Computer Aided COVID-19 Identification on CT images with Deep Learning: A review

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Abstract: The current COVID-19 pandemic is a serious threat to humanity that directly affects the lungs. Automatic identification of COVID-19 is a challenge for health care officials. The standard gold method for diagnosing COVID-19 is Reverse Transcription Polymerase Chain Reaction (RT-PCR) to collect swabs from affected people. Some limitations encountered while collecting swabs are related to accuracy and long time duration. Chest CT (Computed Tomography) is another test method that helps healthcare providers quickly identify the infected lung areas. It was used as a supporting tool for identifying COVID-19 in an earlier stage. With the help of deep learning, learn the CT imaging characteristics of COVID-19. Researchers have proven it to be highly effective for COVID-19 CT image classification. In this study, we review the recent deep learning techniques that can use to detect the COVID-19 disease. Relevant studies were collected by various databasessuch as Web of Science, Google Scholar, and PubMed. Finally, we compare the results of different deep learning models, and CT image analysis is discussed.

Keywords: Artificial Intelligence, COVID-19, CT images,Deep Learning, RT-PCR.

I. INTRODUCTION

The recent coronavirus (COVID-19) pandemic is a dangerous virus disease spreading from China at the end of December2019. The virus spreads all over the world. Recently, there are a total number of COVID-19 confirmed cases, around 19.5 millionand over 4 million deaths [1]. It involves a massive family of viruses. It belongs to the subfamily of Corona virinae and is a part of the coronaviridae family. Corona looks like a spike structure on the virus's outer surface under an electron microscope. Its RNA is single-stranded with 80-120nm diameter and nucleic material ranging from 26 to 32kbs in length [2]. Usually, it is divided into four types, namely alpha(α), beta(β), gamma(γ), and delta, which affect animals, birds, and humans [3]. The origin of the virus can be transmitted from animals to humans. The virus can spread from an infected person's mouthor nose in small liquid particles when they cough, sneeze, speak or breathe [4]. These particles range from larger respiratory droplets to smaller aerosols. COVID-19 transmitted through air and people in close contact with each other. It was declared a global pandemic by the World Health Organization. Symptoms of the COVID-19 virus disease include dry cough, sore throat, fever mainly affects the respiratory system [5]. The incubation period of COVID-19 ranges from 1 to 14 days, symptoms developing 3-7 days, the longest incubation period can reach 24 days.

Early identification can reduce the transmission of COVID-19 infection. Initial Clinical testing RT-PCR conducted is well suited for early detection and collects swabs specimens from the infected patients [6]. The test is manual and time-consuming; results take 2 or 3 days. Researchers prove sometimes false- positive results are shown while proceeding with RT-PCR testing. This test may not be helpful for the faster diagnosis of COVID-19. Speedy, accessible, reasonable, and low-cost spotting of COVID-19 is a key to slowing the transmission of COVID-19 infection. Medical experts and researchers suggest several testing methods are used to detect COVID-19 using X- ray imaging [7], Ultrasound [8], and CT (Computed Tomography) [8].

The X-ray is cost-effective to define lung infections but does not show any abnormalities in the earlier stage[9].Ultrasound images have no side effects and are used in bedside patients. Also, low costs generally do not detect lesions or abnormalities on the lungs [10]. For these reasons, another imaging method is CT. It helps for early detection, observation, and disease evaluation: lung infection problems easily determined and faster diagnosis of COVID-19. Clinicians analyze and predict virus disease based on the variations on CTs. Computer researchers develop an early detection tool for diagnosing COVID-19.

Different DL techniques have been adopted to detect, diagnose, classify, predict, and predict COVID-19. It produces the best accurate models for handling medical datasets such as prediction of brain abnormalities, bacteria classification, different types of cancer, and biomedical image segmentation [11, 12, 13]. Recently, most researchers have involved Deep Learning techniques for COVID-19 identification on chest CT images. Deep learning algorithms can automatically generate the COVID-19 identification characteristics [14]. A well-known deep learning model is CNN performing pixel-wise segmentation to use global and local features. Computer Researchers developed several deep learning architectures for automated detection of COVID-19 and provided efficient accuracy.

In this paper, we systematically review various Deep learning methods that have been used recently to detect and diagnose COVID on CT images. We surveyed more than50 papers. Among these papers, we evaluate how the COVID CT images collected from various databases also implement deep learning techniques to identify the COVID symptoms earlier. The remaining sections of this paper are organized as follows. Section 2 describes the search strategy, and Section 3 suggests the CT image datasets. Also, Section 4 compares various deep learning techniques for COVID identification. Finally, Section 5 discusses this paper's conclusion by highlighting the limitations and future research directions.

