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A Comprehensive Review of various Deep Learning Techniques for SARS-COVID-19 Detection

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Abstract— The COVID-19 pandemic continues to set alarming records in terms of both cumulative and daily infection numbers on a global scale. This unprecedented healthcare crisis necessitates accurate and swift methods for detecting COVID-19 cases through the analysis of patient data. Deep learning (DL) methods have demonstrated their utility in rapidly and effectively identifying and outlining infectious areas within radiological images. The research aims to provide a comprehensive overview of innovative deep learning-based applications in the context of medical imaging modalities, specifically computer tomography (CT), for the detection and classification of COVID-19. Initially, we will establish a taxonomy of medical imaging and offer a concise overview of various types of deep learning (DL) methodologies. Subsequently, we will utilize deep learning techniques to provide an overview of systems developed for the purpose of detecting and classifying COVID-19. Additionally, we will provide an overview of the most commonly employed databases for training these networks. Lastly, we will delve into the challenges associated with the implementation of deep learning algorithms in COVID-19 detection and explore potential avenues for future research in this field.

Keywords— COVID-19, Deep Learning, Computer Tomography, Medical Imaging, Detection.

I. INTRODUCTION

COVID-19, officially known as "Coronavirus Disease 2019," is an exceptionally contagious respiratory illness caused by the novel coronavirus named SARS-CoV-2. This ailment initially emerged in December 2019 in Wuhan, China, and has since evolved into a global pandemic, causing profound effects on health, economies, and society at large.

In December 2019, a novel febrile respiratory tract illness caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) was identified, leading to the emergence of the coronavirus disease 2019 (COVID-19). The common initial symptoms among COVID-19 patients include fever, cough, myalgia, dyspnea, and muscle aches. Despite the implementation of strict quarantine measures aimed at curbing its spread, the COVID-19 infection has swiftly disseminated, affecting countries across the globe. At the conclusion of January 2020, the World Health Organization (WHO) designated COVID-19 as a Public Health Emergency of International Concern. As of Sept., 2023, the WHO had reported a total of 44,997,326 confirmed cases worldwide, resulting in 532,023 deaths. While infection rates have been declining in China, many other countries continue to experience a rapid increase in new infections with new variant.[2]

The scientific community maintains an active focus on researching various aspects of COVID-19, encompassing its epidemiology, treatment options, and long-term consequences. Concurrently, research efforts are directed towards the monitoring and comprehension of new variants of the virus. The COVID-19 pandemic represents an ever-evolving and complex global challenge. Vigorous endeavors persist to vaccinate populations, monitor and respond to emerging variants, and furnish healthcare and support to those impacted by the disease. The implementation of public health measures and individual actions remains instrumental in mitigating the repercussions of COVID-19.

1.1 Role of Anamnesis and Clinical Symptoms:

The diagnosis of COVID-19 cases in patients also relies on their anamnesis, etiological factors, and symptoms, in addition to medical images. Clinical sampling for nucleic acid testing is a reliable criterion but has some limitations, such as insufficient specimens, a shortage of test kits, laboratory errors, uneven detection technology, erroneous sampling, and technical problems. Patients with negative RT-PCR results but with characteristic features in chest CT images have been found to test positive after repeating the swab test. Chest CT images can serve as a vital warning signal for individuals suspected of carrying the virus and can be very helpful for patients with any suspicious symptoms of COVID-19.

1.2 Importance of Early Diagnosis:

Early diagnosis of highly contagious COVID-19 patients can save lives by isolating suspected patients in quarantine or

