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Pulmonary Disease Identification Based on Chest X-ray and Lung Sounds Using Deep Learning Techniques

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Abstract:- In recent years there is heavy demand in healthcare systems due to COVID-19 pandemic. The COVID-19 will mainly cause the Lung infections , which affected the whole world very badly during last two years and still continues to affecting the world, this causes problem to the life of common man. To overcome such problems and also in order to identify the type of the lung disease, and diagnosing abnormalities in the lung area the Chest X-Rays (CXRs) and Lung Sounds are most commonly used medical testings. Accurate identification of diseases helps in saving the life of a human from diseases like covid-19, pneumonia, TB, lung cancer etc. The commonly used medical testings are cost effective and which are very helpful in early diagnosis of pulmonary diseases. The most difficult task for radiologists and pulmonologists is to classify the pulmonary diseases using images of X-rays and Lung sounds. To identify the lung diseases, Computer Aided Diagnosis (CAD) systems assist doctors in identifying underlying diseases. Due to less availability of skilled radiologists and lung sound recording devices will make the situation of the patients more worse. The goal is to resolve the problem using non clinical methods such as Machine and Deep Learning Techniques and these techniques may be very helpful in proper detection of severe respiratory diseases using lung sounds and lung X-ray images. Lung sounds provides better accuracy and also the proposed work provides the precautionary measures to prevent the Lung infections. Hence using usual medical testings and efficient techniques are capable to overcome the severity of lung diseases. So the work aims in identify the type of the Lung disease by employing the machine learning techniques viz. fuzzy logic and Convolutional neural network (CNN) in deep learning for improvement of the performance/accuracy.

Keywords:- *Chest X-rays; Lung sounds; Lung Disease Identification; CNN; Fuzzy Logic.*

I. INTRODUCTION

Healthcare has become one of India's largest sectors, both in terms of revenue and employment. And it considered as one of the fastest growing sectors with high contribution. It includes hospitals, medical devices [26], health insurance, telemedicine etc [27]. Lung disease such as Asthma, COPD, COVID 19, Lung Cancer, Tuberculosis etc. Causing diseases in enormous amount of the population whole world. Among pulmonary diseases asthma and COPD are causing more deaths and these diseases are misclassified from other diseases such as common cold, pneumonia and acute bronchitis. COPD ranks third among all diseases when it comes to death rate worldwide. The primary test for COPD and fibrosis is pulmonary function test which requires a physician and difficult to conduct, so infected person undergo computed tomography (CT) scanning which has ability for the direct evaluation of the lung using quantitative and visual methods [1]. During physical examination of a body, auscultation helps in listening to heart, lung or other organ sounds of a body using stethoscope. United States during a medical study states that only 80% of wheeze sounds can able to identify pulmonary recordings and accuracy remains very bad in developing countries which leads to misdiagnosing of pulmonary diseases [2]. Therefore, to improve workflow priority, assessment of severity, management and diagnosis in bigger projections computer systems must be used to interpret chest radiographs analysis as effectively as radiologists. In practice, this could play an important role in many clinical environments [3]. Due to including of the non stationary signals, it is difficult to analyse lung sounds and divide using conventional auscultation techniques. Thus to overcome such problems use of an artificial intelligent system and stethoscope provides more reliable and efficient methods using automated diagnosis [4].

Deep learning methods demonstrate as the best compared to other methods when diagnosing different kinds of pulmonary diseases. In [5] they have used convolutional neural network for the detection of covid-19 and pneumonia to prevent the diseases as well as to break the chain of virus spreading among the people. Many studies show that artificial intelligence represents an effective method for the medical image examination and pulmonary disease detection [6].

Some of the deep learning models like CNN help in finding patterns of the images and Deep belief network (DBN) model can be described as a stack of Boltzmann machines (RBM). DBN which helps in video sequences for object identification, images and capturing of the motion data. Bag of words (BOW) is a model helps to extract the features using text. Most of the surveyed papers are used CNN for the feature extraction of images. Pre trained model helps to reduce the training cost, meaning that which helps in the new model to train based on the pre trained model. In [7] they explained that Transfer learning is considered as best model with or without using pre-trained model. In [8] authors used the studies which are currently available and done a review and investigation on computerized lung sound[28] as well as its utility in classification of recorded pulmonary sound. During recording of the lung sound the primary objective is to avoid the noises such as patient noises and other environmental noises in the hospital so that it helps to avoid the poor signal transmission. The main advantage of electronic diagnosis of lung sounds is that, noise reduction while recording and amplification of signal due to human ear sensitivity to various diagnostic frequencies and amplification of signal. To provide the analysis of signals, most common used algorithm is Fourier transform and for the classification and feature extraction of different pulmonary sounds, machine learning algorithm like neural network is used.

