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REVIEW ARTICLE

Optimizing AI Models for COVID-19 Detection and Forecasting: A Comprehensive Study

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ABSTRACT

This systematic review explores the use of artificial intelligence (AI) and machine learning (ML) during the COVID-19 disease outbreak. AI/ML models may interpret medical images, auditory input, and patient records to diagnose early enough, thus enhancing the likelihood of positive patient outcomes. Coupled with optimization algorithms, deep learning methods have predicted COVID-19 from chest X-rays and CT scans with unprecedented high accuracy. This review, therefore, synthesizes the existing literature and looks at the significant emphases, gaps, and potential trends of applying AI in diagnosing COVID-19 and forecasting outbreaks. Further, the advancement of AI and ML in this domain needs to be known to enhance global preventive diagnostic techniques for future pandemics.

Keywords: AI ▪ ML ▪ COVID-19 Detection ▪ Deep Learners ▪ CNN ▪ Chest X-ray

1. INTRODUCTION

The COVID-19 pandemic, resulting from the new coronavirus SARS-CoV-2, can be described as one of the most dangerous crises in international public health in recent years. This new virus emanated in late 2019 and has fiercely penetrated several parts of the globe, claiming the lives of millions of its infected persons. By demanding better and more accurate testing methods, there has been a focus on the effects of COVID-19 on patients and how they can be slowed down. The standard methods of diagnosing COVID-19 include the Reverse Transcription Polymerase Chain Reaction (RT-PCR). Nevertheless, these methods have several disadvantages; they are relatively expensive, often inaccessible, and the time required to achieve the results is extended. Moreover, expectations for high frequency and large scale to accommodate the surge during the “wave” also reveal the inefficiency of the existing concept of healthcare facilities [1].

Due to such challenges, scholars have found possible AI and ML remedies to enhance COVID-19 diagnosis. In this way, the successful application of AI and ML technologies allows the processing of significant amounts of diverse and often seeming data: medical images, audio signals, and patients’ records for detecting such patterns that are difficult to recognize otherwise. Such technologies have proven to perform well in several areas within the health sector, such as diagnosing diseases, considering treatment, and predicting epidemics. Such systems enable faster diagnosis and help diagnose COVID-19 cases at an early stage, especially where adequate resources are lacking [2].

Deep learning has been a promising diagnostic tool in detecting COVID-19 from medical images, chest X-rays (CXR), and CT scans. These models can also distinguish COVID-19 pneumonia from other bacterial or viral pneumonia cases. Transfer learning CNNs and feature extraction were used to train models that provide low error rates in classifying infected and healthy patients. For this reason, several sources have demonstrated that AI solutions can accompany traditional diagnostic tools when resources are scarce or when timely disease recognition is possible [3].

Furthermore, optimization algorithms, especially when integrated with AI models, are principal in enhancing those diagnostic methods and tools. Data augmentation, feature selection, and hybrid models in AI systems have improved the reliability and effectiveness of the systems. For example, many optimization algorithms, such as the Firefly algorithm, Whale Optimization Algorithm, and Genetic Algorithms, were employed to select features from medical datasets and improve the models' performance indicators. This optimization also enhances diagnostic accuracy and helps reduce the computational demand as the model becomes more realistic and retrievable in definite healthcare settings [4].

It is noteworthy that AI and ML technologies have been widely used not only to identify the disease but also to predict its further spread. Forecasting models help understand data and distinct trends, including infection incidence, human mobility, and healthcare facilities' capability to contain the infection and manage the human impact. This predictive capability enables governments and health organizations to make strategic decisions concerning resources, restrictions, and vaccines. Due to the effectiveness of utilizing machine learning for outbreak forecasting, the approach has shown appreciable promise in coping with COVID-19 and other epidemic diseases [5].

This systematic review seeks to present a detailed literature review on COVID-19 diagnosis and outbreak prediction using AI and ML. Categorizing the research papers of the last few years, the study illustrates different AI approaches, data sources, and optimization strategies for improving COVID-19 detection systems. The review identifies current achievements, challenges, and future directions, creating a path towards more accurate, reproducible, and available diagnosis resources that are valuable in present and future epidemics.

