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Detection of Pneumonia using Fuzzy Expert System

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Abstract— **Respiratory diseases, especially pneumonia, are a global health problem that still requires accurate and effective diagnosis. The system uses an expert fuzzy system to integrate key measurements such as body temperature, sputum, sputum color, chest pain, dyspnea(shortness of breath), respiratory rate, heart rate, systolic blood pressure and white blood count. These parameters form the basis of a good decision-making model and reflect the complexity of pneumonia diagnosis. Moreover, to improve diagnostic accuracy, our system includes a chest X-ray image processed by convolutional neural networks (CNN), including models such as VGG16 and ResNet50V2. This bimodal approach is designed to use both quantitative clinical data and qualitative data, allowing efficient and accurate assessment of pneumonia pressence. Fuzzy expert systems use fuzzy logic to model uncertainty in diagnosis and provide a flexible model for fuzzy thinking. The integration of image processing technology not only makes it easier to extract X-ray images from X-ray, but also creates hybrid decisions. This combination gives the percentage chance of getting pneumonia to help doctors make decisions. The proposed model was validated using different datasets. Performance measurements including sensitivity, specificity, and accuracy demonstrate the effectiveness of our method compared to traditional methods. The integration of clinical and image-based features makes the system reliable and useful in early and accurate diagnosis of pneumonia diagnosis. This study bridges the gap between traditional clinical examination and new technology, laying the foundation for a more nuanced and sophisticated way to diagnose pneumonia diagnosis.**

Keywords—Pneumonia, fuzzy expert system, VGG16, ResNet50V2, X-Ray image.

I. Introduction

Respiratory infections, particularly pneumonia, continue to be a significant global health challenge, necessitating accurate and timely diagnostic methodologies to improve patient outcomes. In response to this critical need, our research introduces a pioneering approach that amalgamates traditional clinical parameters with advanced image processing techniques for enhanced pneumonia detection. The proposed system harnesses the power of a Fuzzy Expert System, integrating crucial clinical indicators such as body temperature, sputum characteristics, chest pain, dyspnea, respiratory rate, heart rate, systolic blood pressure, and white blood cell count. These parameters collectively form the foundation for a robust decision-making model, reflecting the intricate and multifaceted nature of pneumonia diagnosis.

Recognizing the evolving landscape of medical diagnostics, our approach extends beyond conventional methods by incorporating chest X-ray images processed through cutting-edge Convolutional Neural Networks (CNNs), including well-established architectures such as VGG16 and ResNet50V2. This dual-modality strategy aims to leverage both quantitative clinical data and qualitative imaging information, striving for a comprehensive and precise assessment of pneumonia presence.

The Fuzzy Expert System, underpinning our methodology, employs fuzzy logic to adeptly model the inherent uncertainties and vagueness associated with clinical diagnostics. This introduces a flexible and interpretable framework for reasoning under ambiguity, contributing to a more nuanced and adaptable diagnostic system. The integration of image processing techniques not only facilitates automated feature extraction from X-ray images but also enables the creation of a hybrid decision-making system that yields a percentage-based probability of pneumonia presence, empowering clinicians with a quantitative diagnostic tool.

To validate the efficacy of our proposed model, a diverse dataset encompassing a spectrum of pneumonia cases is employed. Performance metrics, including sensitivity, specificity, and accuracy, underscore the superiority of our approach compared to traditional diagnostic methods. By synergizing clinical parameters with image-based features, our system demonstrates heightened reliability, emerging as a valuable and precise decision support tool for early and accurate pneumonia diagnosis.

In summary, this research aims to address the complexities of pneumonia detection by introducing a holistic and intelligent framework that unifies traditional clinical assessments with state-of-the-art technology. The fusion of fuzzy logic with advanced image processing techniques not only enhances diagnostic accuracy but also establishes a foundation for future advancements in computer-aided medical diagnosis. This study serves as a pioneering exploration into the integration of clinical and imaging data, bridging the gap between conventional diagnostic methods and the evolving landscape of medical technology. prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

II. Related Work

Previous research papers of pneumonia detection encompasses various methodologies to detect the pneumonia. Scan and X-ray images of human organs are valuable medical information that can help diagnose pneumonia by using image processing and different machine learning algorithms.

Md. Mehedi Hasan, Mir Md. Jahangir Kabir, Md. Rakibul Haque, Mohiuddin Ahmed, ICECTE, 2019:
"A Combined Approach Using Image Processing and Deep Learning to Detect Pneumonia from Chest X-Ray Image". This paper presents a method for early detection of pneumonia from chest X-ray images using image processing and deep learning. Utilizes VGG-16 and VGG-19 convolutional neural networks, achieving higher accuracy than the InceptionV3 model. Includes steps like contrast limited adaptive histogram equalization (CLAHE) and vertical cropping to enhance image quality for better disease identification.

