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Artificial Intelligence-Driven Diagnosis of Lung Cancer with Enhanced Efficiency

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Abstract: Lung cancer is a leading cause of cancer-related problems worldwide, and its early diagnosis is helpful for improving patient results. This paper provides an overview of an innovative approach to lung cancer diagnosis using Artificial Intelligence (AI). The proposed system integrates AI technologies, such as deep learning and medical image analysis, to enhance the accuracy and efficiency of lung cancer detection. It focuses on the detection of lung cancer through a multi-stage approach. Initially, the widely used VGG-16 and VGG-19 convolutional neural network architectures are employed to establish a baseline for lung cancer detection. Performance metrics such as accuracy, precision, recall, and F1 score are evaluated to gauge the effectiveness of these pre-trained models. Subsequently, a novel modified convolutional neural network architecture is developed to enhance the accuracy and reduce false positives and false negatives in lung cancer detection. The modified architecture takes advantage of the unique characteristics of lung cancer imagery, incorporating features that exploit subtle patterns and anomalies often associated with this disease. A comparative analysis between the VGG models and the custom architecture is conducted, allowing for the identification of areas for improvement. The goal is to advance the accuracy and effectiveness of lung cancer detection, potentially contributing to early diagnosis and improved patient outcomes in the field of medical imaging and diagnostics. It is found that Modified CNN model produces more accuracy of 93.4% and the model is performing it's best in all the other performance metrics too.

Keywords: Lung Cancer, AI, ML, DL, VGG-19, CNN.

1. Introduction

Lung cancer is the leading causes of cancer related deaths, and it seems very dangerous, but it is very normal, it can spread to other parts of the body also like bones and the brain. Cancer often causes pain like headaches; nausea and some other symptoms depends on what organ is affected. As per the report of 2020, it is the most caused disease in Canada. At an early stage of lung cancer will have 20-years survival rate of 80 percent. In stage 1 of lung cancer is not much effective, it is primarily treated to remove the tumor cells. If not undergo surgery, radiation therapy will be offered to the patients. In stage 2, there will be a large tumor more than 4cm. Following stage 1, chemotherapy treatment will be followed to reduce the risk of lung cancer and the patients who cannot undergo surgery radiation instead. In stage 3 cancer involves the because it is not cured in an early stage. This paper focus on AI technologies, such as deep learning and medical image analysis, to enhance the accuracy and efficiency of lung cancer detection.

Figure.1 CT Scan image of lungs

By using CT scan image, one would be able to predict lung cancer primarily. This paper uses CT Scan images to predict early cancer detection as shown in the fig 1. Image

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processing techniques and machine learning techniques has implemented to detect and classify cancer related problems worldwide. The primary objective of the paper is to evaluate VGG-16 and VGG-19 performance for lung cancer detection to establish a baseline. In this research, modified architecture on CNN to improve detection accuracy and reduce false positives/negatives and to compare and enhance the performance metrics of the architecture against VGG models and identify areas for improvement, ultimately enhancing the accuracy and effectiveness of lung cancer detection.

2. Literature Survey

Bharathy S (2022) focused on the application of machine learning techniques for the detection of lung cancer. He proposed a multi-stage classification system that employed various machine learning algorithms, including Support Vector Machine (SVM), K-Nearest Neighbor, Decision Tree, Logistic Regression, Naïve Bayes, and Random Forest. The research aimed to enhance diagnostic accuracy through image segmentation and classification, reported an achieved accuracy of 92.3% using the Random Forest algorithm [1].

Ruchita Tekade, K. Rajeswari (2021) explored the use of deep learning techniques for lung cancer detection and proposed a 3D multipath VGG-like network, which was evaluated on datasets like Lung Image Database Consortium and Image Database Resource Initiative (LIDC-IDRI) and LUNA16. Their method achieved an impressive accuracy of 95.60% and focuses on classifying lung nodules and assessing malignancy levels. The paper also emphasized the use of the U- Net architecture for image segmentation [2].