II. METHODOLOGY

A. SEARCH STRATEGY

In this review, related journal articles are collected from valid databases. More than 90 papers are gathered, and 25 papers are filtered out. In this study, papers are selected by the keywords Artificial Intelligence, COVID-19, Convolutional Neural Network, CT-images, and Deep Learning. Our search query consists of the following keywords: [Artificial Intelligence] **AND** [Convolutional Neural Network] **AND** [COVID-19] **AND** [CT images] **AND** [Deep Learning]. After the search, filtered papers are mentioned to various deep learning techniques that are primarily applied in the medical field—these papers only direct COVID-19 disease detection by using several deep learning models.

B. CT images

Computer-aided methods are used to detect and diagnose the abnormalities or variations from chest CT (Computed Tomography) images. Several Deep learning studies have evolved while detecting the COVID-19 disease. CT is mainly the best imaging modality for lung infections or variations, and the physician denoted it as the gold standard [15]. While scanning the human lungs, CT produces several images, and physicians quickly analyze the variations. CT scans define the clear radiological findings of COVID-19 patients and help in a more structured and accessible manner produce results at a fast speed [16]. COVID-19 Chest CTs have some abnormalities such as ground-glass opacities (GGO) [17], Broncho vascular thickening in the lesion [18], crazy paving [19], and parenchymal bands [20,21] are present in the lungs. These findings are kept on the COVID-19 patient's chest CT images in Figure 1.

C) COVID-19 detection in CT images:

Diagnostics play an essential role in the control measures of COVID-19. Several detection tools are available to find the disease severity. Chest CT scans are the familiar fast diagnostic tool to diagnose the earlier stage of COVID-19 patients. COVID chest CT appearances are classified into four categories: 1)Typical Appearance 2)Indeterminate appearance, 3) Atypical appearance 4)Negative for Pneumonia.

a) **Typical Appearance:** It describes the expected behavior of the lungs such as reverse halo sign peripheral, bilateral, ground-glass opacities or without consolidation or visible intralobular lines. A central ground-glass opacities characterize the appearance of reversed halo sign is encircled by denser air–space consolidation with the shape of a crescent or a ring.

b) **Indeterminate appearance:** It is not determined or fixed—a few very small GGO with a non-rounded and non-peripheral distribution.

c) **Atypical appearance:** The presence of isolated lobar or segmental consolidation without GGO and smooth interlobular septal thickening with pleural effusion.

d) **Negative for Pneumonia:** There are no features to suggest pneumonia, absence of GGO, and consolidation.

Figure 1. An example CT image of Lung showing different parts and the COVID symptoms.

III. COVID-19 DATASET

Several public databases are available on many websites like Kaggle and GitHub. They provide many Chest CT images; Deep learning models handle large volumes of data using the algorithms to extract the image and show good accuracy results. Kaggle is a large data repository containing different data set types like text, numeric, and multimedia [22]. Also, many COVID-related data set images are available grouped as classes. It supports various file formats anyone can easily access and create their own databases. The main advantage of using Kaggle is notebook creation users can view adding code for the dataset they access as public or private.

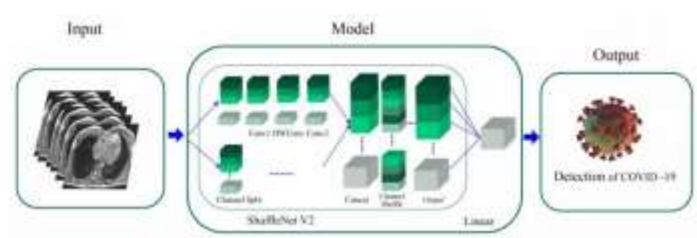


Figure. 2.An example ShuffleNet for COVID detection on CTimages [23]

IV. DEEP LEARNING FOR COVID DETECTION

Various deep learning approaches are developed to diagnose COVID-19 quickly. Using Classification, Segmentation, and prediction tasks done with the help of deep learning models [24]. In this context, the researchers handled various deep learning methods with clinicians' use in the detection of COVID-19. Deep Learning-based models have more efficaciesto proceed with an accurate and efficient system for detecting and diagnosing COVID-19. Using classification models to identify the coronavirus disease patients and with the help of deep layers [25]. Segmentation describes the lungs' affected area, and manual segmentation takes more time. Prediction identifies the risk of COVID-19 infection.