From the literature survey, it is observed that the disease information embedded in the X-ray image is fuzzy/ vague in nature. And the lung sound will also suffer with noise due to the limitations of lung sound acquisition device. Hence the fuzzy logic (FL) and Neural network (NN) techniques can be combined for better classification of the lung disease based on X-ray image and lung sound when the information is ambiguous. The important function of the FNN system is to obtain good results and accuracy which includes fuzzy logic in the neural network structures, activation functions, or learning algorithms. Fuzzy logic and CNN image classification along with lung sound classification indicates the performance will be better as compared to other combination.

Further Literature survey is carried-out in section 2. Issues and challenges of the existing methodologies are enlisted in section 3. Section 4 provides the block diagram of proposed methodology. Final Section 5 describes about the conclusion and future scope.

II. LITERATURE SURVEY

The research in Lung disease identification is excelled due to the pandemic COVID-19. Many research works has been carried-out and several algorithms are proposed in the literature. Some of the literature review is summarized here. In [1], it is to classify and diagnose infected lungs as healthy or diseased using clinical testing methods such as Computerized Tomography (CT) scan. Diseased lungs further classified as COPD and Fibrosis. Using Machine Learning classifier, it is to achieve three main goals which are identification of lung diseases, feature extraction and selection methods from chest X-ray or CT images of lungs. Four machine learning classifiers are applied to get better accuracy such as Support Vector Machine, K Nearest Neighbour, Random Forest and Decision Tree.

In [2], authors concentrated on only two lung sounds such as wheeze and crackle and used semi supervised deep learning algorithm for classification of those sounds. They recorded 284 patient's lung sounds and provided the pulmonary disease results with 11,624 sound files. All the sound files were recorded using mobile application and stethoscope which is pricing less cost. And also showed that how semi supervised deep learning algorithms deals with larger data sets without data labelling requirement. Deep learning method is used to classify the pulmonary diseases. Convolutional neural network consisting of MobileNet V2 model which is used in [3] to get diagnosis better. Authors also did a comparison of their work with other approaches and achieved better accuracy results compared with other. In [4] pre trained CNN model is used for the classification of lung sounds. To increase the classification performance, average pooling and max pooling layers are combined in the CNN architecture. They proposed the deep learning methods such as Linear Discriminant Analysis (LDA) classifier Using Random Subspace Ensembles (RSE) for deep feature utilization. In [5], the fastest and cost effective way of diagnosing pulmonary diseases is convolutional neural networks. Authors used two different datasets for training of two convolutional models, where the binary classification was done in the first model consisting of pneumonia infected and normal chest X-ray images using one of the two datasets. Based on the knowledge gained by the first model, transfer learning was applied for the classification of three classes such as COVID-19, pneumonia and normal chest X-ray images using the second dataset.

In [6], authors proposed deep learning method for the detection of COVID-19 disease using X-ray images. They made three phases for the diagnosis; first one is to detect the presence of pneumonia and second is to differentiate between pneumonia and COVID-19, third is for diagnosing the presence of COVID-19 symptoms in the X-ray. In [7], authors explained about the trends of the current work and identified the issues in lung disease detection using medical imaging techniques. And also shows that importance of deep learning in identification of the pulmonary diseases using X-ray images. In [8], authors done a survey on identification of respiratory disorders using abnormal computerized lung sounds. They explained that most of the studies used Fourier Transform and neural network algorithms for the classification of lung sounds.

In [9], authors used dept wise separable convolutional neural networks (DS-CNN) to classify infected lung sounds efficiently. And extracted three features from the model such as short-time Fourier-transformed (STFT), Mel-frequency cepstrum coefficient (MFCC) and combined features of those two. Tuberculosis is one of the pulmonary diseases caused by the Mycobacterium Tuberculosis. While diagnosing the TB diseases, lung cancer also looks same as TB. So to avoid the misclassification of those two diseases paper [10] presents ensemble deep learning technique using chest X-ray and canny edge detected images. In paper [11] lung sound dataset

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consisting of 110 lungs infected patients. All the collected signals were examined to have frequency of 4 kHz and divided into 5 s segments and many preprocessing techniques were under taken to ensure least noisy signals and smoothing of the signal. They have used deep learning method consisting of two methods, first one to use convolutional neural networks and second one to use bidirectional long short-term memory units.

