Detail-Oriented Capsule Network for classification of CT scan images performing the detection of COVID-19

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ABSTRACT

COVID-19 is one of the biggest pandemics that the world is facing today, and every day, we are coming up with new challenges in this area. Still, much research is already going on to overcome this pandemic, and we also get succeeded to some extent. Diverse sources such as MRI, CT scanning, blood samples, X-ray image, and many more are available to detect COVID-19. Thus, it can be easily said that through image processing, the classification of COVID-19 can be done. In this study, the COVID-19 detection is done by classifying with the use of a type of convolutional neural network termed a detail-oriented capsule network. Chest CT scan imaging for the prediction of COVID-19 and non-COVID-19 are classified in the present paper using a Detailed Oriented capsule network (DOCN). Accuracy, specificity, and sensitivity are parameters used for model evaluation. The proposed model has achieved 98% accuracy, 81% sensitivity, and 98.4% specificity.

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1. Introduction

A global health crisis for every field of human life was created by the pandemic and associated effort to prevent coronavirus disease (COVID-19) [1]. At the beginning of the disease, the threat of the disease was not so high as to be solved mostly spontaneously because of its minimal number of persons. The World Health Organization (WHO) has gradually declared COVID-19 a risk-extreme outbreak that would affect millions of lives in every country, especially those with weaker health systems [2]. For two basic reasons, the virus is fatal: firstly, it is novel, no vaccines are found, and secondly, it is easily transmitted by direct or indirect contact with the affected person.

Two renowned types of SARS-CoV and MERS-CoV coronaviruses have been reported in China and Saudi Arabia in 2003 and 2012, respectively, over the past two decades [3]. Although SARS and MERS outbreaks have confirmed human transmission to humans, the new corona virus does not have the same spread and infection rate (COVID-19). The RT-PCR is a standard diagnostic test for the diagnosis of COVID-19 [4]. However, a long-term test can be considered, and false-negative diagnoses can also be made. And, with the scanning of the medical, chest CT and chest x-ray, COVID 19 diagnosis may be critical. Medical imaging technology is very important for the diagnosis of diseases. Segmentation of images is the necessary task to differentiate externals from regions of interests (ROIs). Image segmentation can also extract critical characteristics, including texture and shape. Overall, methods of feature selection (FS) are widely used in different applications in medical imaging [5]. Some of the researchers has proposed an efficient Radiomics approach for extracting medical images [6]. The analysis of image functionality has shown that more information improved medical imagery.

The rest of the paper is organized in the following way: The background study followed by the materials and methods section is covered in Section 2. Section 4 deals with the conclusion and future work, and finally the references are written.

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2. Background study

In order to analyze pneumonia, Yadav et al. [7] have implemented a chest X-rayed model based on the CNN model. The transfer learning was used on CNN, and two models, namely VGG16 and InceptionV3, were used. In addition, SVM was used to achieve better results. The number of COVID-19-infected patients and fatalities was investigated worldwide by Hassani [8]. A methodology for detecting the use of X-ray imaging (with the Vector Gadget Classifier) for Covid 19 infected patients has been recommended [9]. This method helps hospital doctors to detect the cases of COVID-19 patients at an early stage. They are 97.48 % exact with the various matrix parameters of the proposed lung classification model. Karar et al. [10] discussed how new coronavirus is presented in China, City Wuhan, as a novel pneumonia disease. The main purpose of this article was to present a new, deep learning environment for cascaded deep study classifiers to enhance the performance of CAD systems for highly suspected COVID-19 and pneumonia diseases in X-ray images.

Hao et al. [11] used the pneumothorax detection with SVM technique for the chest X-ray image classification. The Local Binary Pattern (LBP) was used to evaluate lung characteristics. The authors used multiscale texture segmentation in the proposed detection model by removing impurities from pit images to segment abnormal lung areas. Furthermore, a texture change was applied to find several overlapping blocks. Lastly, the authors used the rid border for finding the entire area of the illness with the abnormal part (with sobel edge detection).

Choi et al. [12] gave an X-ray analysis of the new coronavirus MERS (Middle East Respiratory Syndrome). The case of a 30-year-old man with diarrhea, fever, and abdominal pain was examined. The authors analyzed the treatment of infected individuals with chest X-rays. In [13], the authors took into account in France the first three COVID-19 cases. Of these, two in Paris and one in Bordeaux were diagnosed. They stayed in Wuhan, China, before they came into contact with COVID-19 diseases. The model was also used in an X-ray and CT dataset collected chest, and the results have been improved. They also discussed which hospital protocols staff should take care of the infected patients to reduce the risks of healthy patients and take precautions.

Ozturk [14] has implemented a hybrid system based on artificial intelligence should specifically use a different filtering at each layer and deep learning algorithms (i.e. the CNN) termed as DarkNet model. The proposed method is specially designed to detect cases of COVID-19 using X-ray images. In [15], the authors proposed to use X-ray frames to diagnose the COVID-CAAPS disease based on Capsule Networks. In this proposed work, several layers and conversion capsules are used to address the class disequilibrium problem. In the experimental analysis, COVID-CAPS demonstrated its satisfactory performance with a smaller number of trainable parameters. The authors referred to the educated model available for Github open access. Therefore, they found that 95.7 percent of the proposed model is exact, whereas 90 percent of sensitivity and 95.80 percent of specificity are shown while using fewer trainable parameters.

Chung et al. [16], has examined 21 COVID-19 patient CT scans which is considered by the authors in Wuhan, China. The authors focus primarily on the demonstration and effects of COVID-19 diseases. The authors also put forward the COVID-RENet model for the extraction for the classification of features (e.g. edge and region-based) [17 18]. Lee et al. [19] acquire features through the application of CNN and subsequently use SVM to increase classification performance. On a collected COVID-19 data set, they used five-fold cross-validation. This approach applies primarily to the medical early diagnosis specialist for COVID-19 patients. The impact of COVID-19 on people with pneumonia and pulmonary diseases on the data set collected in Chest CT was identified by using a thoroughly trained model.