Deep Learning algorithms handle large volumes of data and produce accurate results. It established a model for showing the coronavirus-affected person in an earlier stage. Deep Learning Technology uses CNN models to analyze how viruses affect humans [26]. The Deep Convolutional Neural Network (DCNN) can learn the imaging characteristics of COVID-19 patients. Deep Learning Architectures such as AlexNet [27], VGG16 [28], VGG19 [28], GoogLeNet [29], Res Net18 [28], ResNet50[30], ShuffleNet [23] are the efficient networks used for early detection of COVID-19 patients using CT images. The ShuffleNet architecture for COVID detection is shown in Fig. 2

Table I. Comparison of deep learning based COVID classification models

Model	**No. of CT images**	**Description**	**Accuracy (%)**
ResNet [31]	Total: 618 COVID: 219 Pneumonia: 224 Normal: 175	Residual Network (ResNet) built with various layers looks like a pyramidal structure.	86.70
DenseNet121 [32]	Total:757 COVID:360 Non-COVID:397	Accurately performs where the infected areas present in the lungs.	84.07
AlexNet [27]	Total: 7500 COVID: 2500 Lung tumour:2500 Normal: 2500	Classify high dimensional convolutional features with less time.	98.25
EfficientNet [14]	Total: 3294 COVID: 1601 Normal: 1693	Compound scaling method based architecture was built .	87.68
DCNN [33]	Total : 1065 COVID: 325 Pneumonia: 740	Multiple units can be defined. Hierarchy structure of the class can be represented.	85.20
GoogLeNet [29]	Total: 746 COVID: 349 Normal: 397	Kernel sizes and inception layers obtained in this model. Reduce the dimensional size and computational cost.	91.72
DRENet [34]	Total:1282 COVID: 777 Pneumonia: 505	Define the top-K information image details of the lungs and also diagnose higher level predictions.	86.00

A. *Overview of Deep Learning*

Deep Learning is a sub-domain of machine learning based on artificial neural networks. A Deep Learning algorithm uses multiple layers to extract higher-level features from the raw input progressively. It trained on large amounts of data using GPU (Graphics processing units) to speed up computational processes. GPUs have been developed and optimized specifically for deep learning. Deep Learning also refers to a class of Artificial Neural Networks (ANNs) composed of many processing layers. ANN helps interpret the features of data and their relationships in which important information is processed through multiple stages of processing the data.

a. *Deep Learning and the Human Brain*

Deep learning works with artificial neural networks designed to imitate how humans think and learn. Deep understandingconsists of artificial neural networks modeled on similar networks present in the human brain. In deep learning, we don't need to program everything explicitly. Deep Neural Networks (DNNs) have several networks where each layer can perform complex operations such as representation and abstraction that make sense of images, sound, and text.

The human brain is the central organ of the human nervous system. The brain and the rest of the nervous system are composed of many different types of cells, but the primary functional unit is a neuron. A single neuron in the human brain receives thousands of signals from other neurons. All sensations,movements, thoughts, memories, and feelings result from signalsthat pass through neurons.

B. *Common Layers in DL model*

The layers are the blocks of Deep Learning. A layer in a deep learning model is a structure or network topology in the model's architecture, which takes information from the previous layers and then passes information to the next layer. There are several familiar layers in deep learning: the Convolutional layer, Recurrent layer, Preprocessing layer, Normalization layer, Regularization layer, Attention layer, Reshaping layer, Merging layer, Locally connected

Activation layer, and Maximum pooling layer. Some of the layers are discussed below

a. Convolutional Layer

A Convolution has a set of rules when two sources of information are interconnected. A convolutional layer contains a set of filters whose parameters need to be learned. The height and weight of the filters are smaller than those of the input volume. Each filter is convolved with the input volume to compute an activation map made of neurons. Convolutional layers apply a convolution operation to the input, passing the result to the next layer [35]. A convolution converts all the pixels in its receptive field into a single value, as shown in fig. 3

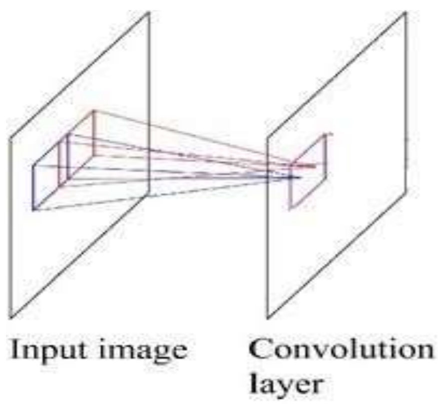


Fig.3. An example of convolutional layer from the input image [36]

b. Recurrent Layer:

A group of Layers to form recurrent networks consists of several classes. It is a type of neural network with previous step outputs. You are fed as an input of the current step. It uses the same parameters for each input as it performs the same task onall the inputs or hidden layers to produce the output. It allows continuing information related to past knowledge by gaining a special kind of looped structure. Recurrent layers can be used similarly to feed-forward layers except that the input shape is expected to be (batch_size, sequence_length, num_inputs) [37]. A reverse operation is performed in the following Fig. 4.

