Pneumonia Severity Diagnosis: A Deep Learning Perspective

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Abstract*— Pneumonia has been responsible for a large number of under-five children deaths worldwide. The most common traditional method of diagnosing pneumonia is through X-ray Images, however, Pneumonia shares common features with other respiratory diseases, such as lung cancer and bronchitis, which make it difficult to distinguish pneumonia from them. Also, there is significant flexibility in the way chest X-ray (CXR) images are acquired and processed, which can greatly impact the quality and consistency of the images. This can cause difficulty in developing powerful algorithms that can accurately identify pneumonia in all types of images. Deep Learning (DL) models with Convolutional Neural Networks (CNN) as the most commonly employed model have significantly contributed to the diagnosis and classification of chest X-ray images into healthy and pneumonia classes. However, there is a need to go beyond binary classification by knowing the severity levels of those diagnosed with pneumonia for faster treatment. This paper proposes a pneumonia severity diagnosis model using a deep learning approach that will assist medical practitioners prioritise pneumonia patients' treatment.

Indexed Terms*— CNN, CXR, DL, Pneumonia, Severity.

I. INTRODUCTION

Pneumonia is a form of acute respiratory infection that causes the tiny air sacs of the lungs to be filled with pus or fluid instead of air. Fig. 1 shows the lungs of a Normal and Pneumonia patient. Cough, fever, chills, muscle aches, and difficulty breathing are some of the symptoms of pneumonia, which can lead to severe complications if left untreated. There is a unanimous agreement worldwide that pneumonia was the single largest infectious cause of death in children five years and below before the outbreak of the COVID-19 pandemic, especially in developing countries where poor sanitation and a lower doctor-to-patient ratio is the order of the day. pneumonia is often caused by bacteria, viruses, and fungi, but the most common cause of the deadly respiratory disease is *Streptococcus pneumoniae bacterium* as it affects the lungs, reduces oxygen intake, and makes breathing difficult. Pneumonia infection ranges from mild to severe illness in people of all ages but children below 5 years and the elderly (65 years and above) are the most vulnerable people. [1] – [3].

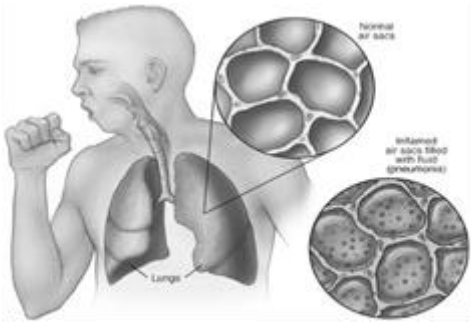

Fig.1 Normal and Pneumonia lung

According to the Global Burden of Disease (GBD), Pneumonia is a leading infectious cause of death and disability in the world causing an estimated 2.5 million deaths across all ages [4]. Pneumonia killed more than 808,000 children under the age of 5 in 2017, accounting for 15% of all deaths of children under 5 years. People at risk for pneumonia also include adults over the age of 65 and people with preexisting health problems. In Nigeria, pneumonia was the biggest killer of children under-five in 2017, causing 19 percent of under-five deaths in 2018, killing 162,000 children and recording 443 deaths per day making Nigeria the country with the highest number of pneumonia-related deaths in the world, with a projection that over 2 million Nigerian children could die by 2030 if not dealt with [5] – [6].

II. REVIEW OF RELATED LITERATURE

A. Pneumonia

Traditional methods of pneumonia diagnosis include physical examination such as listening to the lung with a stethoscope, clinical history assessment (such as surgery, a cold, or travel exposures), laboratory tests such as sputum test, blood test, pulse oximetry (checking oxygen levels in the patient's blood), and radiological imaging. However, the accuracy and efficiency of these methods can be limited by human error and subjectivity. For radiological imaging, chest X-ray has been usually adopted for diagnosis because of its availability, cost efficiency, and low risk level. However, X-ray images usually require the service of expert radiologists whose interpretations are sometimes subjective for some reasons such as confusion with other respiratory diseases and the appearance of the disease which can be unclear in chest X-ray. Adopting advanced technologies such as Machine Learning (ML) and Deep Learning (DL) can assist in overcoming these challenges and thereby enabling early pneumonia diagnosis [7] – [8]. Figure 2 (a) and (b) show samples of a Normal Chest X-ray and a Pneumonia infected chest X-ray.

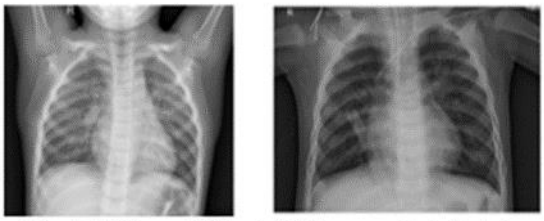

Fig. 2 (a) Normal Chest X-ray image (b) Pneumonia infected chest X-ray image

B. Deep Learning

In recent years, there has been an increased interest in the use of machine learning and deep learning techniques to assist radiologists in the interpretation of chest X-ray images for pneumonia diagnosis. Deep learning models have demonstrated high effectiveness in detecting and diagnosing various diseases and conditions in medical imaging. These models can automatically learn and extract complex features from medical images for disease identification and classification. CNNs have proven to be effective in detecting pneumonia from chest X-ray images.