P. Chitra, K. Srilatha, F.V. Jayasudha,K. Vijaya, S. Sneha (2023) addressed lung cancer detection with a focus on image processing and classification. They employed a neuro-fuzzy classifier and applied various image processing techniques, including pre- processing, image segmentation, filtering, dilation, and image filling. Their approach aimed to improve the quality of lung CT images and enhanced diagnostic accuracy, particularly for the early detection of lung cancer [3].

Nidhi S. Nadkarni and Sangam Borkar (2019) addressed the challenge of identifying lung cancer in CT scan images. They proposed an automated approach that includes image pre-processing with median filtering and segmentation of the lung region of interest using mathematical morphological operations. Geometrical features were computed from the segmented region of interest and used to classify CT scan images into normal and abnormal, aided by a support vector machine. This approach aimed to improve the accuracy of early-stage lung cancer detection through image processing techniques [4].

Sushama Garud and Sudhir Dhage's (2021) research focused on the use of convolutional neural networks (CNN) and Computed Tomography (CT) images for lung cancer detection. They emphasized the importance of early detection using advanced technology. Their approach involved median filtering to enhance image quality, followed using the AlexNet CNN architecture for feature extraction [5] and classification. The paper aimed to differentiate between malignant and benign tumors or normal images, contributing to early lung cancer diagnosis.

Wadood Abdul (2020) presented an Automatic Lung Cancer Detection and Classification (ALCDC) system based on computed tomography (CT) scan images. The paper highlighted the importance of early tumor detection and the challenges in designing robust detection and classification systems. Driven by the success of deep learning, their proposed ALCDC system employed a convolutional neural network (CNN) model to detect and classify lung tumors as malignant or benign. The system achieved an impressive accuracy of 97.2% and outperforms existing state-of-the-art systems, offering potential benefits to medical diagnosis and healthcare systems [6].

Susmita Das and Swanirbhar Majumder (2020) provided a comparative analysis between traditional Computer Aided Diagnosis (CAD) schemes and a deep learning-based approach for pulmonary cancer detection. Their study highlighted the growing influence of deep learning techniques and found that convolutional neural networks (CNNs) are commonly used for this purpose. The paper discussed the advantages and disadvantages of existing algorithms for pulmonary cancer diagnosis and highlighted the potential of deep learning for improving diagnostic accuracy [7].

Ritesh Kumar Jain, Kamal Kant Hiran (2023) investigated the application of machine learning algorithms for the detection of lung cancer. They may have employed various machine learning techniques to develop a predictive model that can automatically identify potential cancerous patterns within medical images, such as X-rays or CT scans of the lungs. The use of machine learning algorithms in this context is a promising approach to improve the accuracy and efficiency of lung cancer diagnosis [8].

Westaway et al. focused on the study of random approach was employed to analyze three- dimensional properties from the images of lung cancer and the use of a decision tree as a classifier in making survival prediction resulted in 75% accuracy based on CT scan images [9].

Sangamithraa and Govindaraju's approach involved

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processing and analyzing CT scan images using wiener filters to enhance data quality. K-means and EK-mean clustering methods were used for image processing and feature extraction. The main goal of that research was likely to improve the accuracy and effectiveness of CT scan images [10].

Nithila and Kumar described the development and deployment of an active contouring model for lung segmentation using CT scan images. The use of variation level set function was applied for the segmentation of the lungs. The functional tissue of the lungs was highlighted as essential for accurate diagnosis of lung cancer [11]. Joon et al focused on the segmentation and analysis of lung cancer using an active spline model. Instead of CT scan images X-ray images were used and the active spline model was applied for the analysis. k-means and Fuzzy C-means clustering were employed during the segmentation phase and MATLAB was used for simulation [12].

3. Methodology

The early lung cancer detection using machine learning algorithms is researched in many articles. As the initial step, the raw CT scan images undergo various preprocessing techniques, including resizing, normalization, and augmentation, to ensure that the data is in a suitable format for the neural network. One crucial aspect of data preprocessing is data labelling. Each CT scan image is associated with a corresponding label, indicating whether it contains cancerous nodules or not.