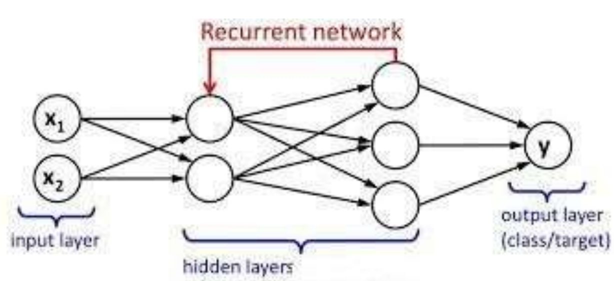


Fig.4. Recurrent layer [38]

c. Preprocessing Layer

Preprocessing Layer takes raw images or raw structured data as input and exports the end-to-end models [39]. It handles its own feature normalization or feature value indexing. Preprocessing Layer includes text, numerical, categorical, image preprocessing, and image augmentation layers. Several classes were obtained, such as text vectorization, normalization, category encoding, etc.

d. Normalization Layer

This layer was first introduced by Ba et al. in 2016. It normalizes the input and also speeds up stabilizes the learning process. It includes two classes, Batch normalization, and Layer normalization, as shown in Fig.5.

Batch Normalization:

Batch normalization focused on the standardized inputs to any particular layer (i.e., activations from previous layers). Standardizing the inputs means that inputs to any layer in the network should have approximately zero mean and unit variance. Batch normalization applied a transformation that maintains the mean output close to 0 and the standard deviation close to 1.

Layer Normalization:

Layer normalization (LayerNorm) is a technique to normalize the distributions of intermediate layers. It enables smoother gradients, faster training, and better generalization accuracy. Layer Normalization directly estimates the normalization statistics from the summed inputs to the neurons within a hidden layer. This normalization happens across the axes.

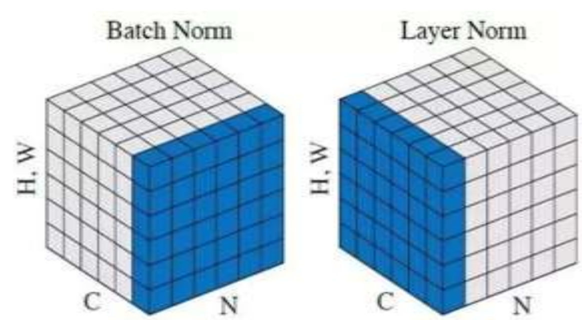


Fig.5. Normalisation and its types [40]

e. Regularisation Layers

During optimization, this layer is used for applying penalties on layer activities. It reduces the error by fitting a functionappropriately on the given training set. Regularizers allow you toapply penalties on layer parameters or layer activity during optimization. These penalties are summed into the loss function that the network optimizes. The Dropout layer randomly sets input units to 0 with a rated frequency at each step during training time, which helps prevent overfitting.

C. Classification Model

Early detection models have been developed for automatically identifying the COVID-19 Patients. Numerous classification models are available to handle disease detection efficiently. Deep learning classification models automatically detect the COVID-19 patients using CT images [41]. A well-known Deep Learning model is Convolutional Neural Network (CNN) is, a type of artificial neural network used in image recognition and processing pixel data. It has convolutional layers, pooling layers,and fully connected layers, and it is used for image processing, classification, segmentation, and other autocorrelated data [42].

a. CNN Architecture

CNN is the sub-class of Deep neural networks. It is used in image recognition and processing specifically designed to process pixel data. CNN is a type of neural network model which allows working with images and videos. Deep Learning has proved to be a potent tool because of its ability to handle large amounts of data. CNN takes the image's raw pixel data, trains the model, and automatically extracts the features for better classification. Common layers occur in a convolutional neural network: the convolutional layer, the pooling layer, the ReLU correction layer, and the fully-connected layer.

