognosis and surgical provision (Washko 2010). Segmentation of infected region of lung is the initial process of diagnosis, and is very vital too as from chest images appropriate segmentation helps in proper diagnosis and treatment of the disease before it becomes acute and difficult to treat. In medical imaging it became an important tool, used in quantifying disease development whether improving or not. This visual presentation is an indicator of attrition and also help the pulmonologist in suggesting right treatment of disease (Doi 2008).

After the outbreak of COVID-19 pneumonia, many researchers have presented various studies to improve prediction accuracy by using segmentation techniques to enhance the quality of image, feature extraction and for highlighting the ROI(Region of Interest), so the objective is to present various current contribution for improving the prediction accuracy.

The rest of the research is organised as follows:: Section 2 discusses various segmentation techniques proposed by different researchers most of the state-of-art approaches with their outcomes and limitations. Section 3 discusses the performance analysis for various lung segmentation techniques used for designing pneumonia disease classifier, their features, year of publication, merits and de-merits, and also accuracy achieved for all algorithms discussed in section 2, and Section 4 concludes the work with study befits to future researchers.

Using seven manuscripts, this paper conducts a study of lung segmentation. The survey is carried out using a variety of Lung segmentation techniques. The techniques considered in this research are listed below.

a. **Lung Segmentation based on OSTU- LSOSTU (**(Sharma, Raju, and Ranjan 2018))
b. **Lung Segmentation based on Unet Architecture- LSUA**(Tursyngaliyeva 2019)
c. **Lung Segmentation based on W-net Architecture- LSWA** (Tursyngaliyeva 2019)
d. **Lung Segmentation based on XLSor Segmentation Method- LSXM** (Tang et al. 2019)
e. **Lung Segmentation based on Snake segmentation Algorithm- LSSS** (Ebenezer, Bhargavi, and Shareefunnisa 2019)
f. **Lung Segmentation based on Quantitative Segmentation Model- LSQS** (Zhang et al. 2020)
g. **Lung Segmentation based on Variational Data Imputation –LSVD** (Selvan et al. 2020)

2. Methodology Adopted for Analyzing Segmentation Techniques

a. **Lung Segmentation based on OSTU,LSOSTU : A**n effective lung segmentation technique for medical images is presented by (Sharma et al. 2018). Researcher used OSTU thresholding to segment out the pneumonia affected part of lung and segregate it from healthy part. OSTU is a one-dimensional discrete analog of Fisher Discriminant Analysis (FDA) technique that returns a single intensity threshold and separates the image pixels in foreground and background class.

Thresholding results in binary image having infected region of image as black and rest in white as shown in figure1.

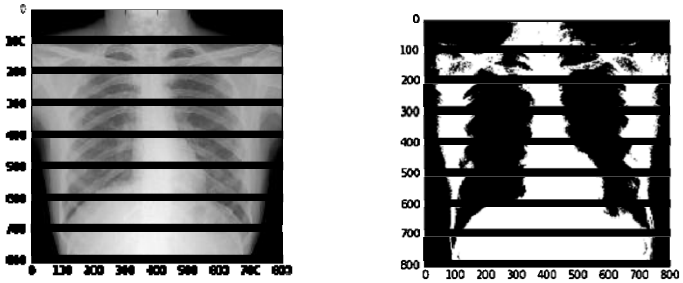

Figure 1: Image before Thresholding and after Thresholding(Sharma et al. 2018)

The objective behind segmentation is to highlight the infected region and improve information utilization. Figure 2 and Figure 3 below depict the results of segmentation when applied on pneumonia infected lung and on normal lung of same database.

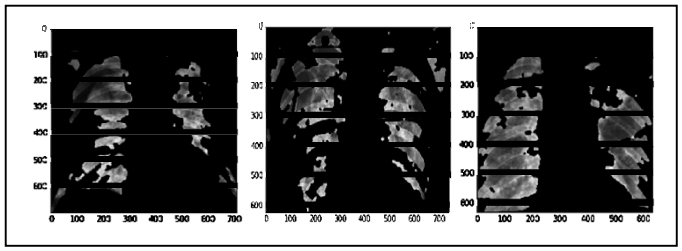

Figure 2: Thresholding of Pneumonia Infected Lung (Sharma et al. 2018)