2. LITERATURE REVIEWS

COVID-19 has brought into sharp focus the importance of accurate diagnostic techniques for detecting communicable diseases. Problems associated with existing approaches, including limited access to RT-PCR, its high cost, and the long time needed to provide results, have led researchers to look for alternatives. The emergence of AI and ML technologies has created a new line of research to integrate automated systems that help predict COVID-19 outbreaks. These technologies utilize medical images, sounds, and IT data to improve diagnostic abilities and speed.

An optimized deep learning scheme was proposed to differentiate infected COVID-19 patients from healthy ones using CT scans [6]. The DenseNet-201 model was pre-trained and fine-tuned using transfer learning, while feature extraction was performed with fully connected layers and average pooling. The Firefly algorithm was used to select the best features for learning and to improve accuracy. A parallel high-index technique was also developed to integrate optimal vectors, and an extreme learning machine classified the vectors. Experimental results, based on a 70/30 training and testing split, showed 94.76% average classification accuracy.

A diagnostic model for COVID-19 based on chest X-ray images and deep neural networks was presented in [7]. The approach involved four phases: data augmentation, preprocessing, and a two-stage deep network model architecture. Using an online dataset comprising 1215 images and an augmented dataset of 1832 images, the network learned to distinguish COVID-19 pneumonia from bacterial and other viral pneumonia. Training-validation-testing and 5-fold cross-validation techniques produced high classification accuracy rates of 97.77%, with recall and precision rates of 97.14%. Averaged metrics included 98.93% accuracy, 98.93% sensitivity, 98.66% specificity, 96.39% precision, and an F1 score of 98.15%.

Coronavirus respiratory disease identification via deep learning was investigated in [8]. The study employed a dataset comprising COVID-19, influenza, bacterial pneumonia, and healthy control chest X-rays. The Fuzzy Color technique was used as an initial data preprocessing step, and the preprocessed images were merged with the original images to create a second dataset. MobileNetV2 and SqueezeNet were then used to extract features. These features were optimized using Social Mimic Optimization and classified with SVM, achieving an overall classification accuracy of 99.27%.

Deep learning approaches for COVID-19 detection from chest X-ray images were compared in [9]. Models including ResNet18, ResNet50, ResNet101, VGG16, and VGG19 were evaluated, with SVM classification over deep features. The study reported 94.7% accuracy using ResNet50 and an SVM with a linear kernel. Another artificial-intelligence model for diagnosing and predicting COVID-19 used CNNs with whale optimization algorithms and reached 96% diagnostic accuracy [10].

A novel deep learning method for COVID-19 detection from CT images was presented in [11]. Using CT scan images and a modified pooling mechanism, the model achieved 99.03% specificity and very low recognition time. DeepCovNet combined convolutional-autoencoder features, SDAR, and SVM to detect COVID-19 infection status from chest X-rays and CT scans, reaching 99.75% accuracy [12]. CheXNet-based deep learning features combined with PCA, RFE, and XGBoost also demonstrated strong performance, including 97% accuracy, 98% precision, 95% recall, 96% F1-score, and 100% ROC-AUC [13].

Deep transfer learning methods using CT and CXR imaging were explored in [14]. Several pre-trained architectures, including ResNet50, InceptionV3, VGGNet-19, and Xception, were tested with data augmentation to reduce overfitting. For CXR images, Xception achieved 98% precision, recall, F1-score, and accuracy. A two-stage pipeline for identifying COVID-19 cases and predicting illness severity from lung CT images used AlexNet, DenseNet-201, and ResNet-50 for feature extraction, followed by ANN and Cubic SVM classification [15]. The method achieved 92.0% accuracy for COVID-19 detection and up to 96.0% accuracy for severity-level discrimination.

Machine learning for detecting and classifying COVID-19 in CT lung scans was investigated in [16]. The method used K-means clustering and radial-basis-function/SVM classification to identify COVID-related lesions. Other studies employed JAYA-optimized fuzzy reinforcement learning with 93.43% accuracy [17], multi-stream convolutional neural net-