For proper and early diagnosis of lung diseases in [12] new deep learning methods by combining data augmentation, VGG and spatial transformer network (STN) along with CNN are used. In [13] authors have classified medical images as healthy, COPD and fibrosis. Used efficient methods like Adaptive Crisp Active Contour Models (ACACM) for lung structure segmentation which helps for pulmonary disease detection. Proposed a novel deep learning method for feature extraction of ACACM segmented images within the co occurrence statistics framework. In [14], authors used the small volume of data with less than thousand chest X-Ray images to address the problem of medical data scarcity for early detection of pulmonary diseases. CNN based deep learning models are implemented for better accuracy and results such as InceptionV3, ResNet-50 and VGG16 using ImageNet dataset for lung disease classification and applied transfer learning approach. In [15] authors used lung audio data for the classification of pulmonary diseases along with X-ray images. Deep learning based convolutional neural network methodologies are used for the detection of Chronic Obstructive Pulmonary Disease (COPD).

In [16], authors used pre-trained models for the classification of X-ray images as pneumonia and non-pneumonia. The models are VGG19, VGG16, ResNET50 and Inception-v3.

Authors proposed novel framework to differentiate between COVID-19 and pneumonia diseases using X-Ray images [17]. For the accurate classification of COVID-19 and pneumonia, some of the deep learning algorithms are used such as support vector machine (SVM), K-nearest neighbour (KNN), ensemble classifier and artificial neural network (ANN). In [18], convolutional neural network is used to classify pulmonary sounds as crackle, wheeze and rhonchi. Authors explained that sometimes trainees may misdiagnose the respiratory sounds. So CNN helps to resolve such problems. In [19], authors explained that clinical method of using X-ray image is considered as common process for classifying lung diseases. Deep learning presents best way for diagnosis of the diseases. Authors created a system for detecting lung diseases so that it helps for the rural areas were radiologists are not easily available. In [20], to classify pulmonary diseases using text and audio, authors compared algorithms like k-nearest neighbor (K-NN), support vector machines (SVM) and Gaussian Bayes (GB).

The only common medical testing for lung disease is chest X-ray which will be tedious to classify various pulmonary diseases and also availability of X-ray dataset is also one of the major issues. To overcome these limitations authors used a novel Text-Image embedding network (TieNet) for obtaining images and text representations in [21]. In [22], authors explained that deep learning offers a robust model to classify pulmonary diseases and Focal loss model is used to resolve the problem of data imbalance.

In [23] authors explained about detection of bronchiolitis and pneumonia in infants using Lung Ultrasound Technology (LUS). And they have used deep learning models such as VGG19, Xception, Inception-v3 and Inception-ResNet-v2 for the diagnosis of pulmonary diseases. In [24], authors done research to overcome the problem of medical data scarcity using small volume of chest X-ray dataset consisting of less than thousand images by identifying pulmonary diseases. Deep learning models are utilized to treat various pulmonary diseases such as cancer, pneumonia, tuberculosis etc.

In [25] various deep convolutional neural networks combining with Artificial Noise Addition were conducted for the analysis of different diseases and for visual inspection, they have applied Fourier Transform.

Many algorithms reported in the literature are good in terms of accuracy, speed, but have several issues and challenges. They are identified and depicted in the ensuing section.

III. ISSUES AND CHALLENGES

Several issues and challenges are identified in the existing methodologies/techniques reported in the literature. They are enlisted in the following.

A. Issues

- Data Imbalance (ii) Limited available datasets (iii) Handling of huge image size (iv) High correlation of errors when using ensemble techniques and (v) Capturing of the lung sound [2,7].
- **Data Imbalance**: From the literature survey it is observed that collecting equal number of samples in every class when doing the classification of images will not leads to data imbalance problem. The outcome of the data results in better accuracy if the data is not imbalanced.
- **Limited available datasets:** It requires more number of images for training to obtain better accurate classifier. However due to the non availability of enough dataset it gets difficult to produce better results.
- **Handling of huge image size:** Original image size of the chest X-ray is usually larger which is very cost effective and also takes much time when training with toughest model. So to overcome such problem researchers have reduced the size of the image during training to lower computational cost.
- **High correlation of errors when using ensemble techniques:** Different types of errors are needed to get better performance. It is described that the very low correlation should be contained when using base classifiers. This in turn ensures that the errors of those classifiers also will be varied.

