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Deep Learning-Based Pneumonia Detection From Chest X-Ray Images

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Abstract: Pneumonia, an infectious disease caused by bacterial contamination in the alveoli of the lungs, leads to the accumulation of pus in infected tissues. Diagnosis typically involves physical examinations, chest X-rays, ultrasounds, or lung biopsies. Misdiagnosis, improper treatment, or overlooked cases can result in severe health consequences or even loss of life. Advancements in deep learning have introduced effective tools to aid medical professionals in diagnosing such conditions. This study utilizes a Convolutional Neural Network (CNN) model to classify chest X-ray images as either normal or pneumonia-affected. The dataset comprises approximately 6,000 chest X-ray images with a resolution of 224×224 pixels and a batch size of 4. The trained CNN model achieved an impressive accuracy rate of 95% during training, demonstrating its capability in distinguishing bacterial and viral pneumonia based on chest X-ray images. This method highlights the potential of deep learning to enhance diagnostic accuracy and support clinical decision-making.

Index Terms - Pneumonia Detection , Deep Learning, Convolutional Neural Network (CNN), Chest X-ray Imaging, Bacterial Pneumonia, Viral Pneumonia, Medical Diagnosis, Image Classification, Accuracy Rate, Healthcare AI Applications.

I. INTRODUCTION

Deep learning is the branch of machine learning which is based on artificial neural network architecture. An artificial neural network or ANN uses layers of interconnected nodes called neurons that work together to process and learn from the input data. Deep learning is a subset of machine learning that uses multi-layered neural networks, called deep neural networks, to simulate the complex decision-making power of the human brain. Some form of deep learning powers most of the artificial intelligence (AI) in our lives today. Pneumonia is an infection that inflames the air sacs in one or both lungs. The air sacs may fill with fluid or pus (purulent material), causing cough with phlegm or pus, fever, chills, and difficulty breathing. In this project, we are using deep learning technique to detect pneumonia from chest x-ray images.

Objectives

- Understand biomedical terms and concepts related to pneumonia.
- Explore various clinical scenarios associated with pneumonia.
- Study methods of data acquisition and image processing techniques.
- Analyse pre-trained deep learning models for medical image analysis.
- Develop a web application for pneumonia detection using chest X-ray images.

II. Related Work

[1] A study utilized a Convolutional Neural Network (CNN) to classify chest X-ray images into two categories: "Normal" and "Pneumonia." The dataset, obtained from Kaggle, included 4,856 JPEG images with a resolution of 1024×1024 pixels, organized into two distinct folders based on the classes. The dataset was split into training (90%) and testing (10%) subsets, with a data augmentation technique applied to enhance the dataset size and diversity. The CNN model employed a six-layer architecture. The study reported that using data augmentation significantly improved performance, achieving an accuracy of 83.38%, compared to 80.25% without augmentation. These findings highlight the importance of data augmentation in improving CNN model accuracy for pneumonia detection.

[2] This paper explores the application of a Convolutional Neural Network (CNN) algorithm for detecting pneumonia in chest X-ray images. The dataset consists of 5,000 JPEG chest X-ray images, divided into three folders: training, validation, and testing. The dataset is split in an 80/10/10 ratio, with 80% allocated for training, 10% for validation, and 10% for testing. The proposed CNN model achieved an accuracy of 88.90%, demonstrating its effectiveness in pneumonia classification.

[3] This study focuses on classifying chest X-ray images into "Normal" and "Pneumonia" categories using a Convolutional Neural Network (CNN). The dataset consists of 4,000 X-ray images sourced from Kaggle, each with a resolution of 224×224 pixels, and categorized into two classes: NORMAL and PNEUMONIA. The images are divided into training and validation sets, with 90% of the data used for training and 10% for validation. Data augmentation techniques were applied to increase the dataset size. The CNN model, consisting of six layers, achieved an accuracy of 87.64%, demonstrating its effectiveness for pneumonia detection.

[4] This study presents a Convolutional Neural Network (CNN) model designed to differentiate between normal chest X-ray images and those showing signs of pneumonia. The dataset, sourced from Kaggle, comprises 4,000 JPEG-formatted chest X-ray images, categorized into two classes: NORMAL and PNEUMONIA, stored in separate folders. The dataset is randomly divided into 90% training and 10% validation sets. The model uses a six-layer CNN architecture and applies data augmentation to increase the dataset size. The proposed CNN architecture achieved an accuracy of 89.64%, demonstrating its effectiveness in pneumonia detection.