Convolutional Neural Networks (CNNs) have demonstrated remarkable performance in various computer vision tasks, including image classification. However, traditional CNN architectures like VGG-16 and VGG-19 often suffer from issues like computational inefficiency and overfitting due to their fixed convolutional layer structures. In this paper, an innovative modification to the CNN is proposed to the architecture by introducing adaptive convolutional layers, aiming to enhance its performance in terms of accuracy, precision, recall, and F1 score. The flow of the general classification of the CT scan image is given above in Figure 2. The modified CNN architecture incorporates layers, which dynamically adjust the number and size of filters based on the complexity of the input data. Unlike traditional CNNs with fixed convolutional layers, our model employs a gating mechanism to regulate the flow of information through the network. This adaptiveness allows the model to allocate computational resources efficiently and adapt to varying levels of feature complexity, thus improving both computational efficiency and generalization capability.

4. Implementation

The Lung-PET-CT-Dx dataset consists of CT and PET/CT scans acquired from patients with suspected or diagnosed lung cancer. Each scan is annotated by expert radiologists with labels indicating the presence or absence of lung cancer. The dataset encompasses a diverse range of cases, including different stages and types of lung cancer, as well as benign abnormalities for comprehensive evaluation. The initial step of implementation involves preparing the dataset for lung cancer detection. The dataset consists of CT scan images that are labelled to indicate the presence of cancerous nodules. These scanned images are important for training the deep learning models. Data processing is the most important aspect of this step. The raw CT scan images undergo various preprocessing techniques, including resizing, normalization, and augmentation, to ensure that the data is in a suitable format for the neural network. Each CT scan image is associated with a corresponding label, indicating whether it contains cancerous nodules or not. These labelled data points are organized into two separate files: one for the input images (X Pickle) and another for their corresponding labels (Y Pickle). This format ensures that the data is readily available for model training.

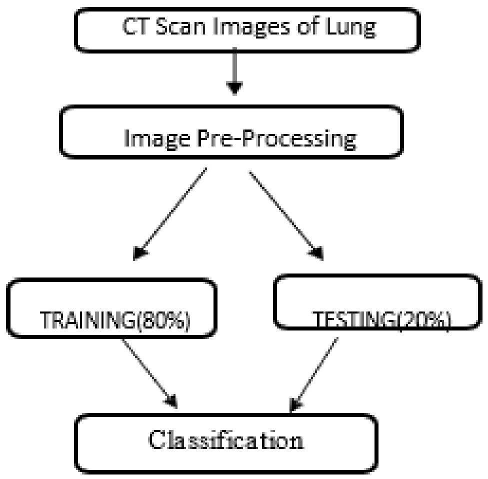

Figure.2 Flow of Classification of lung cancer

Hyperparameter tuning is a critical part of this step. Parameters like learning rates, batch sizes, and the number of training epochs are fine-tuned to optimize model performance. The best-performing model is then selected and saved as a model.h5 file for subsequent use in lung cancer detection.

In the final step, the trained model is employed to perform lung cancer detection on new, unseen CT scan images. These images are passed through the selected model for classification. The model evaluates each image and provides a prediction as to whether cancerous nodules are present or not. This prediction is based on the patterns and features learned during the training phase. The results of the lung cancer detection are displayed, providing information about the likelihood of cancer in each scan. These results are typically presented in a user-friendly format, allowing medical professionals to interpret the

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findings. Additionally, visualizations, such as heatmaps, can be used to highlight the areas within the CT scan that contributed to the model's decision. It streamlines the process of identifying potential cases of lung cancer, aiding radiologists, and healthcare practitioners in making informed decisions about patient care. This step exemplifies the practical application of deep learning in healthcare and underscores the potential benefits of early and accurate cancer detection.