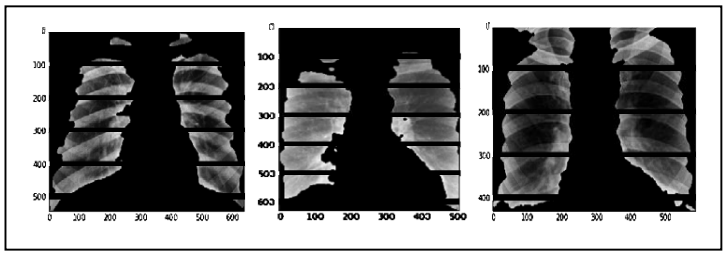

Figure 3: Thresholding of Normal Lung(Sharma et al. 2018)

Lung segmentation method's advantage is that it maximizes information utilization. The disadvantage of this method is that its accuracy depends on human experts to extract lung shape model. One more disadvantage is, that this method does not extract the lung tissues that are overlapping with the heart.

b. **Lung Segmentation based on Unet Architecture,LSUA** : For deep understanding of the region of interest , CXR images need to be processed at various level of granularities and for disease localization semantic segmentation has shown remarkable results. Unet is a CNN, specially designed to analyse biomedical images. It is built upon FCN and modified to give improved results when compared with FCN. It is symmetric in nature and uses skip connection to preserve local information along with global in up-sampling.

Figure 4 shows the result of Unet segmentation of input CXR image. The method has several advantages: it is symmetric in nature, use of skip connection is another advantage of U-net, it can handle images of variable size and many more. Disadvantages includes, It compresses the image linearly results into bottleneck from there all features can-not transmitted (Tursyngaliyeva 2019).

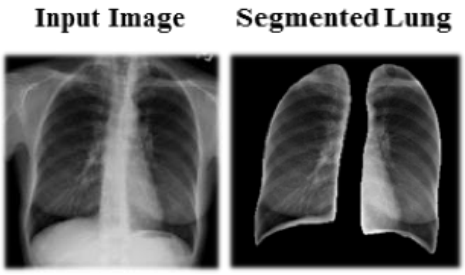

Figure 4: Unet Segmentation Results(Tursyngaliyeva 2019)

c. **Lung Segmentation based on W-net Architecture, LSWA** : For W-net designing the researcher has used 2 FCNs to serve as encoder and decoder, which are known as UEncoder and Udecoder. They both when combine forms a W shape so named as W-net. It is the expanded form of its predecessor architecture Unet with 46 cov. Layer further divided into 18 blocks. Since the technique is new in segmentation ,so very less literature is available explain w-net so its advantages and disadvantages cannot be explained properly, at the primary stages we can say it is more suitable for multi-temporal high- resolution remote sensing images and disadvantage is it is a bit complicated than UNet (Tursyngaliyeva 2019).

d. **Lung Segmentation based on XLSor Segmentation Method, LSXM :** Author here proposes a novel approach of lung segmentation . The main component or contributor of the approach were criss-cross attention based segmentation network and for augmentation, radio realistic CXR image synthesis. The proposed model has shown very good performance results on actual and synthesized data also. It is very robust and accurate approach and is able to capture rich contextual information for real and synthesized images and mat adapt to more challenging images (Tang et al. 2019).

e. **Lung Segmentation based on Snake segmentation Algorithm, LSSS :** For segmentation of lung from chest CXR image author here proposes a hybrid method using snake segmentation and heat maps. The objective was to achieve an accurate approach of segmentation and author successfully achieved his objective by presenting a hybrid model with a remarkable accuracy of 94.6. The achieved accuracy is the best accuracy attained so far by different segmentation techniques proposed. The model is robust and works well for normal and augmented images. Another observation mentioned by researcher was that the model is taking more time in execution , this limitation can be ignored while considering the performance of the approach (Ebenezer et al. 2019).

f. **Lung Segmentation based on Quantitative Segmentation Model, LSQS:** It is a multi-task Unet, a deep learning segmentation method, which is very effectively used to segment of Lung region for CT-images and provide an evidence to pulmonologist about presence and severity of pneumonia. The approach has shown excellent performance in it task and contribute to the classification. Since the segmentation technique was applied for accuracy improvement of classifier for COVID-19. The limitation faced by the system is non availability of COVID-19 dataset and accuracy of dataset available, as it may contain patient's data with other disease also. Which may affect the overall performance of the model when applied on dataset with all patient's data without any other disease (Zhang et al. 2020).

g. Lung Segmentation using Variational Data Imputation ,LSVD author here presented a segmentation approach based on CNN modified CNN and uses generative model for data imputation. The model was trained with normal and augmented images so that it becomes capable to handle images of patient with extreme abnormalities. Researcher applied a variational encoder to impute results by concatenating samples from the learnt latent space to a standard CNN-based segmentation network, which is then jointly decoded to obtain the segmentations. The quality achieved by the method is sufficient for author of the dataset achieved (Selvan et al. 2020)