- **Capturing of the lung sound:** It is to ensure that device captured lung sound should not contain any other noise except the patient respiratory sound. Generally hospitals have various types of noises such as phones, noisy medical equipments and people talking, ambulance etc.

B. Challenges

The different challenges enlisted from the literature review are as follows.

- Collection of respiratory sounds is a challenging task.
- Chest X-ray image may not contain predicted pulmonary diseases.
- Diagnosis of the lung diseases is a challenging task.
- Improper collection of X-ray images from different lung disease.

Proper collection of X-ray image and diagnosis of disease is a major challenging task. X-ray images may fill with full of smoke when the person is highly addicted to smoking which needs to be diagnosed properly for the early detection of lung disease. From the above listed challenges respiratory sound collection is also one among them, where different hurdles like fan sound and other noises will be recorded while recording the respiratory sound which needs to be taken care while recording therefore, problem definition and proposed solution will be explained in the next section.

The main objectives are put forth in the proposed work are used to diagnose the pulmonary diseases in the lungs using chest X-ray images and lung sounds. Which helps in the early prediction of respiratory diseases.The second objective is to achieve the prediction of pulmonary diseases using chest X-ray is a challenging task. Lung sounds are divided into normal and abnormal lung sounds. Abnormal lung sounds indicates that infection in lungs, an inflammation, obstruction or fluid in the area of lungs. Various types of lung sounds are wheezes, stridor, rhonchi and crackles. Third is to provide the precautionary measures to avoid the severity of the lung diseases. It is very difficult for the diagnosis and early treatment when it comes to respiratory diseases so with the help of chest X-rays and lung sounds along with precautionary measures can able to avoid the severity of the respiratory diseases.Fourth objective is to achieve good accuracy by using robust and efficient algorithms.

IV. METHODOLOGY

Chest X-ray is the most commonly used medical imaging technique and it produces images of lungs, airways, heart, blood vessels and the bones of the chest and spine. Millions of people suffer from lung diseases every year. Along with X-ray images, pulmonary sounds are important in detection of diseases such as Tuberculosis, COVID-19, pneumonia, lung cancer etc are the most common diseases affecting the world every year. An useful system for lung disease identification in patients using X-ray images and lung sounds by employing the machine learning techniques viz. fuzzy logic and deep learning based convolutional neural network (CNN) for improvement of the performance/accuracy is proposed in Figure 1.

A. *Proposed Solution*

The first step is to collect the dataset which will be consisting of X-ray images and lung sounds. For the early prediction and accurate diagnosis of the diseases, proposed system will be developed using the medical examination methods such as chest X-ray and recorded lung sounds to assist medical doctors for the proper diagnosis of pulmonary diseases. The system consisting of four steps such as preprocessing of the dataset , identification of the diseases and segmentation of region of interest (ROI) ,extracting features and images of the segmented ROI, feature selection using bio-inspired evolutionary algorithms, classification of pulmonary diseases.

B. Architecture and Block Diagram

An architecture and block diagram is a diagram of a system in which the functions are represented as blocks that shows the relationship of the blocks and abstracts the overall system of the software system. Composites are extensively useful in engineering for hardware development, electrical and software design, and process flow diagramming, as can be seen in Figure.1 [1,18].

1) Preprocessing

It is the first step in building of a software system. In the initial stages, acquiring of the dataset is the crucial step where data gathered from multiple sources which are then combined in a proper format to form a dataset. Importing the python libraries and the dataset, splitting the dataset, resizing of the image, removal of the unwanted noise in the lung sound are helps to enhance the performance and also results in better accuracy of a system.

2) Feature extraction

The method includes the process of extracting higher level information of an image such as color, shape, and texture etc. This step will be performed on the segmented lung region and helps to distinguish from one region of interest from another, which calculates the features mathematically using some information about the ROI. Some of the features which are used to extract lung sound features are melspectrogram (Mel-Spectrogram), Mel-frequency Cepstral Coefficients (mfcc) etc.[9],[15].