Table I. Summary Of Types Of Lung Diseases

Name of author and year	Machine learning or deep learning model used	Binary or multiclass classification	Dataset used CT Images/Xray	Results
Nirmala Devi Kathamuthu et.al [2023] [6]	deep transfer learning, VGG16	COVID-19, Normal	252-COVID 1229-Non COVID	Accuracy-98% Precision, F1 Score, Recall-97.99
Aldimir Bruzadin et.al [2023] [7]	Learned Label Diffusion Segmentation, semi-supervised	COVID-19, Normal	Eight CT datasets sourced from the MedSeg Covid Database	F1- 0.9419 RI- 0.9802
Kapil Gupta et.al [2023] [8]	Employed Dark-Net19 and MobileNetv2 in conjunction with a transfer learning method, and both models underwent training using a reiterated 10-fold holdout cross-validation (10-FHCV) procedure.	COVID-19, Normal	1252-COVID 1230- non-COVID	Accuracy- DLM -95.93 MobileNetV2 - 97.62 DarkNet19 - 98.91
Md. Robiul Islam et.al [2022] [9]	deep learning model	COVID-19, Normal	1252-COVID 1230- non-COVID	Accuracy- 99.73% Recall- 100%.
Cinare Oguz et.al [2022] [10]	deep learning transfer learning ResNet-50 and SVM	COVID-19, Normal	607-COVID 738- non-COVID	Accuracy-96.296%, F1 Score- 95.868%
Dina M. Ibrahim [2021] [11]	deep learning model VGG19 +CNN model	Chest diseases such as COVID-19, pneumonia, and lung cancer.	X-ray and CT images 4320-COVID 5856 – pneumonia (XRAY) lung cancer 20,000 3500-Normal TOTAL- 33,676	accuracy - 98.05% recall 98.05% precision- 98.43% F1 score - 98.24%
TARANJIT KAUR et al. [2021] [12]	Utilizing deep features and the Parameter Free BAT optimized Fuzzy K-nearest neighbor (PF-FKNN) classifier with knowledge transfer learned MobileNetv2.	COVID-19, Normal	1252-COVID 1230-Non COVID	accuracy of 99.38%
Adnan Saood [2021] [13]	SegNet U-NET	COVID-19, Normal	1001 lung CT images	SegNet Sensitivity 0.956 Specificity 0.9542 U-NET Sensitivity 0.964 Specificity 0.948
Naveen Paluru[2021] [14]	Anam Net	COVID-19, Normal	929 lung CT images	Sensitivity 0.927 Specificity 0.998 Accuracy 0.985
Daryl L. X. Fung[2021] [15]	Deep Learning		7586 lung CT images	F1 score 0.63 Recall 0.71 Precision 0.68
Shuangcai Yin [2020] [16]	SD-UNet	COVID-19, Normal	1963 lung CT images	Sensitivity 0.8988 Specificity 0.9932 Accuracy 0.9906

specialized hospitals to control the outbreak. While chest X-rays are normally insensitive for the preliminary detection of the infection, they become useful as the disease progresses and pulmonary opacities develop, potentially leading to "whited-out lungs." Chest CT imaging is highly recommended for the early detection of the disease as it evaluates the extent and nature of the lesion, assessing changes not usually visible in chest X-rays.

1.3 Diagnostic Methods for COVID-19:

Reverse transcription-polymerase chain reaction (RT-PCR) is one of the standard diagnostic methods used to detect nucleotides from specimens obtained via oropharyngeal swab, nasopharyngeal swab, bronchoalveolar lavage, or tracheal aspirate. However, recent reports have indicated that the sensitivity of RT-PCR might not be high enough for detecting COVID-19. This can possibly be attributed to issues related to the quality, stability and insufficient viral material in specimens. On the other hand, chest Computed Tomography (CT) images captured from COVID-19 patients frequently exhibit bilateral patchy shadows or ground-glass opacity in the lungs. CT has become a vital complementary tool for detecting lung involvement in COVID-19. Compared to the RT-PCR test, chest CT is relatively easy to operate and has a high sensitivity for screening COVID-19 infection. Therefore, CT could serve as a practical approach for early screening and diagnosis of COVID-19 in China.

1.4 Comparison between CT and RT-PCR:

Studies have indicated that the effectiveness of chest CT imaging is higher compared to RT-PCR at an early stage of infection, with a reported sensitivity of 98% versus 71% for RT-PCR. This makes CT images a valuable diagnostic tool, especially considering the limitations of RT-PCR testing.

1.5 Challenges with CT Imaging:

However, with the increment of confirmed and suspected cases of COVID-19, manually contouring lung lesions in CT images is a tedious and labor-intensive task. To speed up diagnosis and improve access to treatment, developing a fast automatic segmentation for COVID-19 infection is critical for disease assessment.

1.6 Role of Deep Learning and Automation:

Role of Deep Learning and Automation:Due to the limitations of manual analysis and the increasing number of patients, there is a need for automated prediction techniques to analyze chest CT images with high sensitivity and speed. Researchers have been using publicly available medical images since March 2020 to develop automated methods for COVID-19 detection using deep learning approaches. In recent times, various deep learning schemes have been proposed for COVID-19 infection detection via radiographic images. These methods aim to automate the analysis of chest X-rays and CT images to improve the accuracy and speed of diagnosis.

