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Review Article

# COVID-19 detection and classification: key AI challenges and recommendations for the way forward

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## Abstract

Coronavirus disease (COVID-19) is a viral pneumonia that is found in China and has spread globally. Early diagnosis is important for effective and timely treatment. Thus, many ongoing studies attempt to solve key COVID-19 problems such as workload classification, detection, and differentiation from other pneumonia and healthy lungs using different imaging modalities. Researchers have identified some limitations in the deployment of deep learning methods to detect COVID-19, but there are still unmet challenges to be addressed. The use of binary classifiers or building classifiers based on only a few classes is some of the limitations that most of the existing research on the COVID-19 classification problem suffers from. Additionally, most prior studies have focused on model or ensemble models that depend on a flat single-feature imaging modality without using any clinical information or benefiting from the hierarchical structure of pneumonia, which leads to clinical challenges, and evaluated their systems using a small public dataset. Additionally, reliance on diagnostic processes based on CT as the main imaging modality, ignoring chest X-rays. Radiologists, computer scientists, and physicians all need to come to an understanding of these interdisciplinary issues. This article first highlights the challenges of deep learning deployment for COVID-19 detection using a literature review and document analysis. Second, it provides six key recommendations that could assist future researchers in this field in improving the diagnostic process for COVID-19. However, there is a need for a collective effort from all of them to consider the provided recommendations to effectively solve these issues.

## Introduction

COVID-19 is a form of viral pneumonia that has caused 763,740,140 confirmed cases and 6,908,554 deaths worldwide as of today [1]. The reverse-transcription polymerase chain reaction (RT-PCR) method is typically used to diagnose COVID-19, but due to the method's limitations, physicians are having challenges using it [2,3]. Radiologists are able to complete the diagnosis procedure in urgent situations by utilizing radiological imaging modalities such as chest X-rays (CXR) or lung computed tomography (CT) scans [4]. It is challenging to complete these procedures due to the limited amount of time radiologists have to analyze medical images and distinguish between COVID-19 infection and other lung diseases. Moreover, radiologists with varying skills and less diagnostic accuracy could result in an incorrect diagnosis and produce inaccurate findings [5]. Since the pandemic, governments were left with no choice but to attempt to deploy emerging technologies such as artificial intelligence (AI) algorithms to solve image classification problems [6]. Therefore, deep learning algorithms have been developed through training on medical images, yielding promising results after learning complex problems in radiology [7,8].

This article aims to, first, highlight the gap in the literature by providing a summary of the current challenges in using deep learning during the pandemic generally for COVID-19 detection. Second, it suggests some key recommendations to help meet pressing needs and overcome these limitations for further research direction. The approach followed in this research was based on a literature review that was fully published in the Journal of Applied Sciences [9]. The novelty of this paper consists of the provision of the challenges, gaps, and recommendations based on the analysis and theoretical background on topics relating to these issues that were studied in the previous review and that focus on the methods and main approaches that have been adopted in recent studies for further research and improvement and produce reliable results for other future medical applications.

## Challenges in COVID-19 classification and detection using deep learning

Due to the current epidemic, COVID-19 medical image classification has recently attracted a lot of scientific interest. Many researchers have produced deep learning detection and classification algorithms to diagnose COVID-19 accurately and efficiently by analyzing radiological images. However, most existing approaches to the COVID-19 classification problem contain gaps and areas to extend, which we attempt to clarify in this section. Capturing the outputs of various classifiers using the ensemble learning approach improves the accuracy of deep learning models and helps to achieve robust predictions. When taken as a whole, the findings from studies that employed ensemble learning techniques [10,11] have some limitations because developing ensemble models based on a single modality (in this case, CT over CXR) presents clinical difficulties because, in practice, exposing the patient to CT radiation is not preferred, and CXR imaging is not sufficient for the diagnosis of COVID-19 without the presence of any additional data [12]. In addition, we have recently seen a significant amount of research published on COVID-19 detection and classification models implementing binary or multi-class classifiers for CXR images with ready-to-use networks [13,14]. As shown in these studies, when AI systems learn from more classes, their capacity to distinguish between distinct classes improves [15]. Despite the findings of these studies, there is noticeable misinformation in some of these studies since they used multi-class classifiers (i.e., with only three or four classes) with COVID-19 class samples that were much larger than samples for other classes, giving the algorithm an incorrectly high percentage of sensitivity. Additionally, a significant number of studies on the recognition and classification of pneumonia in medical imaging have emphasized distinguishing between two classes (binary), such as non-COVID-19-infected and COVID-19-infected lungs. Small sample sizes, the use of insufficient pneumonia classifications, and reliance on a single modality are other problems. These restrictions have an effect on how these research findings might be applied in practical healthcare environments.

Multiple studies propose solutions to detect and classify COVID-19 using chest CT scans [16,17]. CT images are preferred because they are accurate in identifying the characteristics of pneumonia and make it simple to find abnormal areas in infected lungs. However, these studies not only have significant shortcomings but also present models that can't be employed in common clinical practice practically or economically. These limitations are caused especially by the high cost and limited availability of CT, as well as the ongoing pandemic's circumstances. Additionally, CT scan procedures require that patients stay in a waiting room while wearing an appropriate suit, and the doctors prefer that they be applied to serious situations where the radiologists can clearly see the infected lungs. Additionally, neither the Italian Society of Radiology (SIRM) nor the American College of Radiology encourage the use of chest CT as a COVID-19 screening method [16].