3. Analysis and Discussion

3.1 Analysis of Methods ,their General Properties , Advantages-Disadvantages and Performance

Table 1: Analysis Based on General Properties

Segmentation Method	Publication	Year	Additional method used for preprocessing/augmentation	Features
OSTU thresholding (Sharma et al. 2018)	IEEE Conference, NUiCONE-2017	2017	Histogram equalization, Cropping abdomen area	Single intensity threshold
W-Net (Skourt et al. 2018)	Research Gate	2019	Nil	Nil
U-Net (Tursyngaliyeva 2019)	Research Gate	2019	Nil	Voxel -Based
XLSor (Tang et al. 2019)	Medical Imaging with deep Learning	2019	Data Augmentation	Robust and accurate
Snake segmentation Algorithm (Ebenezer et al. 2019)	• International Journal of Recent Technology and Engineering (IJRTE)	2019	Data augmentation	Best performance among all discussed methods
Quantitative segmentation model (Zhang et al. 2020)	European Journal of Medical Research	2020	Nil	Multi-task Unet with a single encoder
Lung Segmentation using Variational Data Imputation (Selvan et al. 2020)	• ICML Workshop on Learning from Missing Values	2020	Histogram equalized and Data Augmentation	Quality judged to be sufficient by author

Table 2: Analysis on the Merits and Demerits.

Lung Segmentation Method	Advantages	Disadvantages
OSTU (Sharma et al. 2018)	It maximizes information utilization	Its accuracy depends on human experts, does not extract the lung tissues that are overlapping with the heart.
W-Net (Skourt et al. 2018)	More suitable for multi-temporal high resolution remote sensing images	WNet was a bit complicating comparing with UNet.
U-Net	It is more robust and can take any size of image	With enormous network, takes longer to train with millions of parameters

(Tursyngaliyeva 2019)	as input	
XLSor (Tang et al. 2019)	It improves the accuracy of classifier even with a dataset with abnormalities	Not mentioned
Snake Segmentation Algorithm (Ebenezer et al. 2019)	More accurate as compared to other techniques	Method takes more time as compared to other techniques
Quantitative segmentation model (Zhang et al. 2020)	Not mentioned	Very large sample size is not available. .Dataset may have patient's data with other disease ,which may affect the results.
Lung Segmentation using Variational Data Imputation (Selvan et al. 2020)	It enhances the accuracy of prediction.	Not mentioned

Table 3: Performance Measurement Analysis

Lung Segmentation Method	**Percentage of Accuracy**	**No. of database used**	**Database name**
OSTU (Sharma et al. 2018)	Not given	1	Japan Society of Radiological Technology (JSRT)
W-Net (Skourt et al. 2018)	53.0	1	NIH dataset for pneumonia detection
U-Net (Tursyngaliyeva 2019)	83.7	1	NIH dataset for pneumonia detection
XLSor (Tang et al. 2019)	Not given	1	NIH Chest X-Ray Dataset
Snake segmentation Algorithm (Ebenezer et al. 2019)	94.6	1	JSRT dataset
Quantitative segmentation model (Zhang et al. 2020)	94	6	1. "TongDe Hospital of ZheJiang Province" 2. "The Second people's Hospital of Neijiang" 3. "The First Affliated Hospital of Bengbu Medical College" 4. "Wenzhou People's Hospital"

			5. "Anqing Municipal Hospital" and 6. "The First Affiliated Hospital of Xi'an Jiaotong University"
Lung Segmentation using Variational Data Imputation (Selvan et al. 2020)	88.15	1	Dataset of Shenzhen and Montgomery hospitals

3.2 Discussion

Table 1 compares the general properties of various segmentation strategies used in the development of pneumonia disease classifiers. Table 2 shows the benefits and drawbacks of the approaches discussed, while Table 3 addresses the performance metric of the models, the number of databases used, and the names of the databases contributors.

4. Conclusion

A study on lung segmentation is carried out in this paper. This review uses seven methods of recent journals to make this study and they are OSTU ,U-Net ,W-Net , XLSor , the Snake segmentation Algorithm, Quantitative segmentation model and Lung Segmentation using Variational Data Imputation.

According to the findings, the Snake segmentation Algorithm system has the highest accuracy of 94.6 percent, while the Quantitative segmentation model has a 94 percent accuracy. This study is very beneficial for researchers, they can use this analysis to advance their studies in the area of Lung Segmentation strategies for enhancing the reliability of pneumonia disease classification.

Conflict of Interest

The authors confirm that there is no conflict of interest to declare for this publication.

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