3) Classification of Lung Sound

Breath sounds come from the lungs. These sounds can be heard when breathing or with the help of stethoscope. Breath sounds from lungs are classified as normal lung sound and abnormal lung sound. Normal breath sound is similar to the sound of air. However classification of abnormal lung sounds is very important task and crackles, wheezes and rhonchi are most commonly found among all the other abnormal sounds.

C. The Processing Steps

The proposed methodology will do the preprocessing, segmentation, feature extraction using Chest X-ray images and lung sounds by employing the machine learning techniques viz. fuzzy logic and neural networks and deep learning techniques viz. Convolutional neural network (CNN) for improvement of the performance/accuracy.

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1) Chest X-ray

Chest X-ray is the most used medical testing for the diagnosis of lung issues. It produces the internal structure of the lungs such as heart, spine etc [24]. Due to pandemic most commonly found diseases are COVID-19 and pneumonia and also tuberculosis, lung cancer etc. Disease representations are shown in figure 2. Representations shows that how diseased X-rays are differ from normal X-ray.

2) Lung Sound

Diagnosis of the affected lung helps in detection of various respiratory disorders. And it is important to differentiate between normal and abnormal lung sound. Normal lung sound is similar to the air while abnormal lung sounds includes Crackles, wheezes and rhonchi. Detection of those abnormal lungs sounds leads to the pulmonary diseases. Crackles are discontinuous sounds and wheezes are continuous sounds, rhonchi sound is similar to snores which is cleared by coughing. The signals associated with different Lung sounds are shown in Figure 3.

3) Convolutional Neural Network (CNN)

CNN is a neural network that has one or more convolutional layers as seen figure 4 and is used mainly for image processing, classification, segmentation etc. Each convolutional layer contains series of filters known as convolutional kernels. The filter is a matrix of integers that are used on a subset of the input pixel values, the same size as the kernel. CNN architecture perform exceptionally well across many different image processing tasks such as VGG models, the ResNet models and the google inception models. These models contain a millions of trainable parameters.

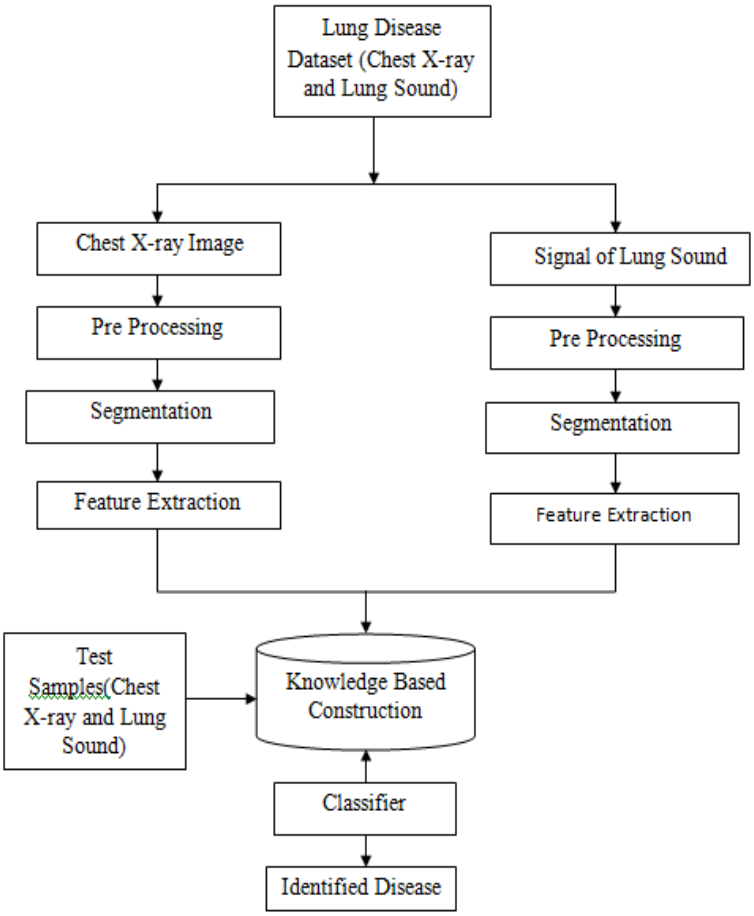
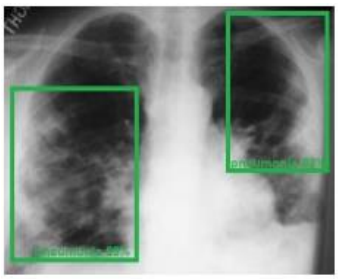


Fig 1:- Architecture and block diagram.

