Detection of Covid-19 from Digital Chest X-Ray and CT Scan Images using Deep Learning and Machine Learning Techniques: A Comprehensive Review

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Abstract
Purpose: *The world was facing a global health crisis in December 2019 and World Health Organization declared a state of biological emergency on 30 January 2020 due to a newly emerged virus called SARS-CoV (Severe Acute Respiratory Syndrome Coronavirus). According to the report published by WHO, there were 761 million confirmed cases and 6.8 million deaths were reported globally as of 21 march 2023. Artificial intelligence which includes Deep learning has played a great role in tackling medical emergencies so far, Purpose of this paper is to throw light on the work done to detect Covid-19 using X-ray images and CT-Scan images, Present paper will act as trailblazing and State of Art for all the future work that needs to be done.*
Methods: *The main challenge for the healthcare department was to detect the virus at the earliest to give suitable treatment to the patient. The prevailing RT-PCR (Reverse Transcription-Polymer Chain Reaction) takes 2-3 days. Therefore, it was an urgent call to engage Artificial intelligence in the system for timely results. Radiological images combined with AI (Artificial Intelligence) proved to be a very powerful tool in the early detection of various diseases. We have collected and scrutinized the best papers that have proposed deep learning models. A total of 104 papers are used for the review.*
Results: *Promising results are given by different deep learning models, some of the models have achieved accuracy and precision of up to 100%. Novel architectures have performed better as compared with the pre-trained deep learning model in terms of accuracy but we cannot justify which model is best as dataset used by each model is different.*
Conclusion: *Deep analysis of the models implemented by different researchers has shown huge potential in winning the war against Covid-19. Our findings also indicate some of the challenges that need to address for the proper implementation of AI models in the medical sphere.*
Keywords: *Covid-19, Artificial Intelligence, Deep Learning, Chest X-ray Images, Computed Tomography Images.*

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I. Introduction

In December 2019, the world was facing the dreadful disease later that was officially named 'COVID-19' by WHO. It was called Severe Acute Respiratory Syndrome Coronavirus 2 by the International Committee on Taxonomy of Viruses [1].

World Health Organization reported around the globe 1,696,588 confirmed cases and 105,952 deaths so far until 12 April 2020 [2]. Coronavirus cases were growing at an exponential rate evidenced by another report published, by WHO which includes 460,280,168 confirmed cases and 6,050,018 deaths on 16 March 2022. To control the increasing death rate, the chain needs to be broken and it can be done by social distancing and massive diagnosis of the disease among the masses [3].

1.1 Background and Origin

In December 2019, many cases of pneumonia of unknown etiology were reported at hospitals in Wuhan city in China. The patients infected with this pneumonia have common symptoms like fever, cough, cold, and throat pain. On 31 December 2019, Health Departments from China informed the WHO about these cases in China, which have been reported in Hospitals since 8 December 2019 [4]. Because of increasing day-to-day cases, Wuhan Health Authorities ordered the shutdown of the Animal Food market because reported cases were suspected to have links with the Huanan seafood market [5]. On 5th January 2020 WHO (World Health Organization) published an official document to request China's Health care Authorities to give detailed information about the patients suffering from unknown pneumonia. Later, WHO published a report, which informs that 11 critically ill patients and other severely infected patients had close contact with the Huanan Seafood market [6]. On 7 January 2020,2019 n-CoV was abbreviated for Novel coronavirus which was later renamed by the research group as SARS-CoV-2 (severe acute respiratory syndrome coronavirus 2) [7]. WHO named this disease COVID-19. According to a report published by PAHO (Pan American Health Organization), there were a total of 7,818 confirmed active cases of Covid-19, with 178 deaths on 30 January 2020. Given the increasing number of Covid-19 cases WHO declared the Public Health Emergency of International Concern on 30 January 2020 [8]. The rise of Covid-19 cases in the world from 22 January 2020 to 16 March 2022 is shown in the graph given in Figure 1.

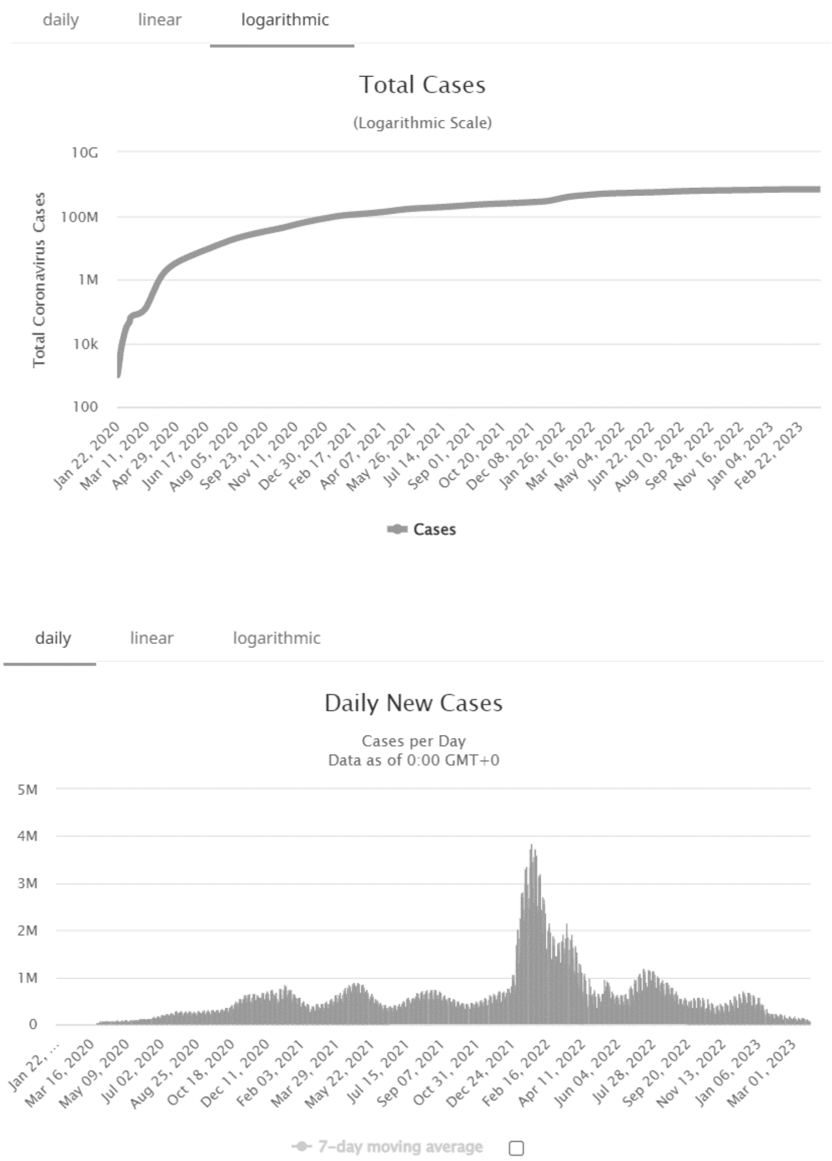

Figure 1: *Upper Graph representing total Coronavirus cases on a logarithmic scale, a Lower graph representing the rise in Covid-19 cases each day (Source:Worldometers)*

1.2 Epidemiology, Etiology, and Clinical Features

Current Studies suggest that Covid-19 is more dangerous to people who are already suffering from other diseases like Cardiovascular disease, diabetes, Hypertension, and many more [9]. The severity of Covid-19 has also shown a positive correlation with the age of a person, it is life-threatening to old age persons [10]. Children and Pregnant Women are also on verge of getting life-threatening effects from this virus. As per current data, Transplacental transmission of the virus from pregnant women to their fetuses has not been noticed [11]. Non-survivor is most likely to have hypertension and diabetes as compared to survivors [12]. According to data published by WHO on 27 February 2022 USA (United States of America) has the highest number of total cases up to 78,050,838 including 529,249 in the last seven days and 935,093 deaths till now followed by India having 42,894,345 total cases including 114, 110 cases in the last seven days and 513,226 deaths. However, the Mortality rate is different for each country. Beginning in China where the first case was reported the second case from outside china was reported in Thailand and then within a month cases were spread all over the world except Antarctica as of 3 February 2020 [13]. As of 15 January 2022, all countries have active cases except 4 countries namely North Korea, Turkmenistan, Tuvalu, and Nauru.

Coronaviruses are mainly found in various species of birds, snakes, bats, and mammals. CoVs are single-stranded RNAs that belong to the family of Coronaviriade [2]. The coronaviridae family has been further divided into Alpha, Beta, Delta, and Gamma. HCoV-NL63, HCoV-HKU1, HCoV-229E, and HCoV-OC43 are some of the CoVs identified in Human beings [14]. Microscopic observations define that COV Virus has a crown-like structure and has about 80-120 nm diameter [15]. The Genome sequencing of SARSCOV2 shows that Bat SARS (SARSr-CoV-RaTG13) and SARS-COV were 96% and 79.5% respectively [1]. SARS-COV 2 binds with the target cell through ACE2 also known as the angiotensin-converting enzyme which is present in the lungs [16]. This virus mainly causes problems in the lungs and is responsible for pulmonary diseases. Although the exact transmitter of the virus hasn't been known Bats are known to have transmitted this virus to a human host [2].

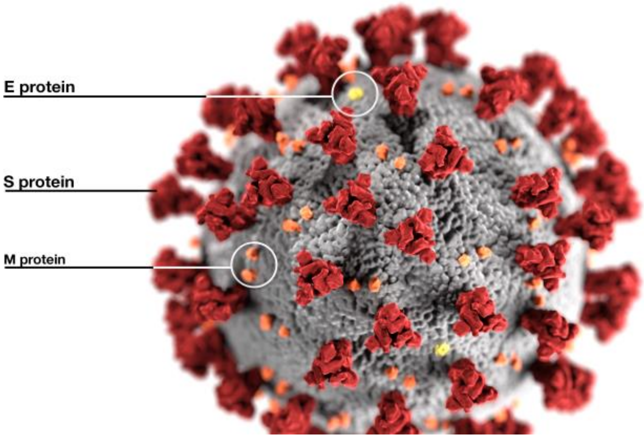

Figure 2: *Coronavirus structure containing E, S, and M protein particles (Source: Public Health Image Library)*

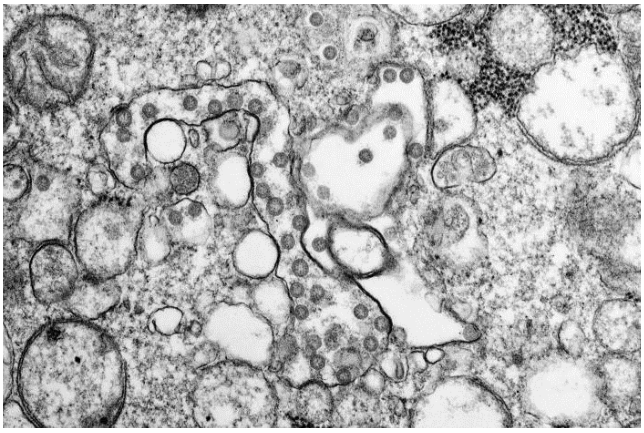

Figure 3: *Microscopic image of transmission electron of Covid-19 (Source: Public Health Image Library)*

Coronavirus is a respiratory disease that has common symptoms of cold, cough, fever, stuffy nose, and problems breathing [10]. However, fever is dominant in all the symptoms. In a large survey at hospitals in China, 44% of patients have a fever at the time of admission but it increased to 88% later on [17]. Patients with a history of Covid-19 created pretentious circumstances for the spread of mucormycosis commonly called black fungus [18].

Laboratory findings of 1099 confirmed cases reported by [19] show that Covid-19 symptoms include 13.6% headache, 5.0% vomiting, 13.9%sore throat, 18.7% shortness of breathing, 67.8% cough, and 88.9% fever [19]. Although most cases are symptomatic 18% of Covid-19 positive cases remain asymptomatic [20]. Multiple studies have justified that Asymptomatic patients also have the potential to infect others [20], [21]. Symptoms at the initial stage of Covid-19 patients are not specific so Medical authorities have to perform different diagnoses [23]. The effect of the disease is seen to be milder in children than in adults [24].

1.3 Transmission, Diagnosis, and Prevention

The virus mainly spread through the air, tiny droplets from infected persons travel through the air and infect other people. It has been seen RNA virus is present in the stool of some patients which can be the cause of Oral transmission [25]. Isolation of an infected person is an effective way to prevent the spread from one person to another. According to the data reported from 2020 and 2021, People lose their olfactory and confirmed that they suffer from hypersomnia, which has been tested from psychophysical testing. Generally, Patients lose their smelling power and recover after 1-2 months after diagnosis with the virus [26]. After the outbreak of the pandemic, healthcare workers faced a major risk because they have to deal with patients so PPE kits come into play for protecting the people who are in contact with patients. Surgical masks and sanitizers were recommended. Prevention measures for Covid-19 include using personal protective equipment, identifying and monitoring contacts, disinfection of the environment, and quarantining the infected person [27].

In the initial stage of the Covid-19 pandemic, specific molecular tests on sputum, throat swab, and other respiratory samples were performed however multiple PCR does not provide any commercial tests specifically for Covid-19 [24]. At the time of writing this paper, multiple diagnostic measures are available which include RT-PCR, Nucleic Acid Test (NAT), Antigen test, Antibody test, and Radio imaging tests [28]. Some precautionary measures that should be taken into consideration while collecting samples are a PPE kit (Personal Protection Equipment) very necessary to avoid contact between suspected patients and health care workers secondly, transportation and storage of collected samples should be done very carefully to prevent false-positive and false-negative results, Also patients suffering from Covid-19 have low platelets so swab collection should be done very cautiously to avoid nose bleeding and other effects [28]–[30]. Currently, RT-PCR has been termed the Gold Standard for diagnosis of Covid-19 [27] but the time taken by RT-PCR to show exact results require 5-6 hour [31]. Various efforts are made from all over the world to reduce the time for diagnosis of the dreadful disease for quick treatment in response to which CT Scan image testing, and X-ray image testing in combination with Artificial intelligence and machine learning have been developed for rapid results but these techniques cannot fully replace the prevailing RT-PCR testing [31]. VTM (Viral Transport Media) solution is used which has the property of extracting nucleic acid due to which RT-PCR does not require extracting extra RNA [32]. Three types of kits are utilized for RT-PCR i.e. CoVirion-CV19-2 SARS-CoV-2 OneStep, QIAseq DIRECT SARS-CoV-2, and Bio speedy SARS-CoV-2 Variant Plus [32].