Harsh Sharma, Jai Sethia Jain, Priti Bansal, Sumit Gupta,2020: "Feature Extraction and Classification of Chest X-Ray Images Using CNN to Detect Pneumonia". This paper describes system provides an automated approach for detecting pneumonia, reducing the reliance on manual examination by experts and also it leverages deep CNN to achieve accuracy in pneumonia detection compared to traditional methods. Demerits of this paper is the system performance is highly relies on the dataset used for training. If the dataset is not representative of diverse cases, the model may struggle to generalize well to unseen data, leading to potential issues and also that the system's performance is sensitive to the chosen hyperparameters like batch size and dropout probabilities. These inappropriate hyperparameters lead to overfitting, underfitting or suboptimal model performance.

Vaishnavi Rohatgi, Rohit Raj, Akshita Sharma, Sumant Bansal, 2022: "Pneumonia Detection using Customized CNN". The paper presents on the deep learning approach to diagnose pneumonia from chest x-ray images using a custom built convolutional neural network model. This paper describes the CNN model's layers activation functions, loss function and optimization algorithm. The model was trained and tested on dataset of 5318 training images and 764 testing images, each labelled as normal or pneumonia.

Krishna More, Prathamesh Jawale, Shubham Bhattad, Jaychand Upadhyay, 2021:
"Pneumonia Detection using Deep Learning".
This paper motivated from the problem that many regions in the world lack access to radiologists, so there is a need for a automated system that can detect Pneumonia with accuracy and low computational cost. In this paper authors have used four different pre-trained convolutional neural network models VGG16, VGG19, Xception and InceptionResNetV2 to extract features from chest x-ray images and classify them as normal or Pneumonia. The performance of the four models on the test set using accuracy, precision, recall, F1score and ROC curve as evaluation matrix.

Yuvraj Sinha Chowdhury, Rupshali Dasgupta, Sarita Nanda,2021: "Analysis of Various Optimizer on CNN model in the Application of Pneumonia Detection".
This paper describes the performance of three different optimizers like RMSProp, Adam, and SGD on CNN models with different number of hidden layers for pneumonia detection from chest X- ray images. They evaluated the models based on training, validation, and testing accuracy and loss. The authors concluded that RMSProp and SGD are the most suitable and reliable optimizers for pneumonia detection from chest X-ray images.

III. Proposed System

The above reviewed papers describe about pneumonia detection using CNN and Image processing. Various optimizers like RMSprop, Adam and SGD are used on a different number of layers to find which combination is the most efficient for the purpose of Pneumonia detection using CNN. The model here is trained only on a particular dataset, hence if any additional chest x-ray image is provided as input then these models fail to detect pneumonia appropriately. In order to overcome all the problems faced in the above papers, the fuzzy expert system is used. In the proposed system along with chest x-ray images various other parameters and symptoms like respiratory rate, heart rate, systolic blood pressure, sputum, chest pain, dyspnea, cough, body temperature and sputum colour are considered. Fuzzy expert systems enable the integration of these diverse criteria in a coherent manner and hence increases the accuracy of the model. The model helps healthcare professionals and students to analyse and detect pneumonia.

IV. Methodology

Image processing technique is performed on chest X-ray images. In image processing the model will be trained on different datasets of chest X-ray images. Based on the trained model the output will be obtained.

Different parameters like body temperature, cough, sputum, chest pain, heart rate, respiratory rate, dyspnea, age, blood pressure will be provided as input to the fuzzy expert system. Along with these parameters the results of image processing will also be provided as input through user interface.

The logic of the fuzzy expert system is implemented using Jupyter notebook and the user interface is designed using Pycharm software. By considering all these parameters fuzzy logic provides result even in ambigious condition.

The major advantage of fuzzy logic over Boolean logic is that it provides results for various probabilities of output. Hence our project is implemented using fuzzy logic to detect pneumonia even in uncertain conditions.

The figure describes the methodology of fuzzy expert system for pneumonia detection.