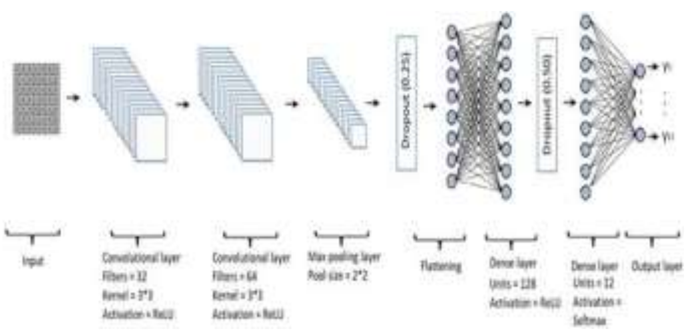


Fig.6. CNN architecture with number of layers [43]

b. Convolutional Layer

The main component of CNN architecture is the convolutional layer; Convolutional layers are the primary building blocks used in convolutional neural networks. It performs feature extraction, which produces a combination of linear and nonlinear operations.

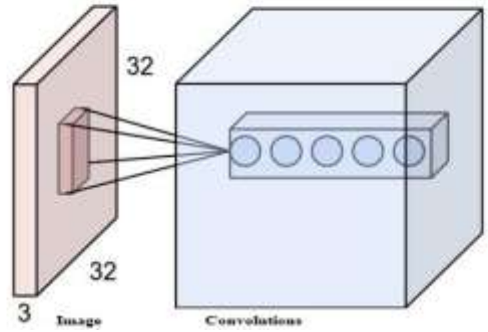


Fig.7. Convolutional layer connected to the respective field [44]

c. Pooling Layer

Another layer is the pooling layer; it is added after the convolutional layer; it reduces the size of the representation to reduce the number of parameters and computation in the network. The vital operation of pooling is max pooling. It extracts patches from the input feature maps and gets outputs from the maximum value in each patch; finally, it discards all the other values.

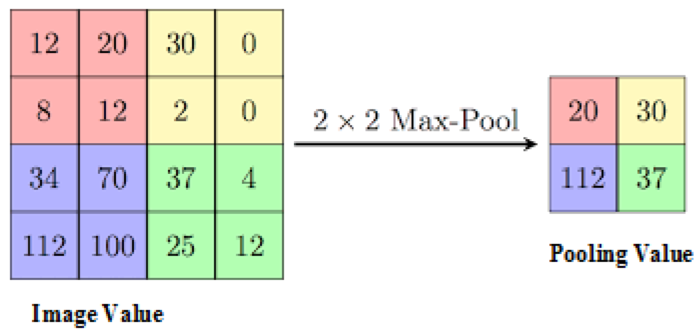


Fig.8. Max pooling with 2x2 filter and stride = 2 [45]

d. Fully Connected Layer

Fully Connected layers in neural networks are those layers where all the inputs from one layer are connected to every activation unit of the next layer. The inputs to the fully connected layer are the output from the final Pooling or Convolutional Layer, which is flattened and then fed into the fully connected layer. A fully connected layer compiles the data extracted by previous layers, such as a pooling or convolutional layer, which is flattened and then fed to form the final output, as shown in Fig.9.

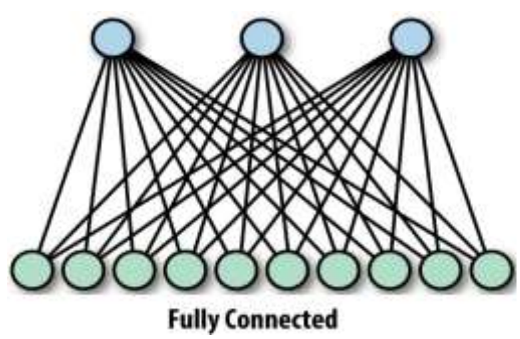


Fig.9.An example figure for Fully Connected Layer [46]

Some sample classification models such as ResNet [31],DenseNet121 [27], AlexNet [27], EfficientNet [14], DCNN [29],GoogLeNet [29], DRENet [34] are defined in Table 1. These models are applied in the CT images and provide efficient accuracy.

e. ResNet:

ResNet was designed by kaiming in 2015 [47] that mound residual blocks on top of each other to form a network. An artificial neural network builds on constructs known from pyramidal cells in the cerebral cortex. ResNet uses residual blocks with connections that connect the input of one layer to the output of another layer, also known as shortcut connections. Residual Network (ResNet), built with various layers, looks like a pyramidal structure. An example of ResNet is shown in figure10. ResNet consists of three layers of three blocks containing theConvolutional layer, Batch normalization, and Relu. There is one fully connected layer at the end. In [31], the authors implemented ResNet and tested its performance on a COVID dataset. This dataset consists of 618 images (COVID: 219,Pneumonia: 224, Normal: 175). The performance of ResNetachieved an accuracy of 86.70%.