II. Overview of Deep Learning and Methods for Covid-19

Before we jump into how researchers have implemented various systems for Covid-19 using X-ray and CT images, we should have a thorough understanding of deep learning. Deep learning is a subset of a broad family of Machine learning algorithms that has the property to deal with both unstructured and structured data. Deep learning is a very powerful tool in view that it can manage even minute details of complex features of unstructured data. Machine learning can be defined as a subpart of Artificial intelligence. Machine learning can help to build such systems, which will automatically improve their performance just by analysing results obtained throughout the time and data fetched during training. Deep learning can be seen as a hot topic in today's world where everything is aligning with technology. Machine learning has been used in a variety of fields due to its never-ending applications such as Image recognition that has its wide scope in medication of different diseases, Speech recognition, unmanned systems, recommendation systems that are used in most social networking sites, and famous eCommerce sites like Amazon, Flipkart, etc. Machine learning is proved very helpful in the fight against Covid-19; researchers have discovered a variety of applications based on machine learning to fight against Covid-19. Development in machine learning has resulted in many health care automated systems [33]. By analysing the patterns from available data, machine learning helps to track the history of the patient and possible risks, also machine learning plays a very significant role in understanding the virus by mapping it to other viruses which will help make the drug for the virus [34], Apart from this Deep learning is one of the main focus to prepare such system which will be helpful in the diagnosis of Covid-19 from radiological images. Different frameworks are designed for contactless working in pandemics [35].

2.1 Types of Deep learning approaches

2.1.1 Deep Supervised learning

Supervised learning is a technique in which a model operates on labeled data i.e. valid outputs of training data are already available and the model learns from those outputs. In the case of Deep learning, there are different supervised learning techniques like convolutional neural networks (CNN), Long Short term memory, and Deep Neural Networks [36]. The main advantage of deep supervised learning is that it learns from the already available dataset and the disadvantage is when the dataset does not have samples, then the decision boundary can get overstrained [36].

2.1.2 Deep Unsupervised learning

Unsupervised learning is a technique in which the model operates on unlabelled data and tries to find out hidden patterns. Outputs are not available for training and testing. K means clustering, neural nets, and Self-organizing maps are some of its famous types. Deep Boltzmann machines and (DAC) Deep autoencoders [37]are famous methods. It found its application in medical image analysis for instance unsupervised learning is used in the classification of brain MRI (Magnetic resonance imaging) [38].

2.1.3 Deep Reinforcement Learning

Reinforcement learning can be defined as feedback-based learning in which the model continuously acts and learn from the results obtained from the action. Reinforcement learning combined with deep learning has a wide variety of applications in IoT, the Gaming world, Graphical user interfaces, etc. It found its application in Medicine as well, for example, In [39] researcher has purposed a deep reinforcement learning model to diagnose lung cancer.

2.2 Types of Deep Learning Networks

2.2.1 Convolutional Neural Network (CNN)

In 1960 Convolutional Neural Network was first-time purposed by Hubel, David H Wiesel, and Torsten N [40]. Convolutional networks are widely used for recognition tasks or more specifically in computer vision [41]. The main advantage of CNN in comparison to other existing networks is that it can extract features from unstructured data or images without human intervention [42]. CNN is helpful to make full use of two-dimensional data like image signals [36]. CNN can be employed in building various applications to mitigate the effect of Covid-19 like Covid-19 mask detection, maintaining social distancing, and Covid-19 diagnosis with X-ray and CT images. In [43] Methods for Screening, detection, and classification of Covid-19 have been provided using CNN which gives medical practitioners multiple benefits.

2.2.2 Recurrent Neural Network (RNN)

A recurrent neural network (RNN) is an extension of a feed-forward network. In this network, the output of one layer is used as input, which helps to predict the next pattern. It has found its applications in Natural Language processing. RNNs are experts to work on time series data and help extract contextual dependencies by finding dependencies in timestamp data [44]. Since RNN is used to predict future results by analysing previous patterns by using this property Researchers have used RNN to build a model for early detection of Covid-19 [45]. Temporal sequence data is used to train RNN to build a mechanism to predict the mortality rate of Covid-19 [46]. RNN and LSTM are used to detect the number of Covid-19 cases in India by feeding the models with data related to prior Covid-19 cases in India [47].

2.2.3 Long Short Term Memory (LSTM)

Long Short-term Memory has a greater capacity of memory than a traditional Recurrent neural network, Unlike Recurrent neural networks, LSTM also includes feedback connections. LSTM recurrent network is used for the sentimental analysis of comments from different social media platforms related to Covid-19, it can help to understand issues related to Covid-19 and appropriate solutions can be provided [48]. In [49], LSTM is used to predict the number of tourists from China who can visit the USA and Australia after the Covid-19 outbreak. LSTM has also played a great role in predicting the possible rate of mutations of the virus in the future [50]. An ensemble method based on LSTM for predicting the number of confirmed Covid-19 cases in India [51].

2.3 CNN Architecture

2.3.1 AlexNet

AlexNet has been used for many years and is one of the oldest Architecture almost 10 years from 2022 [36]. In the beginning, AlexNet was limited to recognizing handwritten text only and now it has been modified to recognize high-resolution pictures. AlexNet resembles Lenet but is deeper than Lenet [52].The author [53] has used AlexNet in combination with ResNet81, SqueezeNet, and DenseNet to classify images into COVID-19 or Normal or pneumonia, and the Author has achieved remarkable results with 99.55% accuracy.

2.3.2 GoogleNet

GoogleNet is a novel inception model, it is also called Inception V1, GoogleNet's main aim is to achieve high-level accuracy and reduce the overall computational cost [36], [54]. The author [55] has used GoogleNet pre-trained model and has achieved an accuracy of 93.98%.

2.3.3 VGG (Visual Geometry Group)

It is one of the most standard deep convolutional networks containing multiple layers for better performance. The word 'Deep' is used to signify the number of layers present in VGG i.e. VGG16 OR VGG19. In [56] The researcher has used VGG16 two-class output and VGG16 three-class output where specificity 97.27 and 91.5 are achieved for both models respectively. VGG19 has achieved an accuracy of 96.6% in detecting Covid-19 from X-Ray images [57].

2.3.4 Xception

Depth wise separating the convolutional layers is the main idea behind Xception while Extreme inception architecture was the main theme of Xception [36], [58]. Xception has achieved the highest accuracy in detecting COVID-19 among all CNN models but it has performed worst in detecting normal cases [59]. In [60] Inception V2 and Inception V3 are concatenated with other layers and two new models are prepared which classify the images into four types: normal, COVID-19 cases, viral pneumonia, and tuberculosis cases. This model has attained an accuracy of 99.80% and 99.71%.

2.3.5 MobileNet

Deep Neural Networks require large memory spaces So, MobileNet can be used to decrease computational complexity and the number of parameters used by applying depth wise separable convolutions [61]. MobileNet is trained from scratch for extracting the features of six different diseases. The model has performed in an excellent way to achieve an accuracy of up to 99.18% [62]. The model was built on top of Mobile-Net V2 and a validation score of 100% is reported from the purposed architecture [63].

2.3.6 DenseNet

DenseNet as its name specifies is a densely connected convolutional network. All its layers are densely connected. Suppose there are n layers then the first layer is connected with the second layer, third layer, fourth layer, and so on to the nth layer similarly the second layer is connected with the third layer, fourth layer, and so on to the n^{th} layer. In [64] researchers used DenseNet predicted 95% accuracy for detecting Covid-19, Pneumonia, and Normal chest X-rays, which shows DenseNet has great interpretability. Many researchers have achieved good results in detecting Covid-19 through x-ray images using DenseNet [65]–[67].

2.3.7 SENet

SENet is widely abbreviated as Squeeze and excitation net. SENet has shown increasingly improved performance with a small amount of increase in computational power [68]. SENet has shown a promising performance of about 99% accuracy in detecting Covid-19 through x-ray images [69]. SENet has shown good results in detecting Covid-19 using x-ray images [70]–[72]. SENet can be extended to form GoogleNet and ResNet architectures. SeNet purposed by [68] was declared the winner of the ILSVRC Challenge having a top-five error rate of 2.251% [59].

2.3.8 ResNet

ResNet introduced as a Residual Network is found to have the largest threshold for depth as compared to traditional Convolutional networks. In [73] ResNet 50 is used to differentiate between Covid-19, pneumonia, and normal x-ray and has resulted in achieving an accuracy of 97.4% at a 95% confidence interval.

2.3.9 Novel Architectures

Besides pre-trained CNN models, There are many Novel Architectures purposed by different researchers which have given astonishing results. Covid-Net is purposed which has achieved an accuracy of 97.99% [74]. The researcher has used modified XceptionNet which results in 95.80% accuracy [3]. Long short-term memory and CNN are used to detect Covid-19 and have resulted in 99.4% accuracy,99.3% sensitivity, 99.2% specificity, and 98.9% F1 score [75].[76] has proposed a LiteCovidNet Architecture which is trained on less than 5 million parameters.

III. Survey Methodology

We have selected articles for our literature review from Research Gate, Google Scholar, Medline, Embase, and PubMed that are readily available and published from 1stJanuary 2020 to 31st March 2023. Search Query includes a combination of SARS-COV-2, Covid-19, Deep learning, CNN, Diagnosis, Detection, Chest X-ray, X-ray, CT Scan, CT images, and Radiological image.

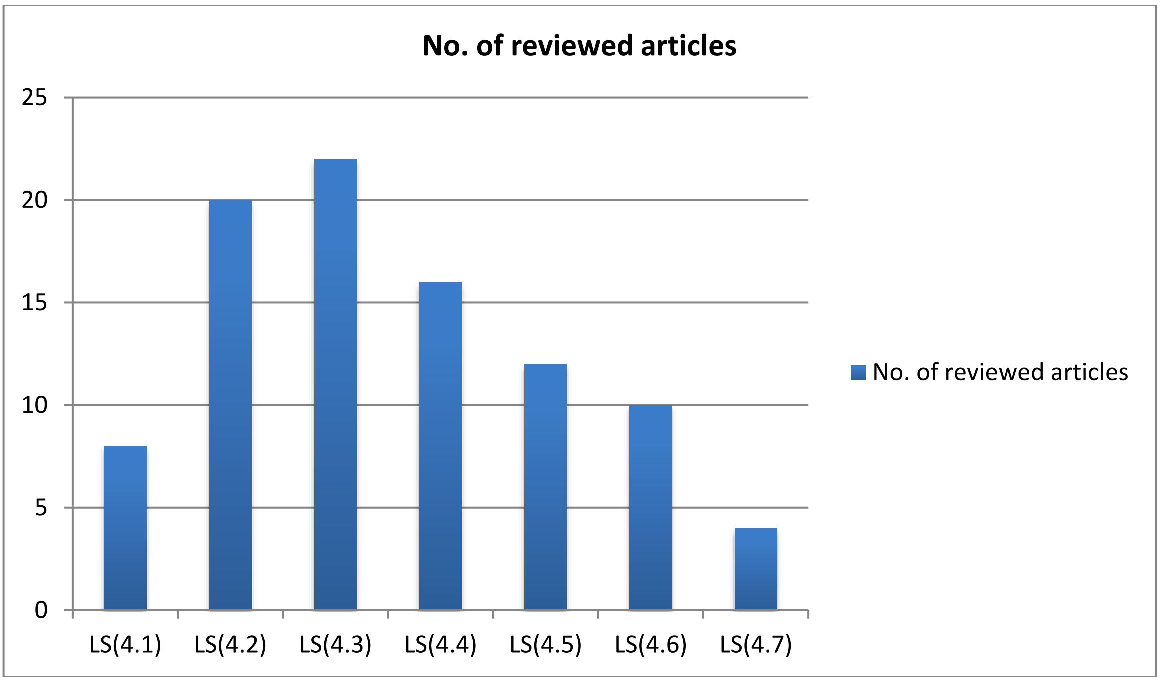

Figure 4: *Number of articles reviewed in each section of the Literature Review*

Here, the Literature review is divided into four months for each section starting from January 2020 to March 2023.

IV. Literature Survey

4.1 January2020 to April 2020

[77] has used 1020 CT (Computed Tomography) images to differentiate Covid-19 from Non-Covid-19 using 10 pre-trained CNN architectures and has observed best performance was given by ResNet-101 and XceptionNet, Where ResNet-101 has AUC i.e Area under Curve of 0.994 with an accuracy of 99.51%,98.04% sensitivity, and 99.02% specificity, In parallel achieving a promising performance Xception was able to achieve AUC of 0.994, 99.02% of accuracy, 98.04% sensitivity, and 100% specificity.[78] used 126 CT scan and X-ray images due to the non-availability of Covid-19 data at the beginning of the pandemic but the small number of images can cause overfitting problems so, image augmentation and data oversampling methods were used to increase the dataset, Handcrafted feature extraction method was purposed which achieved the accuracy up to 90%.Support vector machine(SVM) and Multilevel thresholding was used to distinguish between chest x-ray of lung infected with Covid-19 and normal chest x-ray and the purposed method achieved high accuracy of 97.48%, Specificity of 99.7%, and sensitivity of 95.76% [79]. The large data set of 1500 chest x-ray images of a Covid-19 infected person and the non-infected person, trained the SDD 300 model, and the model a chieved a specificity of 92% and 94.92% sensitivity [80]. YOLO (You Only Look Ones) for real-time detection of the object was used, Darknet model with 17 Convolutional layers was implemented to detect Covid-19 or no Covid-19 and Covid-19 or no Covid-19 or pneumonia for binary and multiclassification respectively [81]. A new enhanced model was purposed which is based on existing 2 Dimensional and 3 Dimensional models, also the latest understanding of clinical features of coronavirus was used to achieve a specificity of 92.2% and sensitivity of 98.2% [82]. A web-based tool for diagnosis of Covid-19 through Chest X-ray was purposed using RESNET-50 and this model has an accuracy of 99%, a precision of 99%, a Recall value of 99.8%, and an F1 score of 99.8% [83]. Convolutional

Neural Network (CNN) was used to classify Covid-19 and normal cases, Good results were obtained from CNN but it has suffered from tunning of hyper parameters [84].[85] Proposed an enhanced CNN using 22 layers to build a model for classifying Covid-19 and non-Covid-19, the model was able to achieve 95.7% accuracy for Covid-19 detection, 96.7% accuracy for detecting pneumonia, and 93% for normal cases.

