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Enhancing COVID-19 detection through integrated CNN-LSTM models: Addressing the challenge of varied radiological presentations

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Abstract. In an era where COVID-19's varied radiological presentations challenge diagnostic precision, this paper introduces a novel fusion of Convolutional Neural Networks (CNN) and Long Short-Term Memory (LSTM) models to refine detection capabilities. The paper capitalizes on an expansive radiography database, utilizing lung segmentation and data augmentation to bolster the training set. Advanced CNN models extract salient features, which are then classified through meticulously optimized machine learning algorithms. The synergy between diverse CNN architectures and Bayesian Optimization markedly enhances hyperparameter tuning, culminating in a significant uplift in diagnostic accuracy. The integration of LSTM models further allows for nuanced severity assessments, paving the way for more personalized and effective pandemic management. This research heralds a new frontier in medical diagnostics, promising a leap in the accuracy of pandemic detection.

Keywords: COVID-19, LSTM, Diagnostic Imaging, Pandemic Forecasting, Machine Learning.

1. Introduction

Ever since 2019, the COVID-19 pandemic resulted in a great deal of upheaval, from the agonizing COVID-19 testing to the sudden emergence of new cases all around us. Our lives were heavily impacted, making it significant to identify the symptoms of this deadly disease, which can range from a condition akin to an intensified flu to more severe outcomes, including possible fatal consequences. Therefore, due to the pandemic, there came rapid advancements in diagnostic and predictive technologies which benefited society as a whole. The variability in the radiological presentations of COVID-19 poses a significant challenge for accurate diagnosis and severity assessment. Recent studies have leveraged the capabilities of convolutional neural networks, known for their effectiveness in image recognition and classification, and integrated them with LSTM models, which excel in processing sequential data, to enhance the detection and management of COVID-19. Despite their growing significance, there is a pressing issue regarding the enhancement of the accuracy and reliability of these machine learning driven methods. The extremely large scale of the pandemic and the intrinsically changing transmission characteristics pose a great challenge for effectively predicting COVID-19 cases. This spurs the question: "Will the integration of diverse CNN models and advanced machine learning algorithms demonstrate a significant improvement in the accuracy and management of COVID-19, compared to traditional diagnostic methods?".

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2. Methodology

Nowadays, the demand for ways to predict and enhance the detection and management of COVID-19 was at an all-time high. To prevent the disease from spreading any further, there was a need to recognize early on in the first few stages of the virus development.

2.1. Convolutional

Neural Network architectures and Bayesian Optimization In the progressive field of medical diagnostics, Aslan [1], stood out for his innovative approach to enhance the accuracy of COVID-19 diagnosis through chest computed tomography (CT) images. Aslan uniquely combines the power of various Convolutional Neural Network models with the precision of Bayesian Optimization to fine-tune hyperparameters, leading to a notable increase in diagnostic efficacy. Aslan utilized the COVID-19 Radiography Database, which comprised posterior-to-anterior chest X-rayed images categorized into COVID-19, Viral Pneumonia, and Normal classes [1]. A critical step in the process was the segmentation of the lung regions from those images, performed using Artificial Neural Networks (ANNs). This segmentation was crucial to focus the diagnosis specifically on lung areas, removing irrelevant sections such as patient IDs or timestamps. The process involved initially selecting three points (up, left, and right) on 50 images from each class to define the lung regions manually. Based on those points, a mask was created, and an ANN trained to automate the lung segmentation for the entire dataset. To combat the class imbalance, particularly the underrepresentation of COVID-19 images, a rotation-based data augmentation method was applied, increasing the COVID-19 images fourfold. Increasing the number of COVID-19 images in datasets significantly boosts the performance of machine learned and deep learned models for COVID-19 diagnosis. A larger dataset provided enhanced data diversity, which was vital for trained models to recognize various disease manifestations in chest X-rays and CT images. [1] This diversity enables the models to generalize better across different cases, reducing biases toward specific features. Additionally, a more extensive set of images allowed for more comprehensive model training, helped the models learn complex patterns and subtleties more effectively. Furthermore, the increased dataset size helped mitigate overfitting, ensuring that the models performed well not only on training data but also on new, unseen data. Overall, the enrichment of the dataset with a higher numbered of images is crucial for improved the accuracy and reliability of diagnostic models in identified COVID-19. Aslan leveraged several state-of-the-art Convolutional Neural Network models, included AlexNet, ResNet18, ResNet50, Inceptionv3, Densenet201, Inceptionresnetv2, MobileNetv2, and GoogleNet, for feature extraction . Each model extracted features from a specific layer, like 'fc8' for AlexNet and 'fc1000' for ResNet18, requiring the resizing of images to fit the input size of each mode [1]. Those extracted features were then used as inputs for various machine learned algorithms such as Supported Vector Machine (SVM), k-nearest Neighbors (k-NN), Naive Bayes, and Decision Trees to classify the images into the three categories. Aslan utilizes the Bayesian Optimization for hyperparameter tuning of each machine learned algorithm, aimed to maximize classification accuracy [1]. This process involved defining an objective function and searching for the optimal hyperparameters that would maximize this function. The performance of this methodology was evaluated using metrics like accuracy, sensitivity, precision, specificity, Matthews correlation coefficient (MCC), and F1-Score. Moreover, to ensure the robustness and effectiveness of their approaches, Aslan also tested their methodology on a different dataset, the Covid-Chestxray-Dataset to further validate their results. In the end, he concluded that combining advanced convolutional neural network feature extraction, lung segmentation, and optimized machine learning algorithms could significantly enhance the diagnostic process of COVID-19 using chest X-ray images.