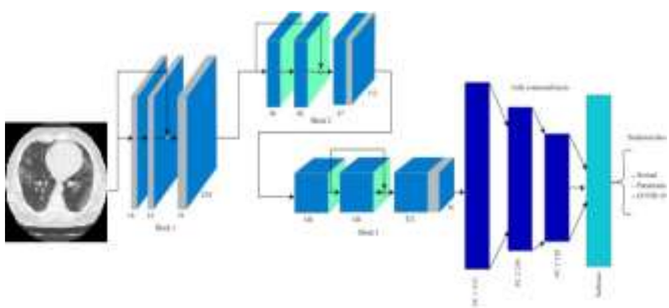
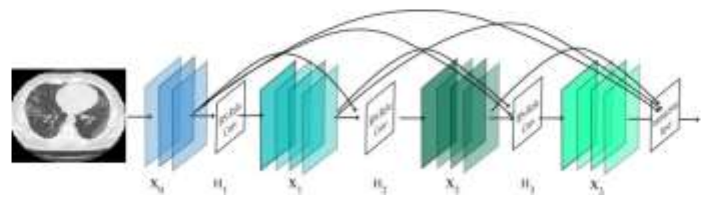


Fig.10.ResNet architecture for COVID-19 detection [48]

a. DenseNet

A DenseNet is similar to a convolutional neural network that utilises dense connections between layers; through Dense Blocks, it directly connects all layers. DenseNet and its concatenated (.) attributes combine the previous layer output with a future layer. An example of DenseNet is shown in figure 11, which shows the four-layer dense block with the growth rate k=3. The DenseNet Architecture aims to fix this problem by densely connecting all layers. Figure 3 shows the DenseNet model consists of four blocks: Batchnormalization, Relu, and convolutional layers. DenseNet is an easy communication model for improving information flow between layers. DenseNet has various transition blocks and dense blocks situated between two adjacent dense blocks. In [32], the authors implemented DenseNet and tested its performance on a COVID dataset. It consists of total 757 images (COVID: 360, Non-COVID: 397). Using these COVID CT images, ResNet achieved an accuracy of 84.07%.

Fig.11.DenseNet architecture for COVID-19 detection [48]



b. Alex Net

The AlexNet was introduced in 2012, and Alex Krizhevsky developed it. AlexNet network performs feature selection and image category classification for input images. The AlexNet network has convolutional layers for image feature selection, and three fully connected layers for image classification [49]. It attached ReLU activations after every convolutional and fully- connected layer. An example of AlexNet is shown in figure 12 consists of five convolutional layers followed by the max- pooling layers finally connected with three fully connected layers. In [27], the authors implemented AlexNet and tested its performance on a COVID dataset. This dataset consists of a totalof 7500 images (COVID: 2500, Lung tumor: 2500, Normal: 2500). From this dataset using this AlexNet achieved an accuracy of 98.25%.

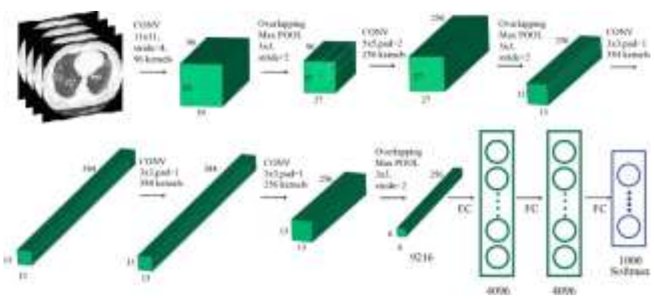


Fig.12. AlexNet architecture for COVID-19 detection [48]

c. EfficientNet

EfficientNet was developed by Mingxing Tan and Quoc V. Lein 2019. It performs the scaling method that scales alldimensions of depth/width/resolution in the same size using a compound coefficient. Efficient-Net Models are pre-trained and used for transfer learning in image classification problems. There are eight original EfficientNet models EfficientNet-B0 - EfficientNet-B7. EfficientNet network architecture and scaling method scale all depth/width/resolution dimensions using a compound coefficient. EfficientNet uses a compound coefficient to uniformly scale network width, depth, and resolution in a principled way [50]. In [14], this dataset contains 3294 CT images (COVID: 1601, Normal: 1693). EfficientNet models achieve both higher accuracy and better efficiency.

d. DCNN

DCNN was first introduced in the 1980s by Yann LeCun. Convolutional networks using convolutional layers. It is usually combined with the pooling layers, and the output is fed to the fully connected layers. A Convolutional neural network (CNN) is a neural network that has one or more convolutional layers and is used mainly for image processing and classification. CNNis that it automatically detects the essential features without any human supervision. An example of DCNN is shown in figure 13; it contains two convolutional layers, two pooling layers, and finally connected with a fully connected layer. In [33], the authors implemented DCNN and tested its performance on a COVID dataset. This dataset consists of 1065 images (COVID: 325, Pneumonia: 740). DCNN model can be used to detect the COVID-19 in Chest CT images and achieve an accuracy of 85.20%.