4.2 May2020 to August2020

nCovnet which is based on the deep neural network has been proposed by the author for the fast detection of Covid-19 using Chest X-ray, nCovnet can detect whether the suspected patient is Covid-19 positive or not in five minutes [86]. [87] has proposed a deep learning model which consists of 41 layers and is based on XceptionNet, In the output section of the model, dense layers are connected and no convolution blocks are repeated, this model was able to achieve 96.48 accuracies for identifying normal chest X-ray, 96.13% accuracy in identifying pneumonia chest X-ray, and 98.94% accuracy in identifying Covid-19 positive chest X-ray. [88] has proposed the CNN model, which achieved sensitivity (94.03%), AUC (95.52%), specificity (97.01%), and accuracy(94.02%). The researcher has used a dataset consisting of 3905 chest X-ray images which correspond to 6 pulmonary diseases to train the CNN model (Mobilenet v2) to identify pulmonary diseases which also include Coronavirus, the proposed model was able to achieve an accuracy of 99.18%, and specificity 99.42% for detecting Covid-19 [62]. A semi-Supervised network using ResNext+ was proposed by the author, which uses only volume data but is capable of providing slice-level predictions, 81.9% precession, and 81.4% F1 score was achieved by the model[88]. In [89] three pre-trained CNN namely NASANet Large, DenseNet, and NASNet Mobile were finely tuned on a dataset consisting of 3309 chest x-ray images, the evaluation of the proposed model showed a satisfying result of about 99.5% specificity and 99.45% sensitivity. AlexNet was modified on MATLAB and 4 systems were proposed, but when compared with the original AlexNet it has been observed that the original AlexNet performed better than all 4 proposed modified AlexNet [90]. [91] has shown the importance of pre-processingthe dataset to enhance the performance of the CNN model to detect Covid-19, Large dataset of 15,134 chest X-ray images helped the author to achieve considerable results (Specificity 97.53%, accuracy 97.48%). We analysed prior work focusing only on a few pathologies for the detection of Covid-19 but [92] has focused on 122 anatomic locations and many different diagnosis features which also include consolidation, ground-glass opacity, and other radiological findings which shows sign of Covid-19. [92] has used one of the largest datasets of chest X-rays that includes a 23159 lung chest x-ray, besides giving the result of Covid-19 positive or not Model also has an interpretability feature that indicates which radiological findings lead to a diagnosis. GoogleNet convolutional Neural Network architecture was used over 349 CT images and 82.14% accuracy was achieved [93]. [94] Has proposed a model, which divides the whole process into three steps for better performance from already available models. Step 1 is an augmentation of data, Step 2 is using Pre-trained CNN models for Covid-19 detection, and Step 3 is finding abnormalities in CT images, For the whole process SequeezeNet, ResNet50, ResNet18, ResNet 101 were used and data was divided into 7:3 to be specific 70% for training the data and 30% for testing, From all the pre-trained Models ResNet18 offered highest accuracy of 99.4% in testing phase [94]. Two CNN based on the Densely connected convolutional neural network was used to enhance the overall performance and 90.27% accuracy was achieved [95]. [96] proposed CNN model, which can give a binary classification between Covid-19 positive or Covid-19 negative, it also can give the percentage of infection in the lungs, so that appropriate treatment can be provided to the patient. The COVID-19Lite architecture was proposed by [97], In the proposed model white balance combined with CLACHE for processing and enhancement of image for better visibility is used, then Depthwise Separable CNN was used for classification, and the model was able to achieve 99.58% accuracy. Four CNN architectures namely DenseNet 121, VGG16, VGG19, and ResNet50 were used for classification between Covid-19 and non-Covid-19, Results obtained depicted that VGG16 and VGG19 performed best among all by achieving 99.3% overall accuracy [98]. The proposed method [99] can identify Covid-19, Normal cases, and Pneumonia Chest X-rays. ResNet50V2 and Xception are combined for achieving the best accuracy of 99.50% in detecting Covid-19 and 91.4% overall average accuracy [99]. Ten thousand CT chest images were used to train the model and 97.17% of AUC is obtained [100]. The proposed model has a specificity of 95% and 0.971 AUC rate and the model is implemented as a mobile application for ease of use, the model has been verified among the population of Zhejiang province[101]. CNN architectures were used for the detection of coronavirus in humans through chest X-rays, 10 epochs with batch size 32 are used, and an overall 87.5% accuracy is achieved [102]. [103]has proposed an optimized ResNet50, which works in 5 phases, it consists of 23M parameters for training, a large number of parameters helped to achieve 96% accuracy with Chest X-ray images.

4.3 September 2020 to December 2020

A 3 Dimensional URDNet is proposed, which is built on U-Net, This model detects ground-glass opacity using images, training is performed in two steps, the Model is trained for feature extraction, and then the whole model is finely tuned using pre-trained weights, with a Sensitivity of 90.8% is achieved for detection of

Covid-19 using chest X-ray [104]. [105] have performed the whole process of detecting Covid-19 in three major steps Firstly, a Gaussian filter was used for extraction of features and classifying the images of chest x-ray, In the third step handcrafted model is prepared which is based on CNN, Inception v3, Adam optimizer is used for the whole process of classification with an excellent result of about 94.08% accuracy, 93.61% sensitivity, and 94.56% of specificity. [106] have designed a system that has AUC 0.996 for detecting Covid-19. [104] have proposed such a system that can perform better even with a small training dataset, Author has also referred to class imbalance problems in a dataset. [107] have explored the depths of pre-trained VGG-16 architecture for Covid-19 detection and have achieved significant results i.e. 96% and 92.5% accuracy for two-class and three-class output. In the proposed method data augmentation and fine-tuning are applied to the Covid-19 chest X-ray dataset, Also 4 CNN DenseNet121, VGG-11, AlexNet, and SequeezeNet were applied where 3CNN reported accuracies greater than 97%, sequeezenet outshines with 99.20% accuracy [69]. [108] have compared pre-trained architectures ResNetXT, Xception, and Inception V3 on a dataset containing 6432 images of chest X-rays, where the Xception model attains the highest accuracy of about 97.9%. In [109], the Dataset of Covid-19 chest x-ray is taken specifically from Mexico, Different algorithms including decision tree, Different algorithms including decision tree, logistic regression naïve Bayes, and Support vector machine were used and the dataset was divided in 8:2, Respective accuracies for the Decision tree, Support Vector Machine, and Naïve Bayes are 94.99%, 93.34%, and 94.30%. Two ensemble methods are used for the diagnosis of Covid-19 using chest radiographs, the proposed method can solve binary(Covid-19vs. non Covid-19) and Multiclassifier(Covid-19, bacterial pneumonia, and Pneumonia) [110]. Firstly, histogram equalization was used for enhancing the image dataset, over fitting problem was also addressed, and augmentation was performed on the dataset by the rotating left, right, and then flipping 27,160, and 70 degrees, Modified AlexNet was used which has 5 layers, and 60M parameters, 100% accuracy was achieved by model [111].DenseNet and OLTS(Optimized transfer learning system) is used, and the proposed method achieved a sensitivity of 96.35%, specificity=96.25%, the precession of 96.29%, and accuracy of 9.30 [58].Many systems have been developed for Covid-19 detection using X-ray, Model proposed by [112] enhances the performance of existing models, Eleven pre-trained architectures have been used, and cascaded classifiers have shown promising results VGG-16, DenseNet-169, ResNet50v2 performed best from all cascaded architectures. Five supervised models are taken into practice to build a model which detects Covid-19 from chest X-ray, proposed model [113] has two types binary classification and multiclassifier. Model has achieved 100% accuracy, 100% senstivity, 100% specificity for binary classification [111].Different Convolutional Neural Network Architecture namely VGG19, DenseNet121, and Xception are used and compared with training and testing accuracies for detection of Covid-19, Through the detailed analysis, it has been observed DenseNet has formed best from all models used in [65]. For any new virus, there is always the problem of data insufficiency supervised learning works on labeled data, but labeled data are scarce. To deal with the problem [114] has proposed a simple but highly effective approach called Mix Match helps to correct data imbalance so that the Model can be trained for detecting Covid-19 without any limitations Mix Match has improved the accuracy for binary classification up to 10%. CT Scan images are used to detect Covid-19 in 10 seconds, DRENet (Details of relation extraction Neural Network) is proposed which can diagnose Covid-19 with an AUC rate of 0.99 [115]. CT-Cap which is also termed as Capsule network framework can extract features and this functionality is used to identify features in chest CT Scan, These extractions feature lead to the diagnosis of Covid-19 with a sensitivity of 94.05% and an accuracy of 90.08% [116].[117] proposed method COVID-19-Net can detect Covid-19 but also has an explanation facility; it does not only give a diagnosis result but also explains the severity of Covid-19.[118] proposed a model, which is trained on 46,096 CT images, for validation and to check the robustness of the system, Qianjiang Central Hospital conducted external testing where 98.85% accuracy is achieved for each image. MSTL(Multi-Source Transfer Learning) is used over the Traditional technique of transfer learning, with a dataset that includes chest X-ray and CT Scan, 0.893 accuracies, and a Recall score of 0.897 achieved [119]. VGG(Visual Geometry Group) Architecture is enhanced to distinguish Covid-19 Chest from normal X-ray, enhanced VGG give overall 98.52% accuracy for binary classification (Covid-19vs. non-Covid-19) and 95.34% for three-class (Covid-19vs. Non-Covid-19vs. Pneumonia)[120]. U-Net has been modified with many cross-validations and CT scan images are used, Model can identify leison which lies in the infected area of lungs and its diagnosis can be helpful for treatment, average Recall Score was 98.29% [121]. [122] has proposed InstaCovNet-19 which has been integrated by stacking different CNN, Proposed model achieved 99.08% accuracy for 3 classes and 99.53% for 2 classes.

4.4 January 2021 to April2021

Modified CNN to detect Covid-19 from Chest X-ray is proposed, but only a few parameters are included in it, Also 5-fold Cross Validation is applied to avoid biases, and 96.92% accuracy and 94.92% sensitivity are a chieved by the model [123]. Transfer Learning is used for the classification of Covid-19 chest X-ray and healthy Chest X-ray, MobileNetV2 Architecture is used, however, no professional radiologist was involved but the model has achieved benchmarking results with 100% accuracy, 100% specificity, and 100%

sensitivity [63]. The ensemble is a combination of different algorithms and is being used in medical fields due to its high performance [124], [125]. [126] has proposed a model that will first enhance the images, then image segmentation is performed and the last ensemble model is deployed with Naïve Bayes for meta-learning and classification of Covid-19 chest x-ray and healthy x-ray, Model has achieved 98.67% accuracy and 0.98 kappa value. In [127] four pertained CNN architectures namely Xception, MobileNetV2, InceptionV3, and VGG16 are optimized with Bayesian optimization, Out of the four optimized architectures, Covid-19Xception-Net outperforms from other three by achieving accuracy up to 0.94, and 0.95 precession. [128] has proposed patch-based CNN which has a very small number of parameters as compared to other existing architecture, this model can give promising results where the dataset is small. [129] has used activation maps, which will help identify the severity of Covid-19 using a chest x-ray. These activation maps help to identify the particular area of the image that belongs to the most similar relevant class. Cascade Classifier is formed from ensemble learning of stacked Generalization in combination with VGG16, a Proposed method [125] that can be classified into three categories i.e. viral pneumonia, normal chest x-ray, and novel coronavirus, 93.57% accuracy, and 94.21% sensitivity is achieved [130].

KNN algorithm is easiest in the category of Supervised learning, it associates the existing feature of the object with a similar class of data. KNNV, where V stands for Variant is proposed by [131] to distinguish between Covid-19 and Non-Covid-19 Xray. KNN was also compared with other algorithms belonging to the same category and it performed best among all.[132] has compared DenseNet121, (ZFNet Zeiler,Fegus Network), and CNN (Convolutional Neural Network) and it has been observed that the CNN algorithm has outperformed ZFNet and DenseNet122 with an accuracy of 91.7%, recall 90%, and precession 100%. [133] has developed CNN to detect Covid-19 using chest CT scan datasets that are available all around the globe, after detailed analysis it has been observed when Non-china sites are included in training the performance and accuracies improved for classification.

[134] has used EffecientNet as a backbone of the model and a feature map is extracted from images, Dataset of 2482 CT images is used and then augmentation is performed with 96.16% accuracy achieved.[135] has used an efficientnet that is pre-trained on ImageNet for binary classification, and 99.64% accuracy is achieved by the model. [136] has developed a model Ctnet-10 which achieved an accuracy of 82.1%, then the model is compared with other existing architectures (DenseNet, VGG-19, VGG-16, InceptionV3, and ResNet-50), VGG-19 has achieved maximum accuracy among all i.e 94.52%.[137] used CT scan dataset to train the deep learning model, this model also includes some clinical features like age, oxygenation, urea, sex, and platelets, which will help to determine the severity of the disease. In [138] hybrid model is proposed for the classification of CT images of Covid-19, Normal, and viral pneumonia, the comparison is done with the existing model.