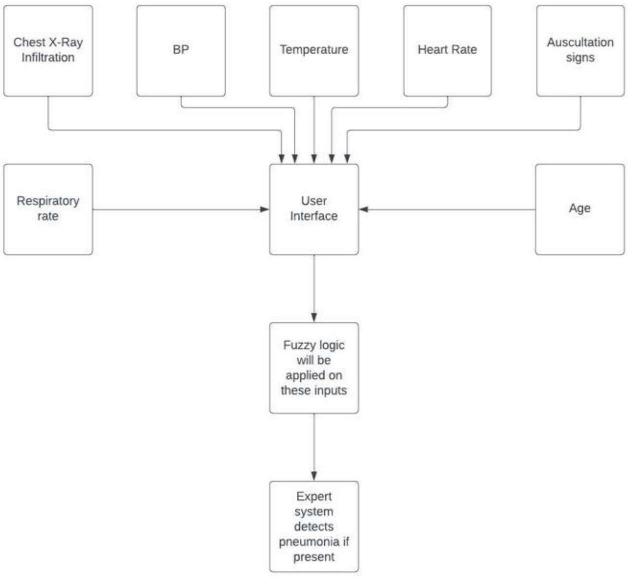


Fig 1. Methodology

V. Brief Description

A. Fuzzy logic

A fuzzy expert system is a type of artificial intelligence system that incorporates fuzzy logic to handle uncertainty and imprecision in decision-making processes. Fuzzy logic, developed by Lotfi Zadeh, allows for the representation of vague or ambiguous information by using degrees of truth. Unlike traditional binary logic (true/false), fuzzy logic allows statements to have varying degrees of truth between 0 and 1.

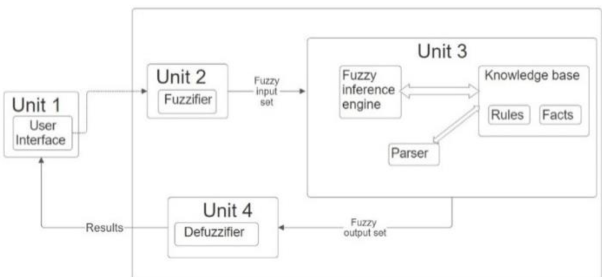


Fig. 2. Fuzzy Expert System Architecture

Fuzzy expert systems use linguistic variables to represent qualitative and subjective information. These variables, such as "high," "medium," and "low," allow for a more humanlike representation of knowledge. Fuzzy sets define the membership functions of linguistic variables. These functions determine the degree to which an element belongs to a particular set. For example, in a set of "high temperature," the membership function might indicate the degree of warmth associated with that term. The rule base contains a set of IF-THEN rules that encode expert knowledge. These rules describe the relationship between input variables and the desired output. Each rule includes fuzzy linguistic terms and their associated conclusions. The inference mechanism processes the rules based on the input data, determining the degree to which each rule contributes to the final output. Fuzzy logic allows for the combination of multiple rules, accommodating the overlap and ambiguity present in real-world situations. The aggregated rule outputs are combined to produce a fuzzy output. Defuzzification is then applied to convert this fuzzy output into a crisp value or decision that can be easily understood and utilized. Fuzzy expert systems find applications in various fields, including control systems, decision support, pattern recognition, and diagnostics. They are particularly useful in situations where information is incomplete or uncertain. Fuzzy expert systems aim to emulate human-like reasoning processes, especially in situations where decisions are influenced by intuition, experience, and imprecise information. This makes them suitable for capturing and modelling expert knowledge in specific domains. Some fuzzy expert systems are designed to adapt and learn from new data or experiences. This adaptability allows them to improve over time, making them valuable in dynamic environments where conditions may change. Fuzzy logic provides a transparent and interpretable framework for decision-making. This is particularly important in applications where human understanding of the decision process is crucial.

A fuzzy expert system integrates fuzzy logic to handle uncertainty and imprecision in decision-making, making it well-suited for situations where traditional binary logic may fall short. Its linguistic variables, fuzzy sets, and rule-based inference mechanism allow for the representation of knowledge in a way that mirrors human reasoning in real-world scenarios.

B. Image processing

Convolutional Neural Network (CNN):

Convolutional neural networks are a class of deep learning models specifically designed for image processing tasks. A CNN consists of layers that perform a convolution process that enables automatic and adaptive learning of the spatial hierarchy of features from the input image. The CNN learns related patterns, such as the presence of structural lung abnormalities on chest X-rays, to detect pneumonia.

VGG-16:

VGG-16 is a unique architecture in the CNN family. It has a large filter size (3x3) and a deep structure of 16 layers including the largest printed layer. VGG-16 has proven its effectiveness in image classification problems, and its simplicity and integrated architecture make it easy to understand and use. .

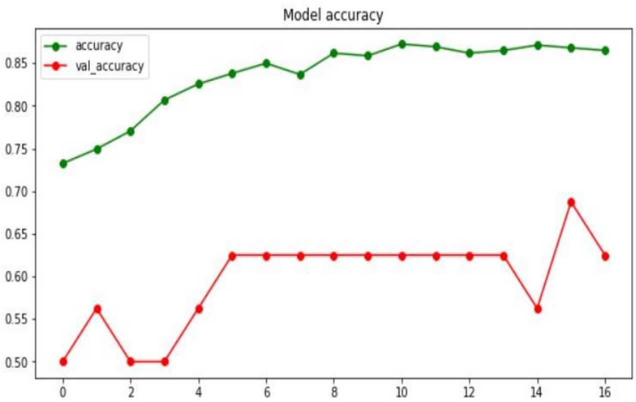
Resnet-50V2:

ResNet-50V2 stands for Residual Network with 50 Layers and V2 (Version 2), a variant of the ResNet architecture. ResNet introduces the concept of residual training, which adds shortcut connections to the network to help alleviate the missing transition problem. ResNet50V2 shows higher performance than VGG-16 in various image recognition tasks. Deep chest X-ray analysis using the ResNet-50V2 can reveal important features related to the diagnosis of pneumonia.