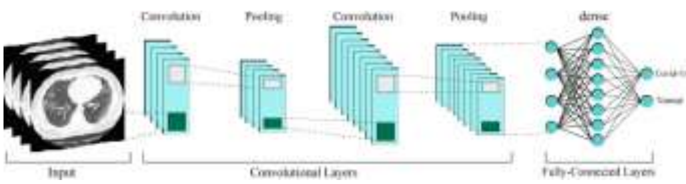


Fig.13.DCNN architecture for COVID-19 detection [48]

e. GoogLENet

The author first proposed GoogLeNet in 2018. The Google team developed it. GoogLeNet neural network based on the Inception architecture allows the network to select between multiple convolutional filter sizes in each block. Receptive fields, various kernel sizes, inception layers are included in this model. An example of GoogLeNet is shown in Figure 14. GoogleNet consists of 4 convolutional layers, including input and output layers. The second layer is a convolutional layer of size (28x28x10) followed by a pooling layer. The following three layers (c2, c3, c4) are also convolutional layers of size, which follow a pooling layer (p2). The seventh layer is an inception layer that combines all those layers. This inception layer aims to allow the network to choose between multiple convolutional filter sizes in each block and enhance the recognition accuracy. It is followed by a pooling layer of size (80). The final layer is fully connected of size (80), followed by the output layer. In [29], the authors implemented GoogLeNet and tested its performance on a COVID dataset. This dataset consists of 746 images (COVID: 349, Normal: 397). They were using this GoogLeNet to achieve an accuracy of 91.72%.

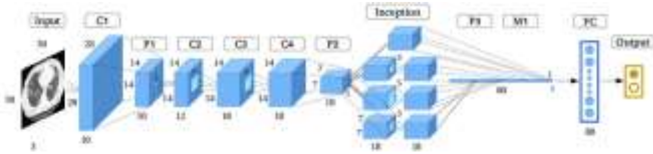


Fig.14.Google Net architecture for COVID-19 detection [51]

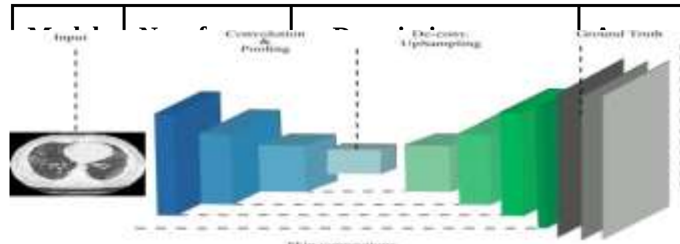
f. DRENet

DRENet has been proven to detect objects in images. It extracts top-k details from each image. Residual neural networksutilized skip connections or shortcuts to jump over some layers. In [34], the authors implemented DRENet and tested its performance on a COVID dataset. This dataset consists of 1282 images (COVID: 777, Pneumonia: 505). This DRENet achieved an accuracy of 86.00%.

D) Segmentation based Models:

Segmentation models can be used to detect the infected lung region. Mainly identify the shape of the present part. It specifies the defect inside the COVID-19 chest CT images. Some of the sample models like U-Net [52], FCN [53], VB-Net [54] are discussed in Table 2. These models are specified accurately inthe symptomatic region in the lungs. Using segmentation algorithms closed with related region merging techniques to perform specific actions. Segmentation performed in the particular areas of the lungs that predicted areas are changed intopixel predictions. Pixel can be labeled depending on the scoring system. Segmentation models handle some other diseases presented inside the lungs. These models characterize the number of CT images for the training and testing process. A fully Convolutional Network (FCN) has connected layers as sampling, pooling, and convolution. U-Net model based on decoder-encoder architecture, fast and exact segmentation of images.