4.5 May 2021 to August 2021

Five pre-trained CNN namely Inception-ResNetV2, ResNet101, ResNet152, ResNet50, and Inceptionv3 have been used on chest Xray, Three different types of binary classification are implemented using four classes (Bacterial pneumonia, Viral Pneumonia, Covid-19, and Normal) ResNet-50 model performs best and have provided 96.1%, 99.5%, 99.7% accuracy in three binary classifications [139]. In [140], the Proposed CNN Model can help in the diagnosis and progress of Covid-19d-19 using CT images and Chest Xray images, the model can detect and classify images of Covid-19 and normal Radiograph images, U-Net and Voxel-based network help in segmentation, this application of CNN can be beneficial with a limited amount of dataset also. SSIM (Structural Similarity Index) is used to form different clusters of classes of Covid-19 chest x-ray and normal chest x-ray, SSIM works as a feature extractor from chest x-ray so it can easily classify on basis of characteristics [141]. [142] has proposed a feature fusion Method firstly small enhancement is performed on datasets like translation, rotation, random transformation, and the 5 pre-trained model extract features and achieved the highest accuracy of 96%. Novel Architecture with 99.03% accuracy and 0.069ms time is the powerful model proposed by [143], The model uses the Mish activation function and batch normalization for optimizing time and performance. CovFrameNet is an enhanced deep learning model by [144], which firstly performs pre-processing, then a deep learning model is deployed for extracting features and classification then performance is measured and the model achieved specificity 1.0, F measure 0.9, Recall 0.85. In [145] traditional deep learning methods are applied for detecting Covid-19 using chest x-ray and CT images, then CNN is deployed for identification and classification of Covid-19 and non-Covid-19. A Gated recurrent unit and convolutional neural network are used for the diagnosis of a Covid-19 chest x-ray. Another has used CNN for extracting features and GRU for the classification of images [146]. ReCOV-101 proposed by [147], which has a backbone of the residual network, can deeper by skipping the connections, and CT scans of the chest are used for diagnosis. The pre-trained convolutional neural network was compared with each other on a huge database of CT images for identification of Covid-19, the analysis of the performance of different models have shown that bigger and peculiar datasets can enhance the performance [148]. The Convolutional neural network proposed by [149] have used 746 and 349 chest images of normal and Covid-19 positive patients respectively, Model have achieved 98.4% accuracy, 98.5% sensitivity, 98,3% specificity, and 97.1% precession.Covid-19 Diagnostic Model is proposed by [150] which can first pre-process images which include resizing images, cleaning remaining unnecessary noisy data, then dividing the data into training, testing, and validation in a ratio of 65:25:10 then presenting results.

4.6 September 2021 to December 2021

The model proposed by [151] has use data transfer learning approach and Convolutional Neural Network for the diagnosis of Covid-19 using chest x-ray, Due to the low availability of the data set, data augmentation is performed, Inceptionv3 and VGG16 were used, which give 100% sensitivity, 98.2% training accuracy, and 96.66% test accuracy. The CNN architectures ResNet-50 and AlexNet are used for multiclass and binary class output from chest x-ray [152]. ResNet-50 achieved 97.10%, 98%,94.5%, 95% AUC, Specificity, Sensitivity, and Accuracy respectively for multiclass whereas in binary class it achieved 97.51%, 98%,98%, 99% AUC, Specificity, Sensitivity, and accuracy respectively [148]. Firstly dataset is augmented and enhanced using NCLACHE before CNN models are applied, then different CNN models (GoogleNet, AlexNet, EfficientNet, DenseNet, ResNet101, MobileNet) are applied where MobileNetV2 has performed best among all by giving 98% accuracy[153]. [154] have used 21,165-chest x-ray which 48% are normal, 17% were Covid-19 positive, 28% were lung opacity, and 6% were viral pneumonia, AlexNet, DenseNet, VGG16, VGG19, and GoogleNet are used for classification, the Highest accuracy was 95.63%. [155] have performed 3 main operations in which, firstly Author has compared different learning architectures on different datasets available worldwide, as a result of which 98.87% was the highest accuracy achieved, Secondly Author has proposed the best performing deep learning architecture with which 95.91% accuracy is achieved, In the last model is evaluated on real-time data where it has achieved only 70.15% accuracy. [156] used pre-trained CNN architecture AlexNet for classification, the previous results with accuracy of 96.5%, Sensitivity of 98.0%, and specificity of 91.7% have proved that Cray combined with deep learning can extract important Genomic information about the Coronavirus. [157] have given due importance to the explanation power of artificial intelligence, Two main steps are performed first is used for filtering and the second is for classification, also it can extract knowledge using IF-THEN statement. Different techniques for pre-processing of images are discussed in [158], the different models are proposed that are based on VGG19, VGG16, and DenseNet201 for classification of Covid-19 using Chest X-ray, 99.62% accuracy is achieved for binary classification and in multiclassification 95.48% is achieved. Pretrained deep learning model is used for feature extraction and then features were selected through information filter, then KNN classifier is trained, In the last classification between Covid-19 and non Covid-19 is done through majority voting [159]. Convolutional Neural Network namely EfficientB0 and ResNet50 are trained using publicly available dataset on modality X-ray and CT scan, EfficientNetB0 outperformed by giving 99.23% and 99.36% accuracies for CT and X-ray, while the proposed hybrid model has given 99.58% overall accuracy [160].

4.7 January 2022 to April2022

In [161], an AI-based model for diagnosing Covid-19 using chest CT is developed, A unique dataset is taken that has not been used in any model, and 97.5% accuracy is achieved by the proposed model. An enhanced CNN model is proposed which is based on Xception, EfficientNet, NASNet, MobileNet, DenseNet, VGG16, and Accuracies achieved by different models (EfficientNet 80.19%, Xception92.47, NASNet 89.51%, MobileNet 96.36%, DenseNet 97.53%, VGG 97.68%) from the results obtained we can observe VGG performed best among all [162]. Modified deep learning model CheXImageNet can diagnose Covid-19 with 100% accuracy, the proposed model is validated for binary and multi-classification on X-ray modality and has given promising results [163]. An enhanced version of ResNet-50 was proposed and evaluated by deploying it on the publicly available dataset, the proposed model has achieved more than 99.73% accuracy [164].The Internet of Things can be combined with Deep Learning for application in different domains, Similarly [165] has implemented an ensemble model by combining Deep learning and IOT for automated diagnosis of Covid-19 disease using Chest X-rays. The proposed ensemble method has been compared with other diagnostic models using different datasets and it has shown significant results. [166] has implemented ResNet-18 a pre-trained model along with a Multiclass Classification layer to distinguish Covid -19 infected and Normal Chest X-ray. In any of the deep learning neural network, last layer is Softmax to distinguish different classes. To enhance the accuracy of the deep learning model to distinguish Covid-19 and normal chest X-ray [167] has replaced Softmax CNN layer with K-nearest neighbour classifier, Also a novel evolutionary algorithm has been proposed by adding improvements in basic version of Swarm optimizer. In [168] Feature of Chest X-ray has been extracted using DenseNet-169 and then output of DenseNet-169 was given as input to Extreme Gradient Boosting algorithm for classification of Normal and Covid-19 infected Chest X-ray.

4.8 May 2022 to August 2022

[169] has implemented five pre-trained deep learning models to distinguish Covid-19 infected and Normal Chest X-rays. Each deep learning model has shown an accuracy of more than 90%. The main aim to implement the 5 deep learning models namely ResNet101, ResNet50, DenseNet169, DenseNet121, and Inception V3 is to highlight the importance of each model and to compare their performances. [170] has proposed a novel CNN architecture CoviXNet having 15 layers to enhance the efficiency of the model, the proposed model has shown tremendous performance with 99.47% accuracy using 10-fold validation and 99.61% accuracy for 3-class. [171] has used different pre-trained models to extract the feature from the dataset, Pre-trained models that have been used by [171] are ResNet-101, ResNet-50, AlexNet, VGG-19, VGG-16, GoogleNet, Xception, and SqueezeNet. Then the extracted features are fed to different classification models like Support Vector Machine (SVM), K Nearest Neighbour (KNN), Decision Tree, Random Forest, and Naïve Bayes, then the performances of each model are recorded and compared with each other. The accuracy of 96.296 was recorded as the best that was obtained from ResNet-50 and SVM. [172] has proposed a method to detect Covid-19 using CT-Scan images.

4.9 September to December 2022

CovidDWNet has been proposed by the author which can detect Covid-19 rapidly with both Chest X-ray and CT-Scan images, the model is based on depth wise dilated Convolutions and Feature reuse residual block(FRB), Both methods are highly capable of extracting the features and has resulted in improving the performance. The Gradient Boosting algorithm has been used for the estimation of feature maps obtained from DDC and FRB [173].A lightweight CNN model (LW-CORONet) has been proposed for faster prediction of Covid-19 infection. The model was able to achieve 98.67% and 99% for multiclass and binary classes respectively[174].

4.10 January to March 2023

The author has collected data from 192 severely infected patients and 4010 mildly Covid-19 infected patients. The data has been collected from March-September 2021 when Covid-19 infection was at its peak. Appropriate characteristics of each patient like Age, Gender, and other features have been taken into account. The most appropriate features have been selected using the minimum-redundancy-maximum-relevance method, Principle component analysis has been used to reduce the dimensions of the dataset, then a different Supervised Machine learning model has been implemented to identify the patients [175]. The main aim of the experiment is to differentiate severely and Mildly infected Covid-19 patients with the application of Machine learning models. [176] has proposed a model which also highlights the area of severe Covid-19 infection in Chest X-rays along with the detection. It has used Explainable AI to implement the model.

V.Observations

Three types of approaches have been used in all the articles - First is the Transfer learning method in which pre-trained CNN architecture is used, these models are pre-trained on the ImageNet database, Many researchers have presented Comparative studies between different combinations of pre-trained architectures (AlexNet, ResNet, Inception, DenseNet, MobileNet, SeNet, GoogleNet, etc.). Second is the Novel Architecture method in which researchers have used different datasets to train models and have introduced new models. The third is the ensemble method, Feature extractor, feature concatenation, and hierarchical classification. Figure 4 shows the overall working of all the methods. In the first step, images (X-ray or CT) are pre-processed then the proposed method is applied for training the model and then classification results are obtained. Preprocessed chest X-rays and CT images are given in Figure 5.

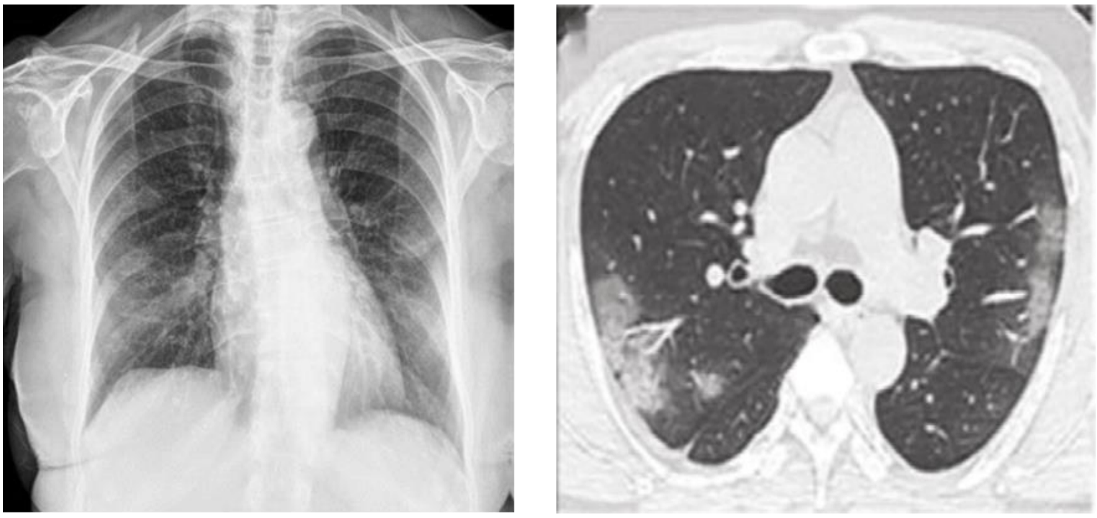

Figure 5: *Covid-19 positive chest X-ray*[177] *and Covid-19 positive Chest CT* [138]

In the last step, the model was evaluated by different matrices. Figure 6 is displaying the distribution of three methods in each section of the literature survey from 4.1 to 4.6; it is depicted from the graph that pre-trained models are dominant over the other two methods. A total of 89 papers were included for review in the six sections, out of which 45 papers have used pre-trained models while the remaining 44 papers have used the remaining two techniques. The scarcity of data had remained a prominent issue in most of the papers, as the limitation of labeled data greatly affects the performance of the model. Some of the available datasets are listed in Table 1. Some papers have performed augmentation to address the problem of data shortage and it has given positive results by increasing the performance of the model. The Data overfitting problem also needs to be addressed.