Table 1. Summary of literature review

Study	AI/ML Method	Data Type	Key Findings
[6]	Optimized deep learning scheme	CT scans	94.76% average classification accuracy using DenseNet-201 and Firefly algorithm.
[7]	Deep neural networks	Chest X-ray images	97.77% classification accuracy, 98.93% sensitivity, 98.66% specificity, 96.39% precision, and 98.15% F1-score.
[8]	MobileNetV2 and SqueezeNet	Chest X-ray images	99.27% overall classification accuracy using Fuzzy Color, Social Mimic Optimization, and SVM.
[9]	ResNet18, ResNet50, ResNet101, VGG16, VGG19	Chest X-ray images	94.7% accuracy using ResNet50 and SVM with a linear kernel.
[10]	COVID-19 AIMDP	Chest CT scans	96% diagnostic accuracy using CNNs and whale optimization algorithms.
[11]	Deep learning model	CT scan images	99.03% specificity and 0.069 milliseconds recognition time.
[12]	DeepCovNet	Chest X-ray images	99.75% accuracy using convolutional-autoencoder, SDAR, and SVM.
[13]	CheXNet DL model	Chest X-ray images	97% accuracy, 98% precision, 95% recall, 96% F1-score, and 100% ROC-AUC using PCA+RFE and XGBoost.
[14]	Deep transfer learning	CT and CXR images	98% accuracy, precision, recall, and F1-score using Xception for CXR images.
[15]	Two-stage feature extraction and classification pipeline	Lung CT images	92.0% accuracy in COVID-19 detection and up to 96.0% accuracy in severity discrimination.
[16]	CAD system using machine learning	CT lung scans	High accuracy in detecting COVID-related lesions using K-means clustering and RBFs/SVM.
[17]	JAYA-optimized fuzzy reinforcement learning	Chest X-ray images	93.43% overall classification accuracy.
[18]	Multi-stream convolutional neural network	X-ray images	97.76% accuracy in diagnosing COVID-19.
[19]	Deep and classical machine learning	Face images	99.64% accuracy in face-mask detection using the RMFD dataset.
[20, 21]	Xception neural network enhanced by genetic algorithm and OTLS-DenseNet	X-ray and CT images	Up to 0.996 accuracy for two-class datasets and 96.30% accuracy in CT-based diagnosis.
[22, 23]	Support vector machine	Clinical data	81.48% accuracy in predicting COVID-19 severity.
[24]	Hybrid classification optimization	CT scan images	11.96% detection improvement, 9.98% classification-accuracy improvement, and 13.42% precision-rate improvement.
[25]	Ensemble deep learning model	Cough audio signals	96% accuracy and 92% precision in diagnosing COVID-19.

works with 97.76% diagnostic accuracy [18], face-mask detection with deep and classical learning methods reaching 99.64% accuracy [19], and Xception enhanced by a genetic algorithm with accuracies of 0.996 for two-class datasets and 0.989 for three-class datasets [20, 21]. Clinical-data severity prediction using SVM reached 81.48% accuracy [22, 23]. Hybrid classification optimization for CT images improved detection and precision compared to existing methods [24], while an ensemble deep learning cough-audio model achieved 96% accuracy and 92% precision [25].

Reviews presented in this section prove that AI-based methods can be helpful in the diagnosis of COVID-19 and the management of the disease. A range of approaches, including deep learning, feature extraction, and optimization techniques, leads to high accuracy and better differential performance across different datasets. However, limitations remain; future studies should achieve larger data sets, be replicated in other populations, and embed these markers into clinical practice. More studies must show how to address these problems while investigating novel AI technologies to strengthen pandemic readiness and management.

3. CONCLUSION

Altogether, the application of AI and ML has shown promising prospects in diagnosing COVID-19 and predicting outbreaks of such diseases. Standard procedures such as RT-PCR are effective but costly and time-consuming compared with rapid alternatives. AI models accompanied by deep learning have clear advantages because they can handle heterogeneous big data, medical images such as CT scans and X-rays, and audio signals to diagnose patients more accurately and quickly.

Several papers indicated that convolutional neural networks could accurately diagnose COVID-19 from chest X-rays and CT scans. Better diagnostic performance was achieved by incorporating Firefly and Whale Optimization algorithms into the feature selection stage. AI has also been used to predict the number of infected people and has assisted governments and health organizations in planning how to allocate resources best.

Nonetheless, limitations exist, including small datasets, inconsistent validation practices, and the need for interpretability before clinical adoption. Future work should focus on developing more accurate, scalable, and explainable AI systems, using larger multi-centre datasets and stronger external validation. Such progress will help improve preparedness for COVID-19 and future pandemics.

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