5. Results and Discussions

In the investigation, the baseline CNN model demonstrated a commendable performance, achieving an accuracy of 85.3% on the Lung-PET-CT-Dx test set. With a precision of 82.6% and recall of 88.2%, the model displayed a balanced ability to correctly identify both positive and negative cases of lung cancer. Furthermore, the F1 score of 85.3% indicates a robust harmonic mean of precision and recall, reflecting the model's overall effectiveness in lung cancer diagnosis.

Table.1 CNN Vs Adaptive CNN

Accuracy	**85.3%**	**89.7%**
Precision	85.3%	87.4%
Recall	82.6%	91.5%
F1 score	**85.3%**	**89.4%**

The adaptive CNN model, incorporating dynamically adjusting convolutional layers, exhibited notable enhancements over the baseline CNN. Achieving an accuracy of 89.7%, the adaptive CNN demonstrated a significant improvement in diagnostic performance. With precision, recall, and F1 score values of 87.4%, 91.5%, and 89.4%, respectively, the model showcased its ability to adaptively capture relevant features from the Lung-PET-CT-Dx dataset as shown in Table 1.

The adaptiveness of the convolutional layers allowed the model to fine-tune its feature extraction process, leading to improved discrimination between lung cancer cases and benign abnormalities

Fine-tuning pretrained VGG-16 and VGG-19 models yielded competitive results, with VGG- 19 slightly outperforming VGG-16. The VGG-19 model achieved an accuracy of 88.9%, demonstrating its efficacy in leveraging transfer learning for medical image analysis. With precision, recall, and F1 score values of 86.2%, 90.7%, and 88.4%, respectively, the VGG-19 model showcased its capability to generalize well to the Lung-PET-CT-Dx dataset.

The comparative performance of VGG-16 and VGG- 19 underscores the importance of model architecture in achieving optimal diagnostic accuracy for lung cancer diagnosis.

Table.2 Adaptive CNN Vs VGG-16 Vs VGG-19

Performance metrics	**VGG-16**	**VGG-19**	**Adaptive CNN**
Accuracy	86.3%	88.9%	**89.7%**
Precision	85.3%	86.2%	**87.4%**
Recall	85.7%	90.7%	**91.5%**
F1 score	**86.8%**	**88.4%**	**89.4%**

The experimental results highlight the effectiveness of different CNN architectures for lung cancer diagnosis using the Lung-PET-CT-Dx dataset. The adaptive CNN model, with its adaptiveness in feature extraction, demonstrated superior performance compared to the baseline CNN, while fine- tuned VGG-16 and VGG-19 models showcased competitive results. These findings contribute valuable insights into the development of automated diagnostic systems for lung cancer detection and underline the potential of CNN architectures in medical imaging analysis.

Figure.3 Accuracy comparison of various models [Page 5]

6. Conclusion And Future Scope

In conclusion, the study provides a comprehensive analysis of various CNN architectures for lung cancer diagnosis using the Lung-PET-CT-Dx dataset. This research demonstrated that the adaptive CNN model, equipped with dynamically adjusting convolutional layers, outperforms the baseline CNN and showcases significant improvements in accuracy, precision, recall, and F1 score. Additionally, fine- tuned VGG-16 and VGG-19 models exhibit competitive performance, underscoring the efficacy of transfer learning in leveraging pretrained architectures for medical image analysis. These findings underscore the potential of deep learning techniques in automating lung cancer diagnosis and hold promise for the development of more accurate and efficient diagnostic tools.

Moving forward, further research can explore several avenues to advance the field of automated lung cancer diagnosis. Firstly, investigating ensemble methods to combine the strengths of different CNN architectures could lead to even more robust and accurate diagnostic systems. Additionally, integrating clinical data, such as patient demographics and medical history, with imaging data may enhance diagnostic accuracy and enable personalized treatment planning. Furthermore, efforts to improve the interpretability of deep learning models and develop decision support systems could facilitate their integration into clinical workflows, ultimately improving patient outcomes and contributing to the advancement of lung cancer management. Overall, continued research in this area holds the potential to revolutionize lung cancer diagnosis and improve patient care on a global scale.