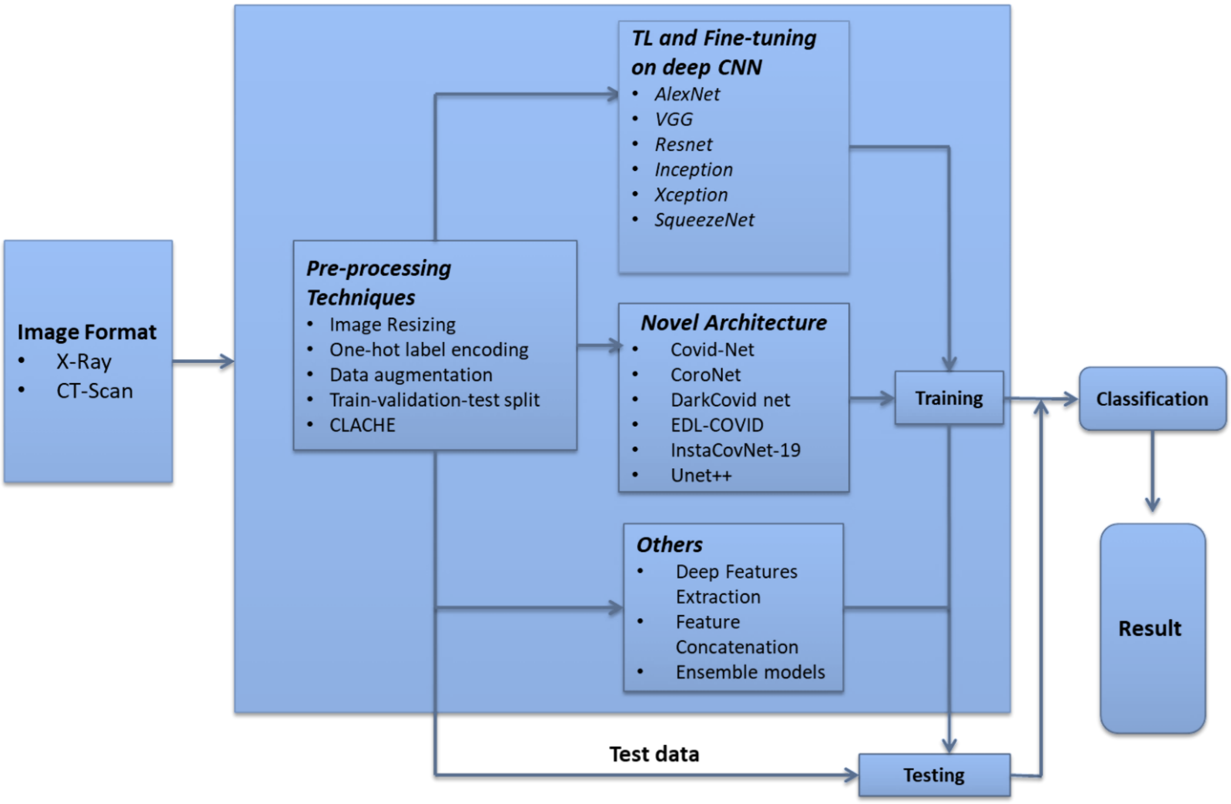

Figure 6: *The overall working of all the three methods*

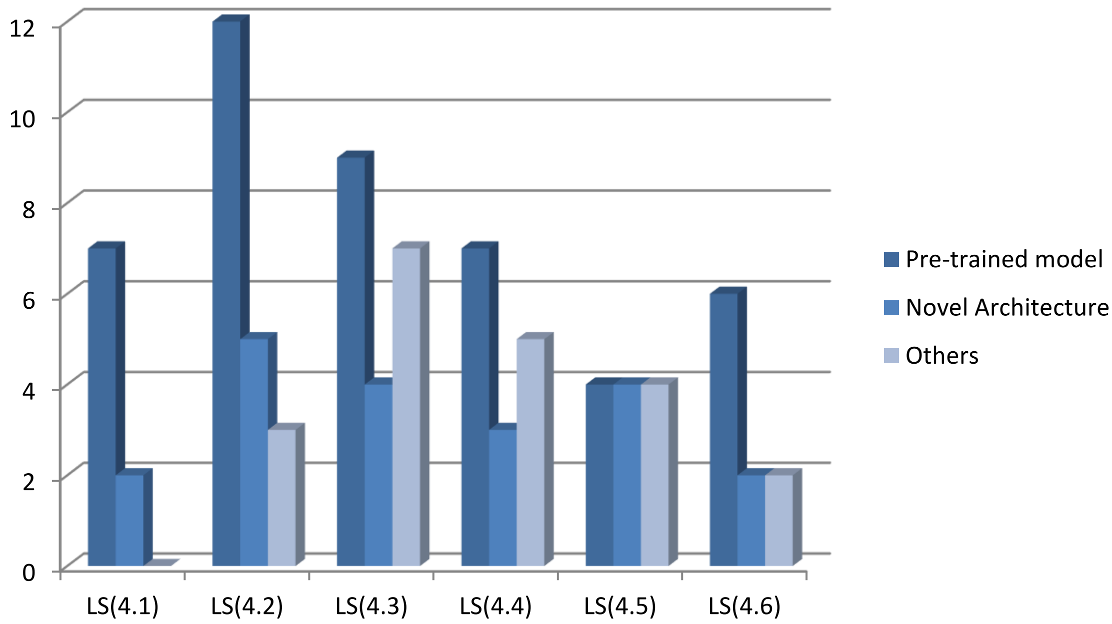

Figure 6: *Distribution of methods used in the literature survey*

There was a lack of involvement of expert radiologists in most of the articles, if we want to implement AI and Deep learning models in the healthcare sector, we should involve more experts for better guidance and results so that reliability can be increased. The models need to be verified by experts in the medical field by considering the clinical features of the human body and the virus. The use of Explainable AI can be helpful for Radiologists or experts to verify the model.

Reference	Modality
[107]	X-ray
[76]	X-ray
[163]	X-ray
[162]	CT Scan
[178]	CT Scan

Table 1:*References of available datasets*

Reference	Framework/Model/Architecture	Accuracy
[105]	FM-HFC-DLF	94.08%
[56]	VGG-16	96%
[86]	Covent	97%
[177]	Ensemble-CVDNet	98.30%
[79]	SVM	97.48%
[62]	Mobile Net	99.18%
[69]	SqueezeNet	99.20%
[108]	XceptionNet	97.97%
[107]	VGG-16	96%
[123]	Shallow CNN-tailored	96.92%
[63]	MobileNetV2	100%
[109]	SVM	94.99%
[110]	Ensemble framework	99.21%
[91]	CNN-based multi-level pre-processing filter block	97.48%
[122]	InstaCovNet-19	99.08%
[127]	COVIDXception-Net	94%
[65]	DenseNet-121	97%
[81]	DarkCovidNet	98.08%
[57]	VGG-19	96.6%
[179]	SVM	99.02%
[66]	Inception v3	99.72%
[135]	EDL-COVID	95%
[60]	Modified Xception and Inception V3 model	99.80%
[74]	Convid-Net	97.99%
[180]	EfficientNetB1	96.13%
[181]	ResNet50	99%
[163]	CheXImageNet	100%
[182]	ResNet	99%
[183]	RCNN	99%
[78]	SVM	99.68%
[184]	UNet++	95.24%
[76]	LiteCovidNet	100%

Table 2: Comparison of different models

Different evaluation matrices were used to evaluate the performance of different models. However, we have considered accuracy to compare the performance of models reviewed in this paper. The formula for Accuracy is given in equation 1.

$$\text{Accuracy} = \frac{TP+TN}{TP+FP+FN+TN} \quad (1)$$

Here, TP, TN, FP, and FN are abbreviated as True Positive, True Negative, False Positive, and False Negative respectively.
In the comparison table given above it has been observed that MobileNetV2 [76], [62] and CheXImageNet [163] have achieved 100% accuracy however, we cannot conclude that any model is superior to others because of other parameters like time taken, Computation Cost, and dataset used is different.

VI.Discussion

In the present paper, We have explored different techniques to identify Covid-19 using Chest X-ray and CT Scan images. All the techniques were broadly based on Machine learning and deep learning. We have explored 104 papers published between January 2020 to March 2023. Different researchers have proposed different techniques and achieved good accuracy and F1 Score but it is also quite evident that there are still many challenges.

As these techniques have used different datasets, and different machines to implement their models so it is not possible to compare the models and justify which model has shown the best performance. Although different Authors have shown promising results and very high accuracy there is no evidence to show how the model has performed on real-world data because Scenarios can be different when we work with Real-world data. It can be the case that high accuracy may be due to the biases in the dataset however the same model can result in decreased accuracy on real-world data.

The proposed model can be interpreted to show how a particular result is obtained so that an end user or Radiologist can get a clear idea that how and why the particular result is given by the AI model. The proposed model work on extracting the features like Ground Glass Opacity or haziness in the lungs but it can be the case where there are no visible symptoms of Covid-19 in the lungs Also, the model can get confused between Covid-19 and other pulmonary diseases like Tuberculosis, Lungs Cancer extra so model need to be trained on other pulmonary diseases so that it can differentiate between Covid-19 and other pulmonary diseases.

One limitation of this paper is that it has only focused on imagery data, where the model has been trained using X-ray images and CT Scan images only but there can be modalities as well that can be used to predict the result and also the paper has mostly focused on deep learning models that are using CNN but there can be other techniques as well like predicting Covid-19 using Cough sound. Future work can be done using the Mucous dataset and predicting covid-19 with other features.

VII. Conclusion and Future Scope

In this paper, we have reviewed different articles and we have concluded Artificial intelligence technique has shown great potential in dealing with the pandemic situation. The highest accuracy of 100% has been achieved in detecting Covid-19 using deep learning techniques, Also precession, Sensitivity, and Specificity of 100% were achieved by researchers which shows AI has great potential. These automated methods can provide results in very little time and with greater efficacy. Convolutional Neural networks were found to have greater scope in medical image analysis to support Radiologists. The existing deep learning models can be extended to provide explanation features for better reliability of these modern techniques. The deep learning model could be able to comprehend why particular results are obtained and what features of the Radiological image led to particular results it will be beneficial for the Radiologist to verify if the results obtained are accurate or not and also for the end-user they can better understand the severity of their disease.

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References

[1] L. Wang, Y. Wang, D. Ye, and Q. Liu, "Review of the 2019 novel coronavirus (SARS-CoV-2) based on current evidence," *Int. J. Antimicrob. Agents*, vol. 55, no. 6, p. 105948, 2020, doi: 10.1016/j.ijantimicag.2020.105948.
[2] D. Kaul, "An overview of coronaviruses including the SARS-2 coronavirus – Molecular biology, epidemiology and clinical implications," *Curr. Med. Res. Pract.*, vol. 10, no. 2, pp. 54–64, 2020, doi: 10.1016/j.cmrp.2020.04.001.
[3] K. K. Singh, M. Siddhartha, and A. Singh, "Diagnosis of coronavirus disease (COVID-19) from chest X-ray images using modified

XceptionNet," *Rom. J. Inf. Sci. Technol.*, vol. 23, pp. S91–S115, 2020.
[4] H. Lu, C. W. Stratton, and Y. Tang, "Outbreak of pneumonia of unknown etiology in Wuhan, China: The mystery and the miracle," *J. Med. Virol.*, vol. 92, no. 4, p. 401, 2020.
[5] F. Jiang, L. Deng, L. Zhang, Y. Cai, C. W. Cheung, and Z. Xia, "Review of the Clinical Characteristics of Coronavirus Disease 2019 (COVID-19)," *J. Gen. Intern. Med.*, vol. 35, no. 5, pp. 1545–1549, 2020, doi: 10.1007/s11606-020-05762-w.
[6] W. H. Organization and M. C. Joint, "Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19)," *WHO-China Jt. Mission Coronavirus Dis. 2019*, vol. 2019, no. February, pp. 16–24, 2020, [Online]. Available: https://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-covid-19-final-report.pdf.
[7] A. E. Gorbalenya *et al.*, "Severe acute respiratory syndrome-related coronavirus: The species and its viruses – a statement of the Coronavirus Study Group," *bioRxiv*, 2020, doi: 10.1101/2020.02.07.937862.
[8] H. Harapan *et al.*, "Coronavirus disease 2019 (COVID-19): A literature review," *J. Infect. Public Health*, vol. 13, no. 5, pp. 667–673, 2020, doi: 10.1016/j.jiph.2020.03.019.
[9] C. Huang *et al.*, "Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China," *Lancet*, vol. 395, no. 10223, pp. 497–506, 2020.
[10] X. Huang, F. Wei, L. Hu, L. Wen, and K. Chen, "Epidemiology and clinical characteristics of COVID-19," *Arch. Iran. Med.*, vol. 23, no. 4, pp. 268–271, 2020, doi: 10.34172/aim.2020.09.
[11] H. Chen *et al.*, "Clinical characteristics and intrauterine vertical transmission potential of COVID-19 infection in nine pregnant women: a retrospective review of medical records," *Lancet*, vol. 395, no. 10226, pp. 809–815, 2020.
[12] J. Li *et al.*, "Epidemiology of COVID-19: A systematic review and meta-analysis of clinical characteristics, risk factors, and outcomes," *J. Med. Virol.*, vol. 93, no. 3, pp. 1449–1458, 2021, doi: 10.1002/jmv.26424.
[13] S. D. Chowdhury and A. M. Oommen, "Epidemiology of COVID-19," pp. 3–7, 2020.
[14] M. Cascella, M. Rajnik, A. Aleem, S. Dulebohn, and R. Di Napoli, "Features, evaluation, and treatment of coronavirus (COVID-19)," *StatPearls*, 2022.
[15] J. F. W. Chan, K. K. W. To, H. Tse, D. Y. Jin, and K. Y. Yuen, "Interspecies transmission and emergence of novel viruses: Lessons from bats and birds," *Trends Microbiol.*, vol. 21, no. 10, pp. 544–555, 2013, doi: 10.1016/j.tim.2013.05.005.
[16] S. A. Hassan, F. N. Sheikh, S. Jamal, J. K. Ezeh, and A. Akhtar, "Coronavirus (COVID-19): A Review of Clinical Features, Diagnosis, and Treatment," *Cureus*, vol. 12, no. 3, 2020, doi: 10.7759/cureus.7355.
[17] W. Guan *et al.*, "China medical treatment expert group for Covid-19," *Clin. Charact. coronavirus Dis.*, vol. 382, no. 18, pp. 1708–1720, 2019.
[18] K. Singh, S. Kumar, S. Shastri, A. Sudershan, and V. Mansotra, "Black fungus immunosuppressive epidemic with Covid-19 associated mucormycosis (zygomycosis): a clinical and diagnostic perspective from India," *Immunogenetics*, vol. 74, no. 2, pp. 197–206, 2022, doi: 10.1007/s00251-021-01226-5.
[19] W. Guan *et al.*, "Clinical characteristics of coronavirus disease 2019 in China," *N. Engl. J. Med.*, vol. 382, no. 18, pp. 1708–1720, 2020.
[20] J. A. Siordia Jr, "Epidemiology and clinical features of COVID-19: A review of current literature," *J. Clin. Virol.*, vol. 127, p. 104357, 2020.
[21] Y. Bai *et al.*, "Presumed asymptomatic carrier transmission of COVID-19," *Jama*, vol. 323, no. 14, pp. 1406–1407, 2020.
[22] C. Rothe *et al.*, "Transmission of 2019-nCoV infection from an asymptomatic contact in Germany," *N. Engl. J. Med.*, vol. 382, no. 10, pp. 970–971, 2020.
[23] H. Tu, S. Tu, S. Gao, A. Shao, and J. Sheng, "Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID- 19 . The COVID-19 resource centre is hosted on Elsevier Connect , the company ' s public news and information ," no. January, 2020.
[24] T. Singhal, "Review on COVID19 disease so far," *Indian J. Pediatr.*, vol. 87, no. April, pp. 281–286, 2020.
[25] J. Hindson, "COVID-19: faecal–oral transmission?," *Nat. Rev. Gastroenterol. Hepatol.*, vol. 17, no. 5, p. 259, 2020.
[26] C. A. Hintschich, M. Y. Niv, and T. Hummel, "The taste of the pandemic—contemporary review on the current state of research on gustation in coronavirus disease 2019 (COVID-19)," *Int. Forum Allergy Rhinol.*, vol. 12, no. 2, pp. 210–216, 2022, doi: 10.1002/alr.22902.
[27] I. Salahshoori *et al.*, "Overview of COVID-19 Disease: Virology, Epidemiology, Prevention Diagnosis, Treatment, and Vaccines," *Biologics*, vol. 1, no. 1, pp. 2–40, 2021, doi: 10.3390/biologics1010002.
[28] S. Umakanthan, V. K. Chattu, A. V Ranade, D. Das, A. Basavarajegowda, and M. Bukelo, "A rapid review of recent advances in diagnosis, treatment and vaccination for COVID-19," *AIMS Public Heal.*, vol. 8, no. 1, pp. 137–153, 2021, doi: 10.3934/publichealth.2021011.
[29] F. Zhou *et al.*, "Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study," *Lancet*, vol. 395, no. 10229, pp. 1054–1062, 2020.
[30] F. Zheng, W. Tang, H. Li, Y. X. Huang, Y. L. Xie, and Z. G. Zhou, "Clinical characteristics of 161 cases of corona virus disease 2019 (COVID-19) in Changsha," *Eur Rev Med Pharmacol Sci*, vol. 24, no. 6, pp. 3404–3410, 2020.
[31] Y. Lee *et al.*, "The application of a deep learning system developed to reduce the time for RT-PCR in COVID-19 detection," *Sci. Rep.*, vol. 12, no. 1, pp. 1–10, 2022, doi: 10.1038/s41598-022-05069-2.
[32] Y. Artik *et al.*, "Comparison of COVID-19 laboratory diagnosis by commercial kits: Effectivity of RT-PCR to the RT-LAMP," *J. Med. Virol.*, no. January, 2022, doi: 10.1002/jmv.27559.
[33] S. K. Sourabh 1∗, Vibhakar Mansotra1, Paramjit Kour1, "Voting-Boosting: A novel machine learning ensemble for the prediction of Infants' Data," *Indian J. Sci. Technol.*, vol. 13, no. 22, pp. 2189–2202, 2020, doi: 10.17485/ijst/v13i22.468.
[34] S. Kushwaha *et al.*, "Significant applications of machine learning for covid-19 pandemic," *J. Ind. Integr. Manag.*, vol. 5, no. 4, pp. 453–479, 2020, doi: 10.1142/S2424862220500268.
[35] S. Shastri, S. Kumar, K. Singh, and V. Mansotra, "Designing Contactless Automated Systems Using IoT, Sensors, and Artificial Intelligence to Mitigate COVID-19," *Internet of Things*, pp. 257–278, Mar. 2022, doi: 10.1201/9781003219620-13.
[36] L. Alzubaidi *et al.*, *Review of deep learning: concepts, CNN architectures, challenges, applications, future directions*, vol. 8, no. 1. Springer International Publishing, 2021.
[37] G. E. Hinton and R. R. Salakhutdinov, "Reducing the dimensionality of data with neural networks," *Science (80-.).*, vol. 313, no. 5786, pp. 504–507, 2006.
[38] S. Goswami and L. K. P. Bhaiya, "A hybrid neuro-fuzzy approach for brain abnormality detection using GLCM based feature extraction," in *2013 International Conference on Emerging Trends in Communication, Control, Signal Processing and Computing Applications (C2SPCA)*, 2013, pp. 1–7.
[39] Z. Liu, C. Yao, H. Yu, and T. Wu, "Deep reinforcement learning with its application for lung cancer detection in medical Internet of