III. Existing System

The proposed model classifies chest X-ray images into normal and pneumonia categories using a Convolutional Neural Network (CNN) with six layers. The dataset includes 1341 normal and 3875 pneumonia images in the training set, reflecting a significant class imbalance. The testing set contains 624 images, with 390 pneumonia and 234 normal cases. The model achieves approximately 90% accuracy.

Limitations

- The model's accuracy requires further improvement.
- No Graphical User Interface (GUI) is implemented for user interaction.
- The training data is significantly imbalanced, which may affect performance.

IV. Proposed System

VGG-Based CNN Model for Pneumonia Detection

This model employs a VGG-based Convolutional Neural Network (CNN) to extract features from chest X-ray images and detect pneumonia. The dataset, sourced from Kaggle, comprises 5863 X-ray images, divided into training, testing, and validation sets, with subcategories for "Pneumonia" and "Normal" images.

VGG16, a widely used CNN architecture for image classification, forms the backbone of this model, consisting of 16 layers (13 convolutional and 3 fully connected layers).

A user-friendly web application is being developed using the Flask framework, enabling seamless interaction with the model. Flask, a lightweight Python-based web framework, facilitates rapid development by providing tools for routing, handling HTTP requests, and rendering templates.

Advantages

- Enhanced accuracy: The use of VGG16 architecture and an expanded dataset is expected to achieve approximately 95% accuracy.
- Improved user experience: The integration of a Graphical User Interface (GUI) allows for better interaction with the model through the web application.

V. SYSTEM DESIGN

System design involves defining the key elements of a system, including its architecture, modules, components, interfaces, and the data flow within the system. The objective is to address specific organizational needs by engineering a cohesive and efficient system. Software architecture represents the high-level structure of a software system. It includes the design of system elements, their relationships, and properties. Similar to building architecture, it provides a framework for understanding and reasoning about the software. The architecture and design process focuses on defining components or modules to meet specific requirements, whether for a new system or the replacement of an existing one. Effective system design emphasizes achieving system objectives while ensuring operational efficiency and seamless integration of components.

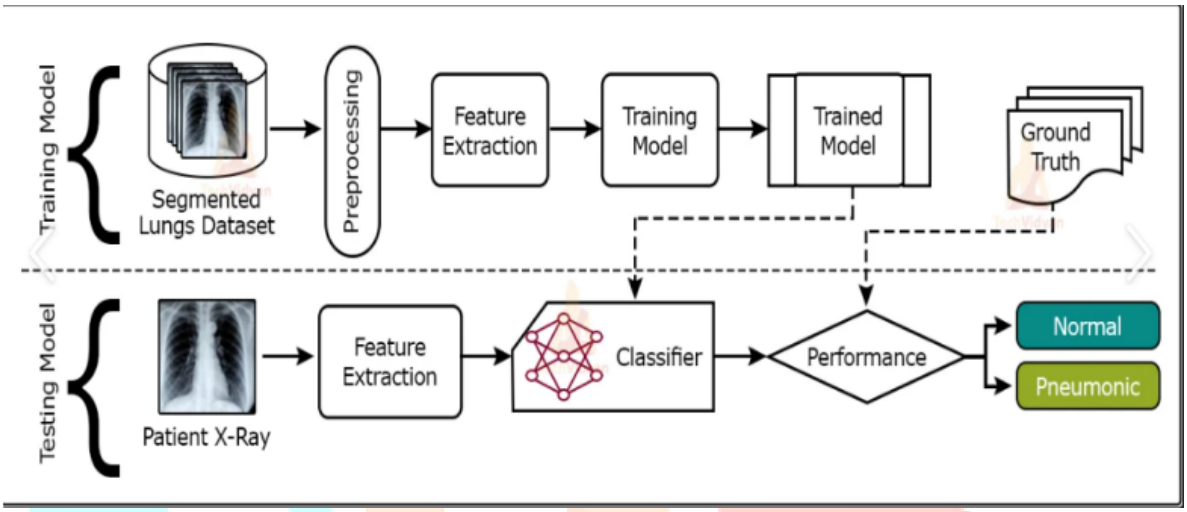

Figure 1:System Architecture

VI. METHODOLOGY

Dataset Acquisition

The dataset used to evaluate the model's performance comprises 5,863 paediatric chest X-ray images sourced from a Kaggle competition created by Dr. Paul Mooney in 2017, aimed at classifying viral and bacterial pneumonia. This updated version of the dataset contains images divided into three folders: train, test, and validation, with subfolders for each category—Pneumonia and Normal. Chest X-ray images often exhibit limited brightness and consist of black, white, and grey tones. The lungs, located on either side of the thoracic cavity, appear almost black due to the low density of lung tissue. The heart, situated centrally, appears white, as X-rays cannot fully penetrate it. Similarly, bones, being dense and composed of protein, appear distinctly white with sharp edges. These unique characteristics of X-ray imaging aid in feature extraction and classification.