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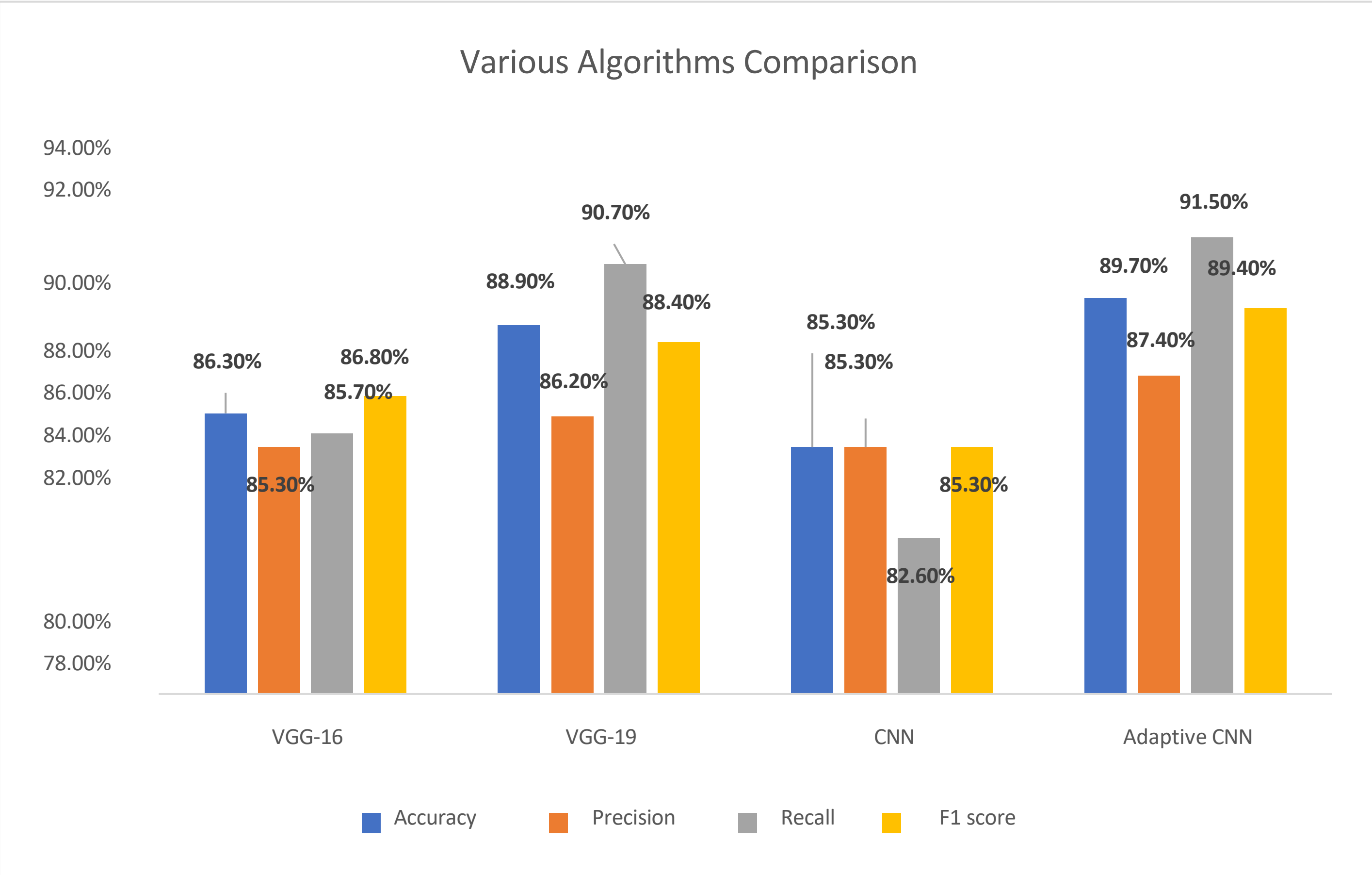

Figure.3 Accuracy comparison of various models