Things," *Futur. Gener. Comput. Syst.*, vol. 97, pp. 1–9, 2019.
[40] D. H. Hubel and T. N. Wiesel, "Receptive fields, binocular interaction and functional architecture in the cat's visual cortex," *J. Physiol.*, vol. 160, no. 1, p. 106, 1962.
[41] W. Wang and Y. Yang, "Development of convolutional neural network and its application in image classification: a survey," *Opt. Eng.*, vol. 58, no. 04, p. 1, 2019, doi: 10.1117/1.oe.58.4.040901.
[42] J. Gu *et al.*, "Recent advances in convolutional neural networks," *Pattern Recognit.*, vol. 77, pp. 354–377, 2018.
[43] N. Y. Khanday and S. A. Sofi, "Deep insight: Convolutional neural network and its applications for COVID-19 prognosis," *Biomed. Signal Process. Control*, vol. 69, no. May, p. 102814, 2021, doi: 10.1016/j.bspc.2021.102814.
[44] T. M. Navamani, "Efficient deep learning approaches for health informatics," in *Deep Learning and Parallel Computing Environment for Bioengineering Systems*, Elsevier, 2019, pp. 123–137.
[45] A. Hassan, I. Shahin, and M. B. Alsabek, "Covid-19 detection system using recurrent neural networks," in *2020 International conference on communications, computing, cybersecurity, and informatics (CCCI)*, 2020, pp. 1–5.
[46] Z. Li *et al.*, "E Fficient R Ecurrent N Eural N Etworks," no. 2018, pp. 1–4, 2018.
[47] K. Shyam Sunder Reddy, Y. C. A. Padmanabha Reddy, and C. Mallikarjuna Rao, "Recurrent neural network based prediction of number of COVID-19 cases in India," *Mater. Today Proc.*, no. xxxx, pp. 4–7, 2020, doi: 10.1016/j.matpr.2020.11.117.
[48] H. Jelodar, Y. Wang, R. Orji, and S. Huang, "Deep Sentiment Classification and Topic Discovery on Novel Coronavirus or COVID-19 Online Discussions: NLP Using LSTM Recurrent Neural Network Approach," *IEEE J. Biomed. Heal. Informatics*, vol. 24, no. 10, pp. 2733–2742, 2020, doi: 10.1109/JBHI.2020.3001216.
[49] S. Polyzos, A. Samitas, and A. Spyridou, "Tourism Demand and the COVID-19 Pandemic: An LSTM Approach," *SSRN Electron. J.*, 2020, doi: 10.2139/ssrn.3636193.
[50] R. Khan, M. Biswas, and M. Uddin, "Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID- 19 . The COVID-19 resource centre is hosted on Elsevier Connect , the company ' s public news and information ," no. January, 2020.
[51] S. Shastri, K. Singh, S. Kumar, P. Kour, and V. Mansotra, "Deep-LSTM ensemble framework to forecast Covid-19: an insight to the global pandemic," *Int. J. Inf. Technol.*, vol. 13, no. 4, pp. 1291–1301, 2021, doi: 10.1007/s41870-020-00571-0.
[52] Y. LeCun, C. Cortes, L. Bottou, and L. Jackel, "Comparison of Learning Algorithms for Handwriting Digit Recognition," *Int. Conf. Artif. Neural Networks*, pp. 53–60, 1995.
[53] M. E. H. Chowdhury *et al.*, "Can AI Help in Screening Viral and COVID-19 Pneumonia?," *IEEE Access*, vol. 8, pp. 132665–132676, 2020, doi: 10.1109/ACCESS.2020.3010287.
[54] C. Szegedy *et al.*, "Going deeper with convolutions," in *Proceedings of the IEEE conference on computer vision and pattern recognition*, 2015, pp. 1–9.
[55] T. Ozcan, "A Deep Learning Framework for Coronavirus Disease (COVID-19) Detection in X-Ray Images," vol. 90, no. 352, 2020, doi: 10.21203/rs.3.rs-26500/v1.
[56] M. K. Pandit, S. A. Banday, R. Naaz, and M. A. Chishti, "Automatic detection of COVID-19 from chest radiographs using deep learning," *Radiography*, vol. 27, no. 2, pp. 483–489, 2021, doi: 10.1016/j.radi.2020.10.018.
[57] A. Bhattacharyya, D. Bhaik, S. Kumar, P. Thakur, R. Sharma, and R. B. Pachori, "A deep learning based approach for automatic detection of COVID-19 cases using chest X-ray images," *Biomed. Signal Process. Control*, vol. 71, no. PB, p. 103182, 2022, doi: 10.1016/j.bspc.2021.103182.
[58] Y. D. Zhang, S. C. Satapathy, X. Zhang, and S. H. Wang, "COVID-19 Diagnosis via DenseNet and Optimization of Transfer Learning Setting," *Cognit. Comput.*, no. November, 2021, doi: 10.1007/s12559-020-09776-8.
[59] H. S. Alghamdi, G. Amoudi, S. Elhag, K. Saeedi, and J. Nasser, "Deep Learning Approaches for Detecting COVID-19 from Chest X-Ray Images: A Survey," *IEEE Access*, vol. 9, pp. 20235–20254, 2021, doi: 10.1109/ACCESS.2021.3054484.
[60] O. El Gannour *et al.*, "Concatenation of pre-trained convolutional neural networks for enhanced covid-19 screening using transfer learning technique," *Electron.*, vol. 11, no. 1, pp. 1–26, 2022, doi: 10.3390/electronics11010103.
[61] W. Wang, Y. Hu, T. Zou, H. Liu, J. Wang, and X. Wang, "A New Image Classification Approach via Improved MobileNet Models with Local Receptive Field Expansion in Shallow Layers," *Comput. Intell. Neurosci.*, vol. 2020, 2020, doi: 10.1155/2020/8817849.
[62] I. D. Apostolopoulos, S. I. Aznaouridis, and M. A. Tzani, "Extracting Possibly Representative COVID-19 Biomarkers from X-ray Images with Deep Learning Approach and Image Data Related to Pulmonary Diseases," *J. Med. Biol. Eng.*, vol. 40, no. 3, pp. 462–469, 2020, doi: 10.1007/s40846-020-00529-4.
[63] S. Sharma, S. Ghose, S. Datta, C. Malathy, M. Gayathri, and M. Prabhakaran, *Corona-19 net: transfer learning approach for automatic classification of coronavirus infections in chest radiographs*, vol. 1200 AISC, no. July 2020. Springer International Publishing, 2021.
[64] L. Sarker, M. M. Islam, T. Hannan, and Z. Ahmed, "COVID-DenseNet: A deep learning architecture to detect COVID-19 from chest radiology images," 2020.
[65] R. Babaeipour, E. Azizi, and H. Khotanlou, "An empirical study on detecting COVID-19 in chest X-ray images using deep learning based methods," *arXiv*, 2020.
[66] Z. Saeed, M. U. Khan, A. Raza, H. Khan, J. Javed, and A. Arshad, "Classification of Pulmonary Viruses X-ray and Detection of COVID-19 Based on Invariant of Inception-V 3 Deep Learning Model," no. December, pp. 1–6, 2021, doi: 10.1109/icecube53880.2021.9628338.
[67] S. Albahli, N. Ayub, and M. Shiraz, "Coronavirus disease (COVID-19) detection using X-ray images and enhanced DenseNet," *Appl. Soft Comput.*, vol. 110, p. 107645, 2021.
[68] J. Hu, L. Shen, S. Albanie, G. Sun, and E. Wu, "Squeeze-and-Excitation Networks," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 42, no. 8, pp. 2011–2023, 2020, doi: 10.1109/TPAMI.2019.2913372.
[69] L. Rodrigues, L. Rodrigues, D. Da Silva, and J. F. Mari, "Evaluating Convolutional Neural Networks for COVID-19 classification in chest X-ray images," no. October, pp. 52–57, 2021, doi: 10.5753/wvc.2020.13480.
[70] B. Cheng, R. Xue, H. Yang, L. Zhu, and W. Xiang, "DPN-SENet: A self-attention mechanism neural network for detection and diagnosis of COVID-19 from chest x-ray images," *arXiv Prepr. arXiv2105.09683*, 2021.
[71] G. Jia, H.-K. Lam, and Y. Xu, "Classification of COVID-19 chest X-Ray and CT images using a type of dynamic CNN modification method," *Comput. Biol. Med.*, vol. 134, p. 104425, 2021.
[72] U. Muhammad, M. Z. Hoque, M. Oussalah, A. Keskinarkaus, T. Seppänen, and P. Sarder, "SAM: Self-augmentation mechanism for COVID-19 detection using chest X-ray images," *Knowledge-based Syst.*, p. 108207, 2022.
[73] S. Rajpal, N. Lakhyani, A. K. Singh, R. Kohli, and N. Kumar, "Using handpicked features in conjunction with ResNet-50 for improved detection of COVID-19 from chest X-ray images," *Chaos, Solitons & Fractals*, vol. 145, p. 110749, 2021.
[74] S. Ahmed, M. F. Hossain, and M. B. T. Noor, "Convid-net: An enhanced convolutional neural network framework for covid-19