While RT-PCR remains a standard diagnostic method for COVID-19, its sensitivity may have limitations. Chest CT imaging has proven to be a valuable complementary tool with a higher sensitivity, especially in the early stages of infection. Automated segmentation and deep learning techniques are being employed to streamline the analysis of medical images and improve the efficiency of COVID-19 diagnosis, which is crucial for controlling the outbreak.

1.7 Types of Lung Disease

Lung infections encompass a range of illnesses that impact the respiratory system, with a primary focus on the lungs. These infections can stem from various microorganisms, such as bacteria, viruses, fungi, and parasites.

The successful treatment and management of lung infections rely on the particular underlying cause. Healthcare providers frequently employ diagnostic procedures like chest X-rays, CT scans, and cultures to pinpoint the responsible microorganism and establish the most suitable course of treatment, which can encompass antibiotics, antiviral medications, or antifungals.

This paper offers an overview of diverse deep-learning algorithms employed in the detection and classification of COVID-19 using CT radiography. The structure of this review is as follows: Section 2 provides fundamental background information on deep learning techniques. In Section 3, we delve into deep learning systems tailored for various image categories. Future directions and challenges are outlined in Section 4. Lastly, Section 5 offers the concluding remarks for this paper.

Table II. Summary Of Types Of Lung Diseases

Sr. No.	Name of Lung Diseases	Features
1.	COVID	White, ground glass opacities (GGO): These refer to areas of hazy opacification in X-rays or increased attenuation in CT scans. They are often seen in cases of corona pneumonia and can result from various factors such as fluid displacement, airway collapse, fibrosis, or neoplastic processes. COVID pneumonia typically manifests along the lung lobe walls, particularly in regions near the chest wall and the lower sections of the lungs.

2.	Pneumonia	Inflames the air sacs of the lungs, known as alveoli. This inflammation can lead to the filling of the air sacs with fluid or pus, resulting in symptoms such as coughing, fever, chills, and difficulty breathing. Typically, the lower lobes of the lungs are the most commonly affected. The presence of patchy areas of consolidation indicates the accumulation of neutrophils in the alveoli and bronchi. Lobar pneumonia is characterized by acute exudative inflammation that affects an entire lobe of the lung.
3.	Tuberculosis	Resulting from infection with the bacterium Mycobacterium tuberculosis. CT scans revealing the reactivation of pulmonary tuberculosis (TB) exhibit certain characteristic features, including Small centrilobular nodules, linear opacities with branching patterns, areas of patchy consolidation, and the formation of cavities. Post-primary TB typically affects the upper lobes and the superior segments of the lower lobes of the lungs.
4.	Asthma	Thickening of the bronchial wall. Constriction or narrowing of the bronchial lumen. Regions exhibiting reduced attenuation and vascularity during inspiration. Inflammation and narrowing of the airways can develop.
5.	Emphysema	Chronic Obstructive Pulmonary Disease (COPD) is characterized by several features, including the enlargement of arteries in the lungs. The air sacs in the lungs, known as alveoli, suffer damage. This damage leads to the weakening and rupture of the inner walls of the air sacs, resulting in larger air spaces rather than numerous small ones. Consequently, the available surface area for gas exchange is reduced. It predominantly affects the upper half of the lungs.
6.	Lung Cancer	A mass in the lungs often appears as a white spot against the black background of the lung tissue. X-ray imaging may not have the sensitivity to detect small or early-stage cancers.
7.	Lung Edema	Occurs when an excessive buildup of fluid in the lungs takes place. accumulates in the multiple air sacs within the lungs, leading to respiration challenges. Although cardiac issues are the primary contributor, other factors can also lead to fluid retention in the lungs. In chest X-rays and CT scans, post-obstructive is commonly identified by the presence of septal lines, parabronchial thickening, and, in serious cases, central alveolar swelling.