Data Preprocessing(augmentation)

Rescale is a value that we will multiply the data by before any other processing in our investigation. Our original photos had RGB coefficients ranging from 0 to 255, but values like this would be too high for our models to handle (given a typical learning rate), so we scale them down by a factor of 1./255. shear range is used to apply shearing transformations at random. When there are no assumptions of horizontal asymmetry, zoom range is used to randomly zoom inside photographs, and horizontal flip is used to randomly flip half of the images horizontally.

Model Selection

Choosing a deep learning model suitable for image classification tasks, such as VGG16, ResNet, or DenseNet. Model selection is the process of choosing one among many candidate models for a predictive modeling problem. There may be many competing concerns when performing model selection beyond model performance, such as complexity, maintainability, and available resources. In this project we are using vgg16 model to train the model.

Model Training

Train the selected model on the preprocessed dataset to learn the features associated with pneumonia. Model training is at the heart of the data science development lifecycle where the data science team works to fit the best weights and biases to an algorithm to minimize the loss function over prediction range. Loss functions define how to optimize the ML algorithms. A data science team may use different types of loss functions depending on the project objectives, the type of data used and the type of algorithm. When a supervised learning technique is used, model training creates a mathematical representation of the relationship between the data features and a target label. In unsupervised learning, it creates a mathematical representation among the data features themselves.

Model Evaluation

Evaluate the trained model using metrics like accuracy, precision, recall, and F1-score to assess its performance. Model evaluation (or model validation) is the process of assessing the performance of a trained ML model on a (holdout) dataset. You want to establish the model's ability to generalize - to make good predictions on new, unseen data. For a binary classification problem, common evaluation metrics include accuracy, precision, recall, F1 score, and area under the receiver operating characteristic curve (ROC AUC). For multi-class classification problems, a confusion matrix is often used that shows the counts of TPs (true positives), FPs (false positives), TNs (true negatives), and FNs (false negatives) for all predictions made using the test set. For regression problems, metrics such as mean squared error (MSE) and R-squared are commonly used.

Deployment

Build a web application using a framework like Flask to deploy the trained model for realtime pneumonia detection. Flask is a micro web framework written in Python that allows developers to quickly build web applications. It provides simple and easy-to-use tools and libraries for routing requests, handling HTTP requests and responses, and rendering templates. Flask is known for its flexibility and extensibility, making it a popular choice among developers for building web applications.

User Interface Design a user-friendly interface for the web application to allow users to upload chest X-ray images and view the detection results. In the industrial design field of human–computer interaction, a user interface (UI) is the space where interactions between humans and machines occur. The goal of this interaction is to allow effective operation and control of the machine from the human end, while the machine simultaneously feeds back information that aids the operators' decision-making process.

Integration

Integrate the deep learning model with the web application to enable automated pneumonia detection. The focus of this is to building a web app around our Deep Learning model for others to try. We will go through some Web programming techniques such as HTML and Flask, as well as deploying it on the Web.

Testing

Conduct thorough testing of the web application to ensure its functionality and performance. The purpose of testing is to discover errors. Testing is the process of trying to discover every conceivable fault or weakness in a work product. It provides a way to check the functionality of components, sub-assemblies, assemblies and/or a finished product It is the process of exercising software with the intent of ensuring that the Software system meets its requirements and user expectations and does not fail in an unacceptable manner.

VII.CONCLUSION

This study describes a CNN-based model aiming to diagnose pneumonia on a chest X-ray image set. The contributions in this paper are listed as follows. We designed a CNN model to extract the features from original images or previous feature maps, which contained sixteen layers combining ReLU activation function, drop operation, and max-pooling layers. The results of the obtained accuracy rate of 95.88% and precision rate of 92.41%, shows that our proposed model performs well in comparison to state-of-the-art CNN model architectures. To illustrate the performance of our proposed model, several comparisons of different input shapes and loss functions were provided. In the future, we will continue the research to explore more accurate classification architectures to diagnose two types of pneumonia, viruses, and bacteria. According to

the description discussed above, the CNN-based model is a promising method to diagnose the disease through X-rays.

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