detection from x-ray images," *Adv. Intell. Syst. Comput.*, vol. 1309, no. January, pp. 671–681, 2021, doi: 10.1007/978-981-33-4673-4_55.
[75] M. Z. Islam, M. M. Islam, and A. Asraf, "A combined deep CNN-LSTM network for the detection of novel coronavirus (COVID-19) using X-ray images," *Informatics Med. Unlocked*, vol. 20, p. 100412, 2020, doi: 10.1016/j.imu.2020.100412.
[76] S. Kumar and R. Rani, "LiteCovidNet : A lightweight deep neural network model for detection of COVID-19 using X-ray images," no. May, pp. 1–17, 2022, doi: 10.1002/ima.22770.
[77] A. A. Ardakani, A. R. Kanafi, U. R. Acharya, N. Khadem, and A. Mohammadi, "Application of deep learning technique to manage COVID-19 in routine clinical practice using CT images: Results of 10 convolutional neural networks," *Comput. Biol. Med.*, vol. 121, no. May, p. 103795, 2020, doi: 10.1016/j.compbiomed.2020.103795.
[78] S. Ozturk, U. Ozkaya, and M. Barstugan, "Classification of coronavirus images using shrunken features," *medRxiv*, 2020, doi: 10.1101/2020.04.03.20048868.
[79] L. N. Mahdy, K. A. Ezzat, H. H. Elmousalami, H. A. Ella, and A. E. Hassanien, "Automatic X-ray COVID-19 Lung Image Classification System based on Multi-Level Thresholding and Support Vector Machine," *medRxiv*, pp. 1–8, 2020, doi: 10.1101/2020.03.30.20047787.
[80] F. Saiz and I. Barandiaran, "COVID-19 Detection in Chest X-ray Images using a Deep Learning Approach," *Int. J. Interact. Multimed. Artif. Intell.*, vol. 6, no. 2, p. 4, 2020, doi: 10.9781/ijimai.2020.04.003.
[81] T. Ozturk, M. Talo, E. A. Yildirim, U. B. Baloglu, O. Yildirim, and U. Rajendra Acharya, "Automated detection of COVID-19 cases using deep neural networks with X-ray images," *Comput. Biol. Med.*, vol. 121, no. April, 2020, doi: 10.1016/j.compbiomed.2020.103792.
[82] C. Butt, J. Gill, D. Chun, and B. A. Babu, "Deep learning system to screen coronavirus disease 2019 pneumonia," *Appl. Intell.*, 2020, doi: 10.1007/s10489-020-01714-3.
[83] E. B. G. Kana, M. G. Z. Kana, A. F. D. Kana, and R. H. A. Kenfack, "A web-based diagnostic tool for COVID-19 using machine learning on chest radiographs (CXR)," *medRxiv*, 2020, doi: 10.1101/2020.04.21.20063263.
[84] D. Singh, V. Kumar, Vaishali, and M. Kaur, "Classification of COVID-19 patients from chest CT images using multi-objective differential evolution–based convolutional neural networks," *Eur. J. Clin. Microbiol. Infect. Dis.*, vol. 39, no. 7, pp. 1379–1389, 2020, doi: 10.1007/s10096-020-03901-z.
[85] M. Al-Asfoor, "Deep Learning Approach for COVID-19 Diagnosis Using X-Ray Images," no. May, 2020, doi: 10.21203/rs.3.rs-31278/v1.
[86] H. Panwar, P. K. Gupta, M. K. Siddiqui, R. Morales-Menendez, and V. Singh, "Application of deep learning for fast detection of COVID-19 in X-Rays using nCOVnet," *Chaos, Solitons and Fractals*, vol. 138, p. 109944, 2020, doi: 10.1016/j.chaos.2020.109944.
[87] K. K. Singh, M. Siddhartha, and A. Singh, "Diagnosis of coronavirus disease (COVID-19) from chest X-ray images using modified XceptionNet," *Rom. J. Inf. Sci. Technol.*, vol. 23, no. 657, pp. 91–115, 2020.
[88] K. Ahammed, M. S. Satu, M. Z. Abedin, M. A. Rahaman, and S. M. S. Islam, "Semi-supervised Network for Dete," *medRxiv*, no. June, p. 2020.06.07.20124594, 2020, [Online]. Available: https://doi.org/10.1101/2020.06.07.20124594.
[89] M. S. Boudrioua, "COVID-19 Detection from Chest X-Ray Images Using CNNs Models: Further Evidence from Deep Transfer Learning," *SSRN Electron. J.*, no. June, 2020, doi: 10.2139/ssrn.3630150.
[90] S. Q. Salih, H. K. Abdulla, Z. S. Ahmed, N. M. S. Surameery, and R. D. Rashid, "Modified AlexNet Convolution Neural Network For Covid-19 Detection Using Chest X-ray Images," *Kurdistan J. Appl. Res.*, no. June, pp. 119–130, 2020, doi: 10.24017/covid.14.
[91] S. Ahmed, M. H. Yap, M. Tan, and M. K. Hasan, "ReCoNet: Multi-level Preprocessing of Chest X-rays for COVID-19 Detection Using Convolutional Neural Networks," *medRxiv*, p. 2020.07.11.20149112, 2020, [Online]. Available: http://medrxiv.org/content/early/2020/07/11/2020.07.11.20149112.abstract.
[92] G. González *et al.*, "UMLS-ChestNet: A deep convolutional neural network for radiological findings, differential diagnoses and localizations of COVID-19 in chest x-rays," no. June, 2020, [Online]. Available: http://arxiv.org/abs/2006.05274.
[93] N. Alsharman and I. Jawarneh, "GoogleNet CNN neural network towards chest CT-coronavirus medical image classification," *J. Comput. Sci.*, vol. 16, no. 5, pp. 620–625, 2020, doi: 10.3844/JCSSP.2020.620.625.
[94] S. Ahuja, B. K. Panigrahi, N. Dey, V. Rajinikanth, and T. K. Gandhi, "Deep transfer learning-based automated detection of COVID-19 from lung CT scan slices," *Appl. Intell.*, vol. 51, no. 1, pp. 571–585, 2021, doi: 10.1007/s10489-020-01826-w.
[95] J. de Moura *et al.*, "Deep convolutional approaches for the analysis of Covid-19 using chest X-ray images from portable devices," *IEEE Access*, vol. 8, no. March, pp. 195594–195607, 2020, doi: 10.1109/ACCESS.2020.3033762.
[96] M. Goncharov *et al.*, "CT-Based COVID-19 triage: Deep multitask learning improves joint identification and severity quantification," *Med. Image Anal.*, vol. 71, no. June, 2021, doi: 10.1016/j.media.2021.102054.
[97] M. Siddhartha and A. Santra, "COVIDLite: A depth-wise separable deep neural network with white balance and CLAHE for detection of COVID-19," pp. 1–25, 2020, [Online]. Available: http://arxiv.org/abs/2006.13873.
[98] I. U. Khan and N. Aslam, "A deep-learning-based framework for automated diagnosis of COVID-19 using X-ray images," *Inf.*, vol. 11, no. 9, 2020, doi: 10.3390/INFO11090419.
[99] M. Rahimzadeh and A. Attar, "A modified deep convolutional neural network for detecting COVID-19 and pneumonia from chest X-ray images based on the concatenation of Xception and ResNet50V2," *Informatics Med. Unlocked*, vol. 19, p. 100360, 2020, doi: 10.1016/j.imu.2020.100360.
[100] M. Mishra, V. Parashar, and R. Shimpi, "Development and evaluation of an AI System for early detection of Covid-19 pneumonia using X-ray (Student Consortium)," *Proc. - 2020 IEEE 6th Int. Conf. Multimed. Big Data, BigMM 2020*, pp. 292–296, 2020, doi: 10.1109/BigMM50055.2020.00051.
[101] N. N. Sun *et al.*, "A prediction model based on machine learning for diagnosing the early COVID-19 patients," *medRxiv*, pp. 1–12, 2020, doi: 10.1101/2020.06.03.20120881.
[102] G. C. Saha, I. A. Ganie, G. Rajendran, and D. Nathalia, "CNN Analysis for the detection of SARS-CoV-2 in Human Body," *nternational J. Adv. Sci. Technol.*, no. June, 2020.
[103] M. Tiwari, "Detection of coronavirus disease in human body using convolutional neural network," *Int. J. Adv. Sci. Technol.*, vol. 29, no. 8, pp. 2861–2866, 2020, [Online]. Available: https://www.scopus.com/inward/record.uri?partnerID=HzOxMe3b&scp=85085312861&origin=inward.
[104] W. Liu, Y. Ren, and H. Li, "URDNet: A Unified Regression Network for GGO Detection in Lung CT Images," *Wirel. Commun. Mob. Comput.*, vol. 2020, 2020, doi: 10.1155/2020/8862353.
[105] K. Shankar and E. Perumal, "A novel hand-crafted with deep learning features based fusion model for COVID-19 diagnosis and classification using chest X-ray images," *Complex Intell. Syst.*, vol. 7, no. 3, pp. 1277–1293, 2021, doi: 10.1007/s40747-020-00216-6.

[106] B. Narayanan, R. Hardie, V. Krishnaraja, C. Karam, and V. Davuluru, “Transfer-to-Transfer Learning Approach for Computer Aided Detection of COVID-19 in Chest Radiographs,” *Ai*, vol. 1, no. 4, pp. 539–557, 2020, doi: 10.3390/ai1040032.

[107] M. K. Pandit and S. A. Banday, “SARS n-CoV2-19 detection from chest x-ray images using deep neural networks,” *Int. J. Pervasive Comput. Commun.*, vol. 16, no. 5, pp. 419–427, 2020, doi: 10.1108/IJPCC-06-2020-0060.

[108] R. Jain, M. Gupta, S. Taneja, and D. J. Hemanth, “Deep learning based detection and analysis of COVID-19 on chest X-ray images,” *Appl. Intell.*, vol. 51, no. 3, pp. 1690–1700, 2021, doi: 10.1007/s10489-020-01902-1.

[109] L. J. Muhammad, E. A. Algehyne, S. S. Usman, A. Ahmad, C. Chakraborty, and I. A. Mohammed, “Supervised Machine Learning Models for Prediction of COVID-19 Infection using Epidemiology Dataset,” *SN Comput. Sci.*, vol. 2, no. 1, 2021, doi: 10.1007/s42979-020-00394-7.

[110] N. Gianchandani, A. Jaiswal, D. Singh, V. Kumar, and M. Kaur, “Rapid COVID-19 diagnosis using ensemble deep transfer learning models from chest radiographic images,” *J. Ambient Intell. Humaniz. Comput.*, no. November, 2020, doi: 10.1007/s12652-020-02669-6.

[111] O. A. Adebisi, J. A. Ojo, and O. M. Oni, “Comparative Analysis of Deep Learning Models for Detection of COVID-19 from chest X-Ray Images,” *Int. J. Sci. Res. Comput. Sci. Eng. Vol*, vol. 8, no. 5, 2020.

[112] M. E. Karar, E. E.-D. Hemdan, and M. A. Shouman, “Cascaded deep learning classifiers for computer-aided diagnosis of COVID-19 and pneumonia diseases in X-ray scans,” *Complex Intell. Syst.*, vol. 7, no. 1, pp. 235–247, 2021, doi: 10.1007/s40747-020-00199-4.

[113] L. Hussain *et al.*, “Machine-learning classification of texture features of portable chest X-ray accurately classifies COVID-19 lung infection,” *Biomed. Eng. Online*, vol. 19, no. 1, pp. 1–19, 2020, doi: 10.1186/s12938-020-00831-x.

[114] S. Calderon-Ramirez *et al.*, “Correcting data imbalance for semi-supervised COVID-19 detection using X-ray chest images,” *Appl. Soft Comput.*, vol. 111, no. August, 2021, doi: 10.1016/j.asoc.2021.107692.

[115] S. Ying *et al.*, “Deep learning enables accurate diagnosis of novel coronavirus (COVID-19) with CT images,” *IEEE/ACM Trans. Comput. Biol. Bioinforma.*, no. September, pp. 1–1, 2020, doi: 10.1101/2020.02.23.20026930.

[116] S. Heidarian *et al.*, “Ct-caps: Feature extraction-based automated framework for covid-19 disease identification from chest ct scans using capsule networks,” *ICASSP, IEEE Int. Conf. Acoust. Speech Signal Process. - Proc.*, vol. 2021-June, no. October, pp. 1040–1044, 2021, doi: 10.1109/ICASSP39728.2021.9414214.

[117] L. Wang, Z. Q. Lin, and A. Wong, “COVID-Net: a tailored deep convolutional neural network design for detection of COVID-19 cases from chest X-ray images,” *Sci. Rep.*, vol. 10, no. 1, pp. 1–13, 2020, doi: 10.1038/s41598-020-76550-z.

[118] J. Chen *et al.*, “Deep learning-based model for detecting 2019 novel coronavirus pneumonia on high-resolution computed tomography,” *Sci. Rep.*, vol. 10, no. 1, 2020, doi: 10.1038/s41598-020-76282-0.

[119] A. R. Martinez, “Classification of COVID-19 in CT Scans using Multi-Source Transfer Learning,” no. September, 2020, doi: 10.13140/RG.2.2.23461.32483.

[120] A. Al-Bawi, K. Al-Kaabi, M. Jeryo, and A. Al-Fatlawi, “CCBlock: an effective use of deep learning for automatic diagnosis of COVID-19 using X-ray images,” *Res. Biomed. Eng.*, 2020, doi: 10.1007/s42600-020-00110-7.

[121] S. Mishra, “A Novel Automated Method for COVID-19 Infection and Lung Segmentation using Deep Neural Networks,” pp. 1–13, [Online]. Available: https://doi.org/10.21203/rs.3.rs-86796/v1.

[122] A. Gupta, S. Gupta, and R. Katarya, “Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID- 19 . The COVID-19 resource centre is hosted on Elsevier Connect , the company ’ s public news and information ,” no. January, 2020.

[123] H. Mukherjee, S. Ghosh, A. Dhar, S. M. Obaidullah, K. C. Santosh, and K. Roy, “Shallow Convolutional Neural Network for COVID-19 Outbreak Screening Using Chest X-rays,” *Cognit. Comput.*, no. April, 2021, doi: 10.1007/s12559-020-09775-9.

[124] S. Shastri, P. Kour, S. Kumar, K. Singh, A. Sharma, and V. Mansotra, “A nested stacking ensemble model for predicting districts with high and low maternal mortality ratio (MMR) in India,” *Int. J. Inf. Technol.*, vol. 13, no. 2, pp. 433–446, 2021, doi: 10.1007/s41870-020-00560-3.

[125] S. Shastri, P. Kour, S. Kumar, K. Singh, and V. Mansotra, “GBoost: A novel Grading-AdaBoost ensemble approach for automatic identification of erythemato-squamous disease,” *Int. J. Inf. Technol.*, vol. 13, no. 3, pp. 959–971, 2021, doi: 10.1007/s41870-020-00589-4.

[126] R. K. Singh, R. Pandey, and R. N. Babu, “COVIDScreen: explainable deep learning framework for differential diagnosis of COVID-19 using chest X-rays,” *Neural Comput. Appl.*, 2021, doi: 10.1007/s00521-020-05636-6.

[127] S. E. Arman, S. Rahman, and S. A. Deowan, “COVIDXception-Net: A Bayesian Optimization-Based Deep Learning Approach to Diagnose COVID-19 from X-Ray Images,” *SN Comput. Sci.*, vol. 3, no. 2, pp. 1–23, 2022, doi: 10.1007/s42979-021-00980-3.

[128] Y. Oh, S. Park, and J. C. Ye, “Deep Learning COVID-19 Features on CXR Using Limited Training Data Sets,” *IEEE Trans. Med. Imaging*, vol. 39, no. 8, pp. 2688–2700, 2020, doi: 10.1109/TMI.2020.2993291.

[129] A. Degerli *et al.*, “COVID-19 infection map generation and detection from chest X-ray images,” *Heal. Inf. Sci. Syst.*, vol. 9, no. 1, pp. 1–11, 2021, doi: 10.1007/s13755-021-00146-8.

[130] X. Li, W. Tan, P. Liu, Q. Zhou, and J. Yang, “Classification of COVID-19 Chest CT Images Based on Ensemble Deep Learning,” *J. Healthc. Eng.*, vol. 2021, 2021, doi: 10.1155/2021/5528441.

[131] A. Hamed, A. Sobhy, and H. Nassar, “Accurate Classification of COVID-19 Based on Incomplete Heterogeneous Data using a KNN Variant Algorithm,” *Arab. J. Sci. Eng.*, vol. 46, no. 9, pp. 8261–8272, 2021, doi: 10.1007/s13369-020-05212-z.