II. Basics & Background

A. Deep Learning

Deep learning constitutes a subset of machine learning hinging on artificial neural networks. This approach excels at deciphering intricate patterns and connections within datasets, eliminating the need for explicit, rule-based programming. The surge in deep learning's popularity can be attributed to advancements in computational capabilities and the accessibility of extensive datasets. Central to deep learning are artificial neural networks, also referred to as deep neural networks (DNNs). These networks draw inspiration from the architecture and operations of biological neurons in the human brain, allowing them to acquire knowledge from vast datasets. Machine learning encompasses a field wherein models are trained on substantial datasets to make predictions based on input data. Within this domain, neural networks represent a collection of algorithms engineered to identify patterns. One specific form of deep neural network, known as the Convolutional Neural Network (CNN), finds widespread use in diverse applications.

B. Convolutional Neural Networks

CNNs, or Convolutional Neural Networks, find extensive application in visual document analysis and various pattern recognition tasks [8,9]. Their utilization in the medical field has witnessed a significant upsurge, yielding noteworthy achievements in the classification of medical images [10]. Researchers have introduced several distinct CNN models tailored to the detection of anomalies in medical images, including the identification of lung nodules.

Recent findings underscore the pivotal role of CNNs in the detection of COVID-19 through medical imaging modalities like Computed Tomography (CT). These neural networks are characterized by multiple layers dedicated to the extraction of distinctive features from input images, which are subsequently employed in the classification process.

- **CNN Architecture**

CNN architecture is stacked with three primary layers namely the Convolutional layer, Pooling layer, and Fully Connected layer.

- **Convolutional layer**

In CNNs, the responsibility of extracting various features from input image patterns is achieved through the use of convolutional layers. These layers consist of a set of learnable filters or kernels, which are essentially small matrices. These kernels slide or convolve over the input data, performing a dot product operation with the input data at each position they traverse. As the kernels slide over the input from left to right and top to bottom, they generate feature maps by applying this dot product operation. Each feature map corresponds to a specific filter and captures a particular feature or pattern from the input image. These feature maps highlight different aspects of the input, such as edges, textures, or more complex patterns. In deeper layers of a CNN, feature maps are constructed by combining and processing the feature maps from earlier layers through additional convolutional operations and other neural network operations like pooling and activation functions. This hierarchical feature extraction process allows CNNs to learn and represent increasingly abstract and complex features from the input data.

- **Pooling layer**

The pooling layer, typically located after a convolutional layer in a neural network, serves the purpose of down sampling and reducing the number of parameters and computations. One of the most widely utilized pooling operations is known as max pooling, which selects the maximum element from a given region within the feature map. This process of downscaling via pooling helps to preserve important features while reducing the spatial dimensions of the feature maps, making them more computationally efficient and manageable.

- **Fully Connected layer**

The fully connected layer, often referred to as the FC layer, is typically the final layer in the neural network architecture. This layer is designed with a dimensionality that matches the number of output classes. It receives input from the previous stages of the network and is responsible for making the final classifications or predictions for the input data, such as images.

- **Dropout Layer**

The dropout layer is often employed as a preventive measure against overfitting, particularly when all features are connected to the fully connected (FC) layer. Positioned before the output layers, the dropout layer introduces randomness by randomly deactivating a subset of neurons within the neural network. This random deactivation of neurons leads to a reduction in the model's size [1].

- **Activation Function**

Activation functions are crucial components within neural networks. They transform the output from the preceding layer into a format suitable for the subsequent layer to process as its input. These functions are indispensable because, without them, the model would be unable to capture intricate patterns in the data. One of their key functions is to introduce nonlinearity into the network, which is essential for enabling the network to learn and represent complex relationships in the data. Among the commonly employed activation functions are Rectified Linear Unit (ReLU), SoftMax, sigmoid, and tanh, with ReLU being the most prevalent choice in deep learning models [2,3].

III. BINARY CLASSIFICATION

Binary classification is a type of categorization in which the outcome consists of only two categories. Examples of such classifications include distinguishing between COVID-19 and normal cases, COVID-19 and non-COVID-19 cases, and COVID-19 and pneumonia.

IV. CONCLUSION

In conclusion, this review primarily focused on the application of deep learning networks for automated detection of COVID-19. The paper discusses various algorithms developed in previous studies that utilize deep learning techniques for the detection and classification of SARS-CoV-2, utilizing two imaging modalities: CT scans and X-ray samples. Several studies have made use of combined datasets to enhance the performance of deep learning models in COVID-19 detection. Within this paper, we have compiled sources of accessible datasets for the convenience of researchers. One of the prominent challenges highlighted is the lack of standardized benchmarks for COVID-19 classification systems built upon deep learning methods. It is imperative to urgently develop deep learning systems that exhibit superior performance in the early-stage identification of COVID-19 and offer support to radiologists in their diagnostic processes.