In an attempt to improve healthcare quality with reduced cost and faster response, Almaslukh in [9] proposed a lightweight Deep Learning-based pneumonia detection model using pre-trained DenseNet-121-based feature extraction. The model employed a random fine-tuning technique to allow for faster processes and improve the efficiency and accuracy of the model. The model detects pneumonia with an accuracy of 98.90% and low execution time.

[10] proposed a multi-layer Convolutional Neural Network (CNN) model for the detection and classification of pediatric pneumonia to find solutions to the interpretation variability and subjectivity problem when reading a Chest-X-ray (CXR) image. Using data from the National Institute of Health,

Reza in [11] proposed a classification method that can be used to distinguish posteroanterior (PA) and anteroposterior (AP) view positions of chest X-ray images before any analysis.

CNN and three different VGG16 models were employed by [12] to improve diagnostic accuracy of pulmonary diseases using chest X-ray images, the model achieved an accuracy of 98%.

VGG16 and Xception pre-trained transfer learning models were used to classify X-ray images into pneumonia and normal in [13], the model achieved an accuracy of 87%.

Siddiqi [14] presented an 18-layer deep sequential convolutional neural network model using a publicly available pediatric chest X-ray images dataset achieving a classification accuracy of 94.39%.

[15] employed Xception, Visual Geometry Group 16, and Visual Geometry Group 19 with fine-tuning to classify chest X-ray images into COVID-19-induced pneumonia, regular pneumonia, and normal conditions.

Salehi [16] employed VGG19, Xception, ResNet50, and DenseNet121 models in classifying pediatric chest X-ray radiographs into pneumonia and normal cases, data augmentation techniques were employed to improve the classification accuracy and to prevent

overfitting during the training, their models achieved an accuracy of above 83.0%.

A convolutional neural network model trained from scratch to detect the presence of pneumonia from a collection of chest X-ray image samples and classify it into pneumonia or healthy was proposed in [17].

Li et al.[18], carried out an exploratory diagnostic systematic review and meta-analysis of a deep learning (DL) computer-aided design for pneumonia detection using chest X-ray images.

Barbosa and Canuto [19] proposed a machine-learning model using a Histogram of Oriented Gradient in extracting features from chest X-ray images to classify and detect the presence of pneumonia from scratch, if pneumonia is detected, the model is further classified into either viral or bacterial pneumonia.

[20] proposed a stacked ensemble learning of deep learning-based features extraction for pediatric pneumonia classification into Normal and Pneumonia.

Boyadzhiev, et al. 2022 employed deep learning is used by to automatically determine if a patient has pneumonia based on computer tomography (CT) scans or X-ray images.

All the reviewed literature attempts to classify X-ray images into either Pneumonia or not pneumonia, without taking cognizant of the disease severity level. This study attempts to design a deep-learning model that will be able to classify pneumonia chest X-ray images into their respective severity classes.

III. PNEUMONIA SEVERITY DIAGNOSIS MODEL

The pneumonia severity model architecture is shown in Fig. 3, and the methodology for achieving the proposed deep learning model is described:

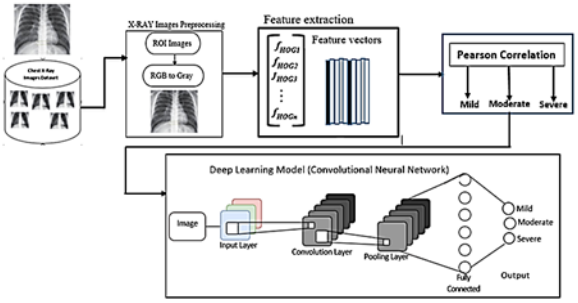

Fig. 3 Deep Learning Mode for Pneumonia Severity Diagnosis

a. Dataset. Publicly available labeled Pneumonia dataset from Kaggle was employed. The dataset contains 5856 chest X-ray images of JPEG with 3,883 classified as pneumonia (2,538 bacterial and 1,345 viral) and 1,349 normal.The bacterial and viral images were merged and classify as pneumonia
b. Image preprocessing: A fixed-sized window of an input image is pre-processed by resizing to 64 × 128 pixels to match with the original HOG feature extraction algorithm, and converted to grayscale if it is a color image to improve its robustness against lighting variations and noise.
c. Gradient Computation: For edges and texture boundaries identification, both the magnitude and orientation of the gradient in both the horizontal and vertical directions are calculated for every single pixel in the cell.
d. Orientation Binning and Calculating the Gradients by dividing the image into 8×8 cells, and calculating the gradients for all the 8×8 cells.
e. Normalization is applied within each block to enhance the algorithm's robustness to changes in lighting and contrast.
f. Obtaining HOG feature vector by concatenating all the normalized blocks into a single vector to get the final vectors
g. Computation of the strength of the relationship between randomly picked Normal X-ray images and all Pneumonia X-ray images using Pearson Correlation. Based on the strength, the Pneumonia X-ray images are reclassified into three severity classes {Mild, Moderate, and Severe).
h. Training and testing of the reclassified multiclass with convolutional neural networks.
i. Evaluation of the designed proposed deep learning Pneumonia severity model using standard metrics.

CONCLUSION

A pneumonia severity diagnosis model using a deep learning approach that will assist medical practitioners in adequately and timely prioritizing pneumonia patients' treatment was designed by extracting features from X-ray images using a histogram of oriented gradient, computing the correlation strength between the Normal X-ray images and Pneumonia X-ray Images, which reclassified the pneumonia images into different severity classes, the resulting output is trained using Convolutional Neural Network. The system will be implemented in future research work.

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