[132] H. C. Reis, “COVID-19 diagnosis with deep learning,” *Ing. e Investig.*, vol. 42, no. 1, pp. 1–8, 2022, doi: 10.15446/ing.investig.v42n1.88825.

[133] E. H. Lee *et al.*, “Deep COVID DeteCT: an international experience on COVID-19 lung detection and prognosis using chest CT,” *npj Digit. Med.*, vol. 4, no. 1, 2021, doi: 10.1038/s41746-020-00369-1.

[134] M. M. Al Al Rahhal, Y. Bazi, R. M. Jomaa, M. Zuair, and N. Al Ajlan, “Deep Learning Approach for COVID-19 Detection in Computed Tomography Images,” *Comput. Mater. Contin.*, vol. 67, no. 2, pp. 2093–2110, 2021, doi: 10.32604/cmc.2021.014956.

[135] S. Tang *et al.*, “EDL-COVID: Ensemble Deep Learning for COVID-19 Case Detection from Chest X-Ray Images,” *IEEE Trans. Ind. Informatics*, vol. 17, no. 9, pp. 6539–6549, 2021, doi: 10.1109/TII.2021.3057683.

[136] V. Shah, R. Keniya, A. Shridharani, M. Punjabi, J. Shah, and N. Mehendale, “Diagnosis of COVID-19 using CT scan images and deep learning techniques,” *Emerg. Radiol.*, vol. 28, no. 3, pp. 497–505, 2021, doi: 10.1007/s10140-020-01886-y.

[137] N. Lassau *et al.*, “Integrating deep learning CT-scan model, biological and clinical variables to predict severity of COVID-19 patients,” *Nat. Commun.*, vol. 12, no. 1, pp. 1–12, 2021, doi: 10.1038/s41467-020-20657-4.

[138] V. Perumal, V. Narayanan, and S. J. S. Rajasekar, “Prediction of COVID-19 with Computed Tomography Images using Hybrid Learning Techniques,” *Dis. Markers*, vol. 2021, 2021, doi: 10.1155/2021/5522729.

[139] A. Narin, C. Kaya, and Z. Pamuk, “Automatic detection of coronavirus disease (COVID-19) using X-ray images and deep

convolutional neural networks," *Pattern Anal. Appl.*, vol. 24, no. 3, pp. 1207–1220, 2021, doi: 10.1007/s10044-021-00984-y.
[140] S. Kugunavar and C. J. Prabhakar, "Convolutional neural networks for the diagnosis and prognosis of the coronavirus disease pandemic," *Vis. Comput. Ind. Biomed. Art*, vol. 4, no. 1, 2021, doi: 10.1186/s42492-021-00078-w.
[141] M. Pal and F. Analytics, "Effective clustering and accurate classification of the chest X-ray images of COVID-19 patients from healthy ones through the mean structural similarity index measure," no. May, 2021, doi: 10.13140/RG.2.2.33801.57441.
[142] D. Ji, Z. Zhang, Y. Zhao, and Q. Zhao, "Research on Classification of COVID-19 Chest X-Ray Image Modal Feature Fusion Based on Deep Learning," *J. Healthc. Eng.*, vol. 2021, 2021, doi: 10.1155/2021/6799202.
[143] S. M. JavadiMoghaddam and H. Gholamalinejad, "A novel deep learning based method for COVID-19 detection from CT image," *Biomed. Signal Process. Control*, vol. 70, no. July, 2021, doi: 10.1016/j.bspc.2021.102987.
[144] O. N. Oyelade, A. E. S. Ezugwu, and H. Chiroma, "CovFrameNet: An Enhanced Deep Learning Framework for COVID-19 Detection," *IEEE Access*, vol. 9, no. May, pp. 77905–77919, 2021, doi: 10.1109/ACCESS.2021.3083516.
[145] R. Arora *et al.*, "AI-based diagnosis of COVID-19 patients using X-ray scans with stochastic ensemble of CNNs," *Phys. Eng. Sci. Med.*, vol. 44, no. 4, pp. 1257–1271, 2021, doi: 10.1007/s13246-021-01060-9.
[146] P. M. Shah *et al.*, "Deep GRU-CNN model for COVID-19 detection from chest X-rays data," *IEEE Access*, pp. 1–13, 2021, doi: 10.1109/ACCESS.2021.3077592.
[147] V. S. Rohila, N. Gupta, A. Kaul, and D. K. Sharma, "Deep learning assisted COVID-19 detection using full CT-scans," *Internet of Things (Netherlands)*, vol. 14, pp. 0–8, 2021, doi: 10.1016/j.iot.2021.100377.
[148] W. Zhao, W. Jiang, and X. Qiu, "Deep learning for COVID-19 detection based on CT images," *Sci. Rep.*, vol. 11, no. 1, pp. 1–13, 2021, doi: 10.1038/s41598-021-93832-2.
[149] I. Kumar *et al.*, "Deep learning approach for analysis and characterization of COVID-19," *Comput. Mater. Contin.*, vol. 70, no. 1, pp. 451–468, 2021, doi: 10.32604/cmc.2022.019443.
[150] I. Kumar and J. Rawat, "Deep Learning Method for Quantitative Analysis of Covid -19 using CT Chest Images," 2021, [Online]. Available: http://dx.doi.org/10.21203/rs.3.rs-540369/v1.
[151] N. Alrefai and O. Ibrahim, "Deep learning for COVID-19 diagnosis based on chest X-ray images," *Int. J. Electr. Comput. Eng.*, vol. 11, no. 5, pp. 4531–4541, 2021, doi: 10.11591/ijece.v11i5.pp4531-4541.
[152] E. M. Senan, A. Alzahrani, M. Y. Alzahrani, N. Alsharif, and T. H. H. Aldhyani, "Automated Diagnosis of Chest X-Ray for Early Detection of COVID-19 Disease," *Comput. Math. Methods Med.*, vol. 2021, 2021, doi: 10.1155/2021/6919483.
[153] S. Akter, F. M. J. M. Shamrat, S. Chakraborty, A. Karim, and S. Azam, "Covid-19 detection using deep learning algorithm on chest X-ray images," *Biology (Basel).*, vol. 10, no. 11, pp. 1–25, 2021, doi: 10.3390/biology10111174.
[154] A. Bashar, G. Latif, G. Ben Brahim, N. Mohammad, and J. Alghazo, "COVID-19 pneumonia detection using optimized deep learning techniques," *Diagnostics*, vol. 11, no. 11, pp. 1–18, 2021, doi: 10.3390/diagnostics11111972.
[155] A. Loddo, F. Pili, and C. Di Ruberto, "Deep learning for covid-19 diagnosis from ct images," *Appl. Sci.*, vol. 11, no. 17, 2021, doi: 10.3390/app11178227.
[156] E. Cortes and S. Sanchez, "Deep Learning Transfer with AlexNet for chest X-ray COVID-19 recognition," *IEEE Lat. Am. Trans.*, vol. 19, no. 6, pp. 944–951, 2021, doi: 10.1109/tla.2021.9451239.
[157] I. De Falco, G. De Pietro, and G. Sannino, "Classification of Covid-19 chest X-ray images by means of an interpretable evolutionary rule-based approach," *Neural Comput. Appl.*, vol. 0123456789, 2022, doi: 10.1007/s00521-021-06806-w.
[158] A. Badawi and K. Elgazzar, "Detecting Coronavirus from Chest X-rays Using Transfer Learning," *Covid*, vol. 1, no. 1, pp. 403–415, 2021, doi: 10.3390/covid1010034.
[159] G. Zazzaro, F. Martone, G. Romano, and L. Pavone, "A deep learning ensemble approach for automated COVID-19 detection from chest CT images," *J. Clin. Med.*, vol. 10, no. 24, 2021, doi: 10.3390/jcm10245982.
[160] C. Chola, P. Mallikarjuna, A. Y. Muaad, J. V. Bibal Benifa, J. Hanumanthappa, and M. A. Al-antari, "A Hybrid Deep Learning Approach for COVID-19 Diagnosis via CT and X-ray Medical Images," *Comput. Sci. Math. Forum*, vol. 2, no. 1, p. 13, 2021, doi: 10.3390/ioca2021-10909.
[161] O. KATAR and E. DUMAN, "Deep Learning Based Covid-19 Detection With A Novel CT Images Dataset: EFSCH-19," *Eur. J. Sci. Technol.*, no. January 2022, 2021, doi: 10.31590/ejosat.1021030.
[162] S. V. Kogilavani *et al.*, "COVID-19 Detection Based on Lung Ct Scan Using Deep Learning Techniques," *Comput. Math. Methods Med.*, vol. 2022, 2022, doi: 10.1155/2022/7672196.
[163] S. Shastri, I. Kansal, S. Kumar, K. Singh, R. Popli, and V. Mansotra, "CheXImageNet: a novel architecture for accurate classification of Covid-19 with chest x-ray digital images using deep convolutional neural networks," *Health Technol. (Berl).*, vol. 12, no. 1, pp. 193–204, 2022, doi: 10.1007/s12553-021-00630-x.
[164] W. Gouda, M. Almurafeh, M. Humayun, and N. Z. Jhanjhi, "Detection of COVID-19 Based on Chest X-rays Using Deep Learning," *Healthc.*, vol. 10, no. 2, pp. 1–19, 2022, doi: 10.3390/healthcare10020343.
[165] A. S. Kini *et al.*, "Ensemble Deep Learning and Internet of Things-Based Automated COVID-19 Diagnosis Framework," vol. 2022, 2022.
[166] S. Chakraborty, B. Murali, and A. K. Mitra, "An Efficient Deep Learning Model to Detect COVID-19 Using Chest X-ray Images," *Int. J. Environ. Res. Public Health*, vol. 19, no. 4, 2022, doi: 10.3390/ijerph19042013.
[167] S. Mohammad, J. Jalali, M. Ahmadian, S. Ahmadian, and R. Hedjam, X-ray image based COVID-19 detection using evolutionary deep learning approach," no. January, 2020.
[168] H. Nasiri and S. Hasani, Radiography Automated detection of COVID-19 cases from chest X-ray images using deep neural network and XGBoost," no. January, 2020.
[169] M. Constantinou, T. Exarchos, A. G. Vrahatis, and P. Vlamos, "COVID-19 Classification on Chest X-ray Images Using Deep Learning Methods," *Int. J. Environ. Res. Public Health*, vol. 20, no. 3, 2023, doi: 10.3390/ijerph20032035.
[170] G. Srivastava, A. Chauhan, M. Jangid, and S. Chaurasia, Biomedical Signal Processing and Control CoviXNet : A novel and efficient deep learning model for detection of COVID-19 using chest X-Ray images," no. January, 2020.
[171] Ç. Oğuz and M. Yağanoğlu, "Detection of COVID-19 using deep learning techniques and classification methods," no. January, 2020.
[172] T. Choudhary, S. Gujar, A. Goswami, V. Mishra, and T. Badal, "Deep learning-based important weights-only transfer learning approach for COVID-19 CT-scan classification," pp. 7201–7215, 2023.
[173] G. Celik, "Detection of Covid-19 and other pneumonia cases from CT and X-ray chest images using deep learning based on feature reuse residual block and depthwise dilated convolutions neural network[Formula presented]," *Appl. Soft Comput.*, vol. 133, p. 109906, 2023, doi: 10.1016/j.asoc.2022.109906.
[174] S. R. Nayak, D. R. Nayak, U. Sinha, V. Arora, and R. B. Pachori, "An Efficient Deep Learning Method for Detection of COVID-19 Infection Using Chest X-ray Images," *Diagnostics*, vol. 13, no. 1, pp. 1–17, 2023, doi: 10.3390/diagnostics13010131.

[175] M. T. Huyut, "Automatic Detection of Severely and Mildly Infected COVID-19 Patients with Supervised Machine Learning Models," *Irbm*, vol. 44, no. 1, p. 100725, 2023, doi: 10.1016/j.irbm.2022.05.006.

[176] F. Mercaldo, M. P. Belfiore, A. Reginelli, L. Brunese, and A. Santone, "Coronavirus covid-19 detection by means of explainable deep learning," *Sci. Rep.*, vol. 13, no. 1, pp. 1–11, 2023, doi: 10.1038/s41598-023-27697-y.

[177] C. Öksüz, O. Urhan, and M. K. Güllü, "Ensemble-CVDNet: A Deep Learning based End-to-End Classification Framework for COVID-19 Detection using Ensembles of Networks," no. December, 2020, [Online]. Available: http://arxiv.org/abs/2012.09132.

[178] W. Hariri and A. Narin, "Deep neural networks for COVID-19 detection and diagnosis using images and acoustic-based techniques: a recent review," *Soft Comput.*, vol. 25, no. 24, pp. 15345–15362, 2021, doi: 10.1007/s00500-021-06137-x.

[179] D. Sharifrazi *et al.*, "Fusion of convolution neural network, support vector machine and Sobel filter for accurate detection of COVID-19 patients using X-ray images," *Biomed. Signal Process. Control*, vol. 68, 2021, doi: 10.1016/j.bspc.2021.102622.

[180] E. Khan, M. Z. U. Rehman, F. Ahmed, F. A. Alfouzan, N. M. Alzahrani, and J. Ahmad, "Chest X-ray Classification for the Detection of COVID-19 Using Deep Learning Techniques," *Sensors*, vol. 22, no. 3, 2022, doi: 10.3390/s22031211.

[181] L. J. Muhammad *et al.*, "Deep Learning Models for Predicting COVID-19 Using Chest X-Ray Images," in *Trends and Advancements of Image Processing and Its Applications*, Springer, 2022, pp. 127–144.

[182] S. R *et al.*, "An Efficient Hardware Architecture Based on An Ensemble of Deep Learning Models for COVID -19 Prediction," *Sustain. Cities Soc.*, p. 103713, 2022, doi: 10.1016/j.scs.2022.103713.

[183] S. Nurmaini *et al.*, "Automated detection of COVID-19 infected lesion on computed tomography images using faster-RCNNs," *Eng. Lett.*, vol. 28, no. 4, pp. 1295–1301, 2020.

[184] J. Chen *et al.*, "Deep learning-based model for detecting 2019 novel coronavirus pneumonia on high-resolution computed tomography," *Sci. Rep.*, vol. 10, no. 1, pp. 1–12, 2020, doi: 10.1038/s41598-020-76282-0.