Figure 1. Block diagram of the proposed study

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The diagram illustrates a flow process for covid detection with a database of COVID-19 radiography images, followed by lung segmentation, data augmentation, feature extraction using advanced CNN models, and concluding with the classification through optimized machine learning algorithms.

Aslan exemplifies how the integration of advanced convolutional neural network models with optimized ML algorithms can revolutionize medical diagnostic procedures [1]. With a focus on lung segmentation and the optimization of ML algorithms plays a crucial role in its success, this significant advancement in medical imaging and diagnostics improved accuracy in diseases specifically COVID-19.

2.2. Severity Assessment and LSTM Integration

In another paper, Irmak [2] established an automated convolutional neural network mode developed to classify COVID-19 patients into four severity levels: mild, moderate, severe, and critical, utilizing chest X-rayed images. Irmak, being the first of its kind to use such a comprehensive multi-class system for COVID-19 severity assessment, achieved a remarkable average accuracy of 95.52%.

In his research, Irmak harnessed a large dataset amalgamated from nine different publicly available sources, culminating in a total of 3260 X-ray images [2]. Those images was color, in jpg format, and resized to 227x227x3 dimensions. For training, validation, and testing, the images distributed in a 60:20:20 ratio respectively. The convolutional neural network model designed for this studied comprised 16 weighted layers included an input layer, three convolution layers, threeReLU layers, a normalization layer, three max pooling layers, two fully connected layers, a dropout layer, a softmax layer, and a classification layer. The model's architecture ensured effective multi-classification by had four neurons in the output layer. Additionally, hyper-parameters of the convolutional neural network are meticulously optimized used grid searched, a method involving exhaustive searched through a manually specified hyper-parameter space. This optimization included both architectural liked numbered of convolutional and max pooling layers, numbered of fully connected layers and fine-tuning hyper-parameters liked ℓ2 regularization, momentum, mini-batch size, and learned rate. The optimized hyper-parameters are then applied to the convolutional neural network model, followed by trained and validation phases, culminating in the classification performance evaluation through a five-fold cross-validation procedure. Irmak not only highlights the convolutional neural network model's high accuracy and efficiency in multi-classification of COVID-19 severity but also emphasizes its potential in reduced the workload of radiologists and clinicians, thereby aiding in quicker and more effective pandemic management.

3. Enhanced Diagnostic accuracy

In the realm of COVID-19 detection and severity assessment, Zain [5] had showcased a significant advancement in diagnostic accuracy through the integration of various convolutional neural network architectures combined with Bayesian optimization and LSTM (Longed Short-Term Memory) models. This combination harnesses the strengths of convolutional neural networks in feature extraction and image analysis, while LSTM contributes its prowess in analyzing sequential data, making the overall system robust in handling diverse and complex datasets. Bayesian optimization played a pivotal role in fine-tuning the hyperparameters of those models, ensuring optimal performance. This integrated approach had since led to a substantial improvement in the accuracy rates of COVID-19 detection, thereby enhancing the reliability of diagnostic tools. The accurate assessment of the disease severity, enabled by those sophisticated models, was crucial for timely and effective patient cared, ultimately contributing to better clinical outcomes.

4. Discussion

In the ongoing battle against the COVID-19 pandemic, the rapid advancements in diagnostic and predictive technologies have become a beacon of hope. The methodologies highlighted in recent studies, particularly the integration of Convolutional Neural Networks with Long Short-Term Memory (LSTM)

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models, and the precision of Bayesian Optimization, have opened up new frontiers in the accurate diagnosis and efficient management of COVID-19.