CNNs are versatile and suitable for image processing and capture the spatial hierarchy of features through an innovative process. VGG-16 is known for its simplicity with 3x3 convolution layers and maximum compression layers. Although computationally expensive, it helps to understand and implement simple architectures. ResNet50V2 solves gradient fading problems with hop connections that require deep network training. It shows excellent performance in various image recognition tasks.
For chest X-rays, this algorithm can be trained to automatically learn features related to healthy lungs and pneumonia in a labelled database. Its hierarchical representation enables the extraction of related patterns and helps accurately and efficiently diagnose pneumonia in medical image processing.

VI. Result And Discussion

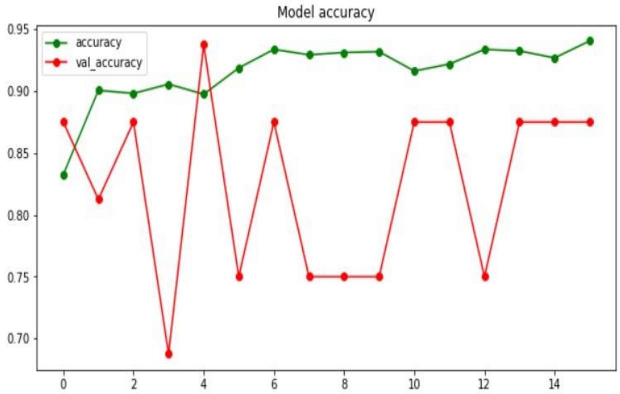
CNN




```
50/50 [==============================] - 10s 194ms/step - loss: 0.6033 - accuracy: 0.6202
The testing accuracy is:  62.0192289352417 %
The testing loss is:  60.32620668411255 %
```

Fig. 3. CNN Model Accuracy vs. Epochs (in percentage)

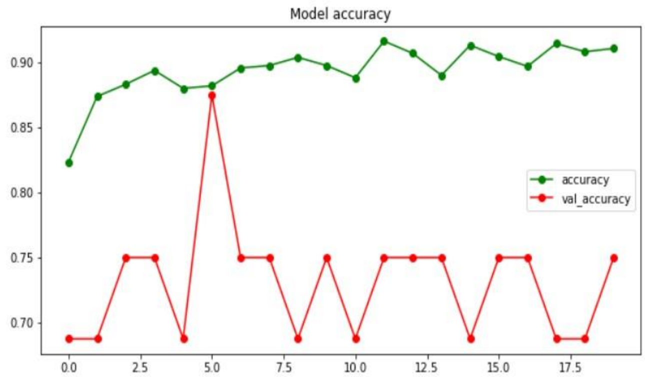
ResNet50V2




```
50/50 [==============================] - 6s 126ms/step - loss: 0.3022 - accuracy: 0.8638
The testing accuracy is:  86.37820482254028 %
The testing loss is:  30.220526456832886 %
```

Fig. 4. ResNet Model Accuracy vs. Epochs (in percentage)

VGG

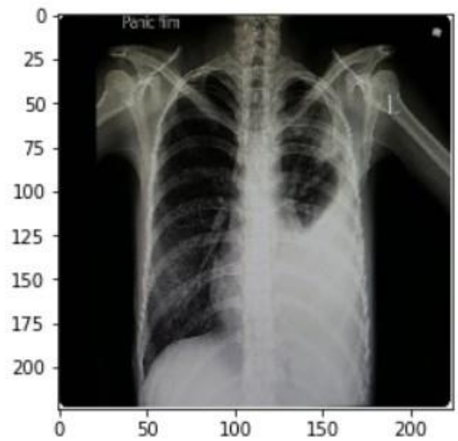



```
50/50 [==============================] - 6s 127ms/step - loss: 0.2884 - accuracy: 0.9006
The testing accuracy is:  90.06410241127014 %
The testing loss is:  28.84087860584259 %
```

Fig. 5. VGG Model Accuracy vs. Epochs (in percentage)

Final Output

This image is 100.000 percent P N E U M O N I A



```
Accuracy: 86.85897435897436%
Precision: 86.15023474178403%
Recall: 94.1025641025641%
F1-score: 89.95098039215685
CPU times: user 179 µs, sys: 3 µs, total: 182 µs
Wall time: 173 µs
```

Fig. 6. Result for the given X-ray image

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