Table II. Comparison of Segmentation models for COVID identification



	Normal:150	performedare also recommended for medical imaging segmentation.	
FCN [53]	Total: 939 COVID: 492 Normal: 447	Minimize the number ofparameters and less computational time to provide accuracy.	99.00
VB-Net [54]	Total: 649	They have segmented theinfected regions of the lungs in a loop method.	91.60

a. U-Net:

U-Net was created by Olaf Ronneberger et.al in 2015 [55]. It consists of contracting and expansive paths, which gives it a U-shaped architecture. A convolutional network consists of convolutions, each followed by a rectified linear unit (ReLU) and a max-pooling operation. U-net and an equal number of pooling and sampling layers [56]. All the Convolutional layers are connected with sigmoids. It utilizes deconvolutional layer skip connections between up-sampling and down-sampling layers. It applies convolution blocks followed by a max pool downsampling to encode the input image into feature representations at multiple different levels. An example U-Net is shown in figure 15, consisting of 9 convolutional layers connected with the sigmoid. In [52], authors implemented GoogLeNet and tested its performance on a COVID dataset. This dataset consists of 270 CT slices (COVID: 120, Normal: 150). This U-Net achieved an accuracy of 94.8%.

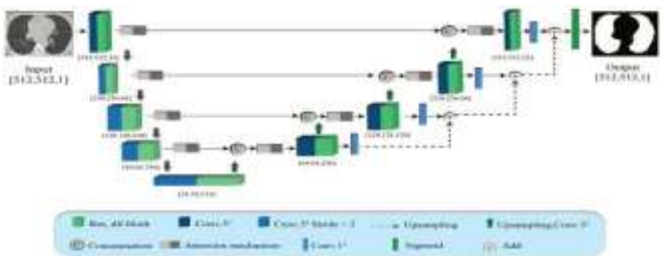


Fig. 15.U-Net architecture for COVID-19 detection [48]

1) FCN:

Fully Convolutional Networks (FCNs) are built using locally connected layers, such as convolution, pooling, and upsampling [57]. It only performs convolution operations; no dense layer is used in FCN. It also reduces the number of parameters and computation time. FCN model contains downsampling path and upsampling path. The downsampling path is responsible for capturing semantic/contextual information, and the Upsampling path is responsible for recovering spatial information. In this model, networks transform the whole convolutional models replacing FC layers, and get output as a local map. It performs the tasks only in fully connected layers. Many skip connections have been added to the network from the lower layers to the end layer. An example FCN is shown in figure 16, describing the four convolutional layers combined with pooling layers. In [53], the authors implemented FCN and tested its performance on a COVID dataset. This dataset consists of 939 CT images (COVID: 492, Normal: 447). This FCN achieved an accuracy of 99.00%.

Fig.16.FCN architecture for COVID-19 detection [48]

a. VB-Net:

VB-Net is a modified 3D convolutional neural network that combines V-Net with a bottle-neck structure [58]. VB-Net consists of two paths. This model segments the infected lung region based on the loop method. The Contracting path performs downsampling done convolution operations to extract the image features. The expansive path serves up-sampling to integratefine-grained image features [59]. The speed of VB-Net is much faster because the bottle-neck structure is incorporated in VB- Net. An example VB-Net is shown in figure 17. In [54], the authors implemented VB-Net and tested its performance on a COVID dataset. This dataset consists of a total of 649 CT. This VB-Net achieved an accuracy of 91.60%.

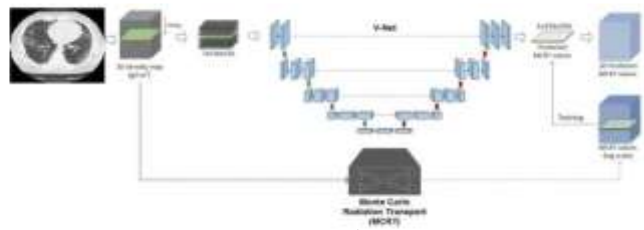


Fig. 17.VB-Net architecture for COVID-19 detection [60]

CONCLUSION AND FUTURE WORK

In this review, deep learning methods identified the severity of COVID-19 with CT images. Analyzing the infected lung area with the help of a radiologist and RT-PCR test resultsis an aid of the final decision. Large numbers of open source CT image databases are available. Other than COVID-19, infections inside the lungs like lesions, cancer, pneumonia, and lung- related problems are also detected while analysing CT images using deep learning models. Abnormalities are present in the lung area researchers find out with the help of deep learning methodology. Deep learning models raised the accuracy level of classification and segmentation. Classification models automatically separate the COVID-19 CT images and other diseases. The future challenge of the review is differentiating the stages of COVID-19 and the accuracy level.

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