Multimodal deep-learning approaches have also been used to identify and classify COVID-19. However, only a small amount of research [18,19] focuses on multimodal deep-learning models for different types of data. These studies tried to address the issues mentioned above by developing solutions based on the analysis of CXR and CT images for the same patient in the context of the COVID-19 pandemic. Models based on data from diverse radiological imaging modalities or different data resources can achieve a higher accuracy rate compared to models that use only one data source. However, this approach is impractical in clinical practice and is not possible in healthcare settings with limited resources (especially in low- and middle-income countries) due to the use of two imaging modalities for the same patient at the same time, and it was therefore considered that there was a significant gap in such studies.

## The gap in the literature

Despite the research efforts by current studies, such efforts have two key limitations: First, most solutions rely on a flat imaging modality without using any clinical information or benefiting from the hierarchical structure of pneumonia, which may support the findings. For other purposes, there were many studies at the time of the pandemic that were based on clinical information [20]. Furthermore, a hierarchical deep convolutional neural network model can clearly distinguish between classes that were difficult to classify using fine-category classifiers and those that were simply classified using coarse-category classifiers. In comparison to flat models, hierarchical classification models perform better due to the breakdown of the problem and significantly reduce classification errors [21,22]. The outcomes proved that the loss function had been incorporated through the hierarchical structure and improved generalization between classes. This is due to the use of shared features within classes at various levels, which helps to solve the data scarcity issue [23]. Second, most of such solutions rely on small public sample size and/or a binary classifier. While deep learning models should be evaluated on larger datasets to verify the model's generalization abilities, and on private multi-class datasets that can help ensure that they are robust and reliable when used in real-world applications [24].

Such limitations create a gap in the literature that needs bridging to equip today's healthcare systems for more effective COVID-19 detection.

### Recommendations to bridge the gap

This section presents a summary of key recommendations covering several disciplines that may assist researchers in this field based on the challenges and restrictions that have been addressed. The following are a few recommendations.

- Notably, in medical research, multimodal deep learning models that integrate multiple types of data in a process of data fusion are more accurate than single-modality models. On the other hand, radiologists have mentioned the challenges that arise from relying entirely on portable CXR to verify an accurate diagnosis of COVID-19.
- The most recommended tool for radiologically examining the lungs is CXR due to the many constraints associated with CT imaging modalities, particularly in light of the continuing epidemic. As a result, it is preferable to build AI models for diagnosing COVID-19 by combining CXR imaging analysis with other clinical data.
- When compared to binary classifiers, multi-class classifiers (with multiple classes) are more accurate and generate more reliable outcomes.
- Due to the natural hierarchical structure of diseases established by the ICD-10 [25] and the superior results obtained by hierarchical classification compared to flat classification in prior studies, hierarchical classification can improve performance compared to flat classification [26].
- In comparison to smaller datasets, deep learning models perform better with larger datasets. As a result, the large amount of training data from each class that is included plays a role in the model's performance.
- Most of these studies have been tested and assessed on publicly accessible online datasets that include COVID-19 image examples. There is no assurance that the examples presented are COVID-19 cases, and there is a chance that certain images may be duplicated in these repositories. This makes it challenging to guarantee the evaluated models' performance, especially on big datasets. Private Datasets, on the other hand, are typically more reliable and validated.

### The way forward

There is definitely still room for further and enhanced research in the area, especially in light of the challenges that were stated earlier in this work and its limits. It is expected that when trained, the model that integrated a larger dataset, multiple types of data, and a hierarchal multi-class classifier into one model could eventually be accurate enough to be widely used in healthcare applications by considering the gaps and taking advantage of the outstanding achievements of earlier research. In addition, we must consider that such a model requires more computational power compared to others in these papers, but not to the point of limiting its use.

Finally, recommendations made due to these limitations are designed to assist researchers in building helpful models that advance AI applications in radiology for the detection of pneumonia, generate reliable results for other upcoming medical applications, and lead future interdisciplinary research in this area. As well, as to overcome and avoid applying these limitations that were implemented in research related to the COVID-19 pandemic, which can help radiologists, manufacturers, computer scientists, and clinicians adopt and employ the right and practical model for the upcoming pandemic. This will significantly save costs governments and hospitals a lot, provide an accurate diagnosis in a short time, and help overcome crises with the least possible losses.

## Conclusion

Despite significant advancements in AI models and an increase in extensive studies in healthcare applications, there is still a lack of utilization of AI models in healthcare. The problem of classifying and detecting COVID-19 has been the focus of numerous studies, especially in light of the pandemic's continuing influence. The novelty of this paper consists of the provision of the more prominent challenges and gaps in the prior studies of COVID-19 image classification, followed by a list of recommendations based on the analysis and theoretical background on topics relating to these issues that were studied in the previous review and that focus on the methods and main approaches that have been adopted in recent studies for further research and help develop an effective radiological diagnostic model for clinical applications.

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