REFERENCES

[1] Keiron O'Shea, Ryan Nash, "An introduction to convolutional neural networks," in arXiv preprint arXiv:1511.08458, 2015.

[2] Himadri Mukherjee, et al., "Deep neural network to detect COVID-19: one architecture for both CT Scans and Chest X-rays," Applied Intelligence, 2021, pp. 2777–2789.

[3] Chandra Kusuma Dewa, "Suitable CNN weight initialization and activation function for Javanese vowels classification," in Procedia Computer Science 144, 2018, pp. 124–132.

[4] M. Qian, Q. Yi, F. Qihua, and G. Ming, "Understanding the influencing factors of nucleic acid detection of 2019 novel coronavirus," Chin J. Lab Med., vol. 10, pp. 1–7, 2020.

[5] Link- https://covid19.who.int/region/searo/country/in

[6] N. D. Kathamuthu et al. ," A deep transfer learning-based convolution neural network model for COVID-19 detection using computed tomography scan images for medical applications," Advances in Engineering Software, Oct. 2022.

[7] A. Bruzadin et al.," Learning label diffusion maps for semi-automatic segmentation of lung CT images with COVID-19," Neurocomputing, pp. 24-38, Dec. 2022.

[8] K. Gupta and V. Bajaj," Deep learning models-based CT-scan image classification for automated screening of COVID-19", Biomedical Signal Processing and Control, Sept 2022.

[9] M.R. Islam and M. Nahiduzzaman," Complex features extraction with deep learning model for the detection of COVID19 from CT scan images using ensemble based machine learning approach", Expert Systems With Applications,Feb. 2022.

[10] Ç. Oğuz and M. Yağanoğlu," Detection of COVID-19 using deep learning techniques and classification methods", Information Processing and Management, July 2022.

[11] D.M. Ibrahim et al.," Deep-chest: multi-classification deep learning model for diagnosing COVID-19, pneumonia, and lung cancer chest diseases" Computers in Biology and Medicine, March 2021.

[12] Kaur et al." Automated Diagnosis of COVID-19 Using Deep Features and Parameter Free BAT Optimization", Medical Imaging and Diagnostic Radiology, July 2021.

[13] A. Saood, et al.," COVID-19 lung CT image segmentation using deep learning methods: U-Net versus SegNet", BMC Med.Imaging,2021.

[14] Paluru et al.," Anam-Net: Anamorphic Depth Embedding-Based Lightweight CNN for Segmentation of Anomalies in COVID-19 Chest CT Images". IEEE Trans. Neural Networks Learn. Syst., vol-32, pp. 932–946. 2021.

[15] D.L.X. Fung et al.,"Self-supervised deep learning model for COVID-19 lung CT image segmentation highlighting putative causal relationship among age, underlying disease and COVID-19", J. Transl. Med., vol. 19, PP. 1–18, 2021.

[16] Shuangcai Yin et al.," SD-UNet: A Novel Segmentation Framework for CT Images of Lung Infections", Electronics, 2022.

[17] Wang, W., et al.,"Detection of SARS-CoV-2 in different types of clinical specimens", JAMA vol. 323(18),pp. 1843–1844, 2020.

[18] A.S. Al-Waisy et al., "COVID-DeepNet: hybrid multimodal deep learning system for improving COVID-19 pneumonia detection in chest X-ray images," in Computers, Materials and Continua, pp.2409–2429,2021.

[19] Patrice Y. Simard et al., "Best practices for convolutional neural networks applied to visual document analysis," in Icdar Vol. 3, 2003.

[20] [20] Z. Li et al., "From community-acquired pneumonia to COVID-19: a deep learning–based method for quantitative analysis of COVID-19 on thick-section CT scans," Eur. Radiol., vol. 30, no. 12, pp. 6828–6837, Dec. 2020.

[21] F. Shan et al., "Abnormal lung quantification in chest CT images of COVID‐19 patients with deep learning and its application to severity prediction," Med. Phys., vol. 48, no. 4, pp. 1633‐ 1645, Apr. 2021.