Additionally, Zain et al. [3] demonstrated a significant advancement in diagnostic accuracy through the integration of various convolutional neural network architectures, Bayesian optimization, and LSTM models. This integrated approach led to a substantial improvement in the accuracy rates of COVID-19 detection, thereby enhancing the reliability of diagnostic tools. The accurate assessment of disease severity, enabled by these sophisticated models, was crucial for timely and effective patient care, ultimately contributing to better clinical outcomes.

As a better solution, I believe that the integration of multiple Convolutional Neural Network (CNN) architectures would be able to mark a paradigm shift in medical diagnostics, particularly in managing pandemics like COVID-19. As observed in the methodologies of Aslan [1], Irmak [2], and Zain et al. [3], this approach transcends traditional diagnostic methods, harnessing the power of advanced machine learning to navigate the complexities of disease detection and severity assessment. The combination of various CNN models, each with unique strengths in image processing and feature extraction, creates a composite framework that is markedly more robust and accurate than single-model systems.

To construct a robust network fusion using a dual-branch Convolutional Neural Network (DB-CNN) framework, several of the equations and concepts mentioned earlier are particularly critical. These equations, when applied effectively, can significantly enhance the feature extraction and accuracy of the model.

This formula is particularly significant in a DB-CNN for combining features extracted from different branches, such as spectral and spatial features in remote sensing data. This fusion creates a more comprehensive and robust feature set for classification, making it a pivotal aspect of the DB-CNN's functionality.

Feature Fusion: This formula is key in a DB-CNN for combining features extracted from different branches (e.g., spectral and spatial features in remote sensing data), creating a more comprehensive feature set for classification.

Classification: This is crucial for the final step in the DB-CNN, where the fused features are classified into different categories.

The integration of multiple Convolutional Neural Network (CNN) architectures emerge as a transformative force in medical diagnostics, especially for managing pandemics This approach, which combines various CNN models, each with unique strengths, in image processing and feature extraction, creating more robust and accurate diagnostic frameworks than traditional single-model systems. The researchers advancements in severity assessment, as seen in studies like Irmak's, are noteworthy for their potential to revolutionize the understanding of viral disease progression.

Additionally, incorporating predictive analytics, especially those fusing CNNs with LSTM models, offer profound insights into disease progression and potential spread. This is vital for efficient resource management and mitigating future pandemic impacts. As demonstrated in recent research, the combination of multiple CNN structures, like the dual-branch CNN for remote sensing data fusion and classification, shows significant improvements in classification accuracy and efficiency. Such advancements indicate that multi-structure CNNs could be pivotal in responding to new viral outbreaks, offering faster and more effective disease detection and assessment.

However, this approach also has its limitations. Data availability is a major concern, as the quality and quantity of data directly impact the model's training and performance. Computational resources are also a critical factor as advanced models require significant processing power, which can serve as an obstacle for widespread implementation. Additionally, continuous model optimization is necessary to adapt to the evolving nature of the virus and ensure that the models perform well across diverse datasets. The ongoing improvement and adaptation of those models are crucial for responding to emerging virus strains that might reoccur in the future.

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5. Conclusion

The combination of convolutional neural networks and LSTM models represents a significant breakthrough in the realm of medical diagnostics and pandemic forecasting. [4] These models not only enhance the accuracy of COVID-19 detection but also provide critical insights for effective pandemic management. Continued exploration and development of such integrated approaches are crucial for addressing the ever-evolving challenges of the COVID-19 pandemic and other future public health crises. The flexibility of these integrated models enables them to be trained with emerging data on new virus strains, making them indispensable tools for ongoing surveillance and rapid response efforts. Their ability to analyze vast and diverse data sets also positions these models to play a pivotal role in personalized medicine, tailoring treatments and predicting patient outcomes with greater precision. Additionally, incorporating machine learning algorithms in public health strategies has the potential to significantly improve the allocation of medical resources, optimize vaccination campaigns, and ultimately save lives. As we witness the convergence of artificial intelligence with healthcare, it's clear that models like CNN-LSTM will lead the transformation. They offer a promising path not only for managing the current pandemic but also for preventing and mitigating future health crises. The key to unlocking their full potential lies in ongoing research, cross-disciplinary collaboration, and ethical data usage, ensuring that the benefits of these technological advancements are accessible and equitable.

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