(a) Tuberculosis

(b) Lung Cancer



(c) Pneumonia

(d) Covid

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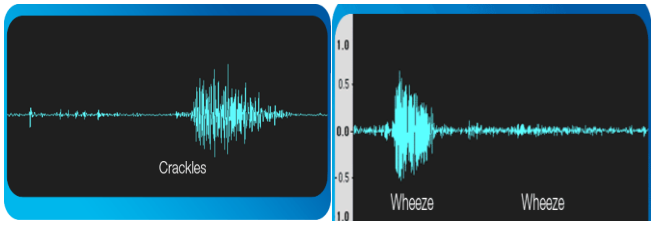
(e) Healthy

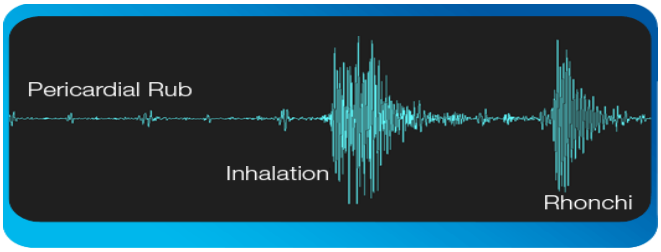
Fig 2:- Chest X-ray images (a) Tuberculosis (b) Lung Cancer (c) Pneumonia (d) Covid (e) Healthy

4) Fuzzy Logic

The information available in X-ray images and lung sounds are vague in nature and may prone to misclassification of the disease. The fuzzy logic provides very valuable flexibility for reasoning for accurate decision making. Employing the fuzzy logic the inaccuracies and uncertainties of the lung X-ray and lung sound are considered.



(a) (b)



(c)

Fig 3:- Lung Sound Signals (a) Crackles. (b) Wheeze (c) Rhonchi.

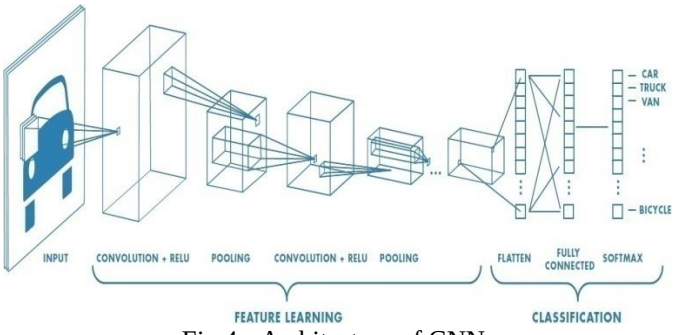


Fig 4:- Architecture of CNN

The convolution layer transforms the input image in order to extract features from it. This also contains a set of filters, parameters which are to be learned throughout the training. In the above shown architecture provides steps which are applied to choose parameters, apply filters with strides, padding if requires. Three types of layers such as convolutional layers, pooling layers, and fully-connected layers. Pooling layer is to decrease the size of the convolved feature map to reduce the computation costs. Fully connected layer consists of weights and biases along with the neurons and is used to connect the neurons between two different layers. These layers are placed before the output layer and form the last few layers of a CNN Architecture.

V. CONCLUSION

The pulmonary disease identification using Chest X-ray and lung sound is performed in the proposed work. Efficient algorithms have the ability to identify the severity of lung diseases. The proposed work identifies the Lung diseases by employing the machine learning techniques viz. fuzzy logic and deep learning techniques based Convolutional neural network (CNN) for improvement of the performance/accuracy. CNN contains multiple hidden layers which helps in accurate diagnosis of the lung disease and also provides better accuracy. These hidden layers are very effective in performing convolution and sub sampling for the purpose of extracting low to high levels of features of the input data. The combination of CNN and fuzzy logic is better compared to other combination. The proposed work identifies the pulmonary diseases and in future aims to prevent the further lung infections to the patient with the combination of machine and deep learning algorithms.

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