Diao et al. [20] has shown the effect of COVID-19 on the kidney and acute renal failure. Nair et al. [21] have built a CNN model on more levels and modified its internal parameters for a specific task such as classification or recognizing objects. There is a typical CNN structure with an extract filter from the input by a convolution layer. It enhances the performance of the computer and the neural network with a fully connected layer. The authors suggested in [22], the KE Sieve Neural Network architecture to find analyses of COVID-19 using chest x-rays. The model has reached 98 percent precision.

Gomathi et al. [23] offer an option to develop a predictive model on the machine, which predicts the continuation of severe patients, such as Kaggle dat.gov and the World Health Organisation, with more than 95 percent accuracy. The rationality of only three elements can depend on the tissue injury, immunity and inflammation indicators. Goyal et al. [24] examined chest x-ray (CXR) for lung abnormality identification. They showed that due to its complete availability and reduced infection control, the medical community relies on CXR. In [25], the detection of Covid 19 diseases was done using 123 x-ray front views. In addition, the authors talked in [26] about the importance of healthcare for AI tools. Using AI tools for fewer X-ray image datasets was also discussed (which is available publicly). The authors examined X-ray and CT data by dedicating themselves to detecting COVID-19 from various media and the transfer of learning algorithms. In a collected dataset, AlexNet used pre-trained and modified CNN models. This showed 98% accuracy and 94,1% precision in the pre-trained model. Ozkaya [27], has extraced two sub-sets of datasets (16*16 and 32* 32), derived from 150 CT images, and COVID-19 was labelled with 3000 X-ray images. To improve the performance of the proposed methodology, the merger and rating methods have also been used. To categorize processed data, the Authors used SVM and the CNN model to transfer learning. Consequently, they demonstrated that set 2 was well accurate compared to set 1.

The introduction of a deep anomaly detection method in reliable COVID-19 patients was discussed by Zhang et al. [28]. They have taken 100 COVID-19 X-ray photos, confirmed by 70 optimistic people. Zhao et al. [29], also discussed the effects of COVID-19 on humans. They took into account 101 cases of infected pneumonia COVID-19. The main aim of this study was to compare COVID-19′s clinical condition with CT images. COVID-19 is a virus disease that has an impact not only on human beings but also on a country, after examining all the views and suggestions given by various researchers. They discussed several methods used to detect COVID-19 cases early. Three models of a collected X-ray picture chest were implemented (i.e. Inception V3, XCeption, and ResNet). Moreover researchers are proposing various protocols in the field of healthcare[38–43] and vehicle communication[44–50] to protect the information exchanged among various devices to devices. Some researchers are providing various techniques for image privacy[51–55]

3. Material and methods

This study has implemented the capsule network for the classification of chest CT scan images during the prediction of COVID-19. So the section will discuss about the capsule network then move to the implemented work.

3.1. Capsule network

In the case of deep learning model, many times the important information is lost during the max-pooling process since only the most active neurons are chosen to move into the next layer. This is because valuable spatial data are lost between the layers. Hinton suggested that we use the "routing-by-agreement" procedure to address this matter [30]. This means that features at a lower level (fingers, eyes, mouth) are only transferred to a higher, corresponding content level. It becomes a "face", or if it contains fingers and a palm, it will be transmitted to a "hand" if the features resemble those of the eye or mouth. At NIPS 2017, Geoffrey Hinton (Capsule Networks) presented this comprehensive solution that encodes spatial information into features while also using dynamic routing (by agreement routing).

3.1.1. Capsules

When we build objects in computer graphics, we must specify and provide certain geometric data, indicating to the computer where the object should be drawn, the scale of this object, its angle and other space data. All of this information is presented on the screen as an object. However, what if only by looking at an object in an image we could extract that information? The process of reverse rendering is based on the capsule networks.

3.2. Dataset used for the analysis

Datasets used in this work are Soares et al. dataset [31] and the Italian dataset [32]. The dataset includes 360 COVID-19 scans and 397 CT scans for other diseases and healthy subjects. The Italian dataset includes 100 CT scans of COVID-19.

3.3. Detail-oriented capsule network

Fig. 1, which consists of 3 layers of convolution and three capsule layers, illustrates the architecture of the proposed COVID-CAPS [15]. The network inputs are 3D X-ray pictures. The first layer of batch normalization is a convolutionary one. The layer two is also convolutionary, and average age pooling is followed. Consequently, the routing process includes three layers of the capsule did in the COVID-CAPS. Positive as well as negative COVID-19 parameters are included in the final capsule layer. Every class is likely to have the length of both capsules. We haven't expanded data because we developed network architecture without a large dataset. Lets discuss the components of the proposed flowchart are as follows:

i. Input dataset – Image size of 224 * 224 *3 is fetched in to the convolution layer.
ii. Convolution layer – This study has used the 3 Convolution Layer (3x3x64) with stride = 1.
iii. Capsule Network – In this work we have used 3 Capsule Network of different sizes with routing agreement. Finally the last capsule network is of size 16x2 for the prediction of COVID-19 disease.

As mentioned above, we considered initial pre-training of the model to potentially enhance COVID-CAPS diagnostic capabilities. However, we built and used a dataset for CT scans. Image Net is not used for pre-training because, in that dataset, the image (natural photographs) is different than the COVID-19 scan dataset. The COVID-CAPS is expected to improve a pre-trained model for x-ray images of a like type. First, the entire COVID-CAPS model has to be trained on external data with external data. The number of outside classes determines the number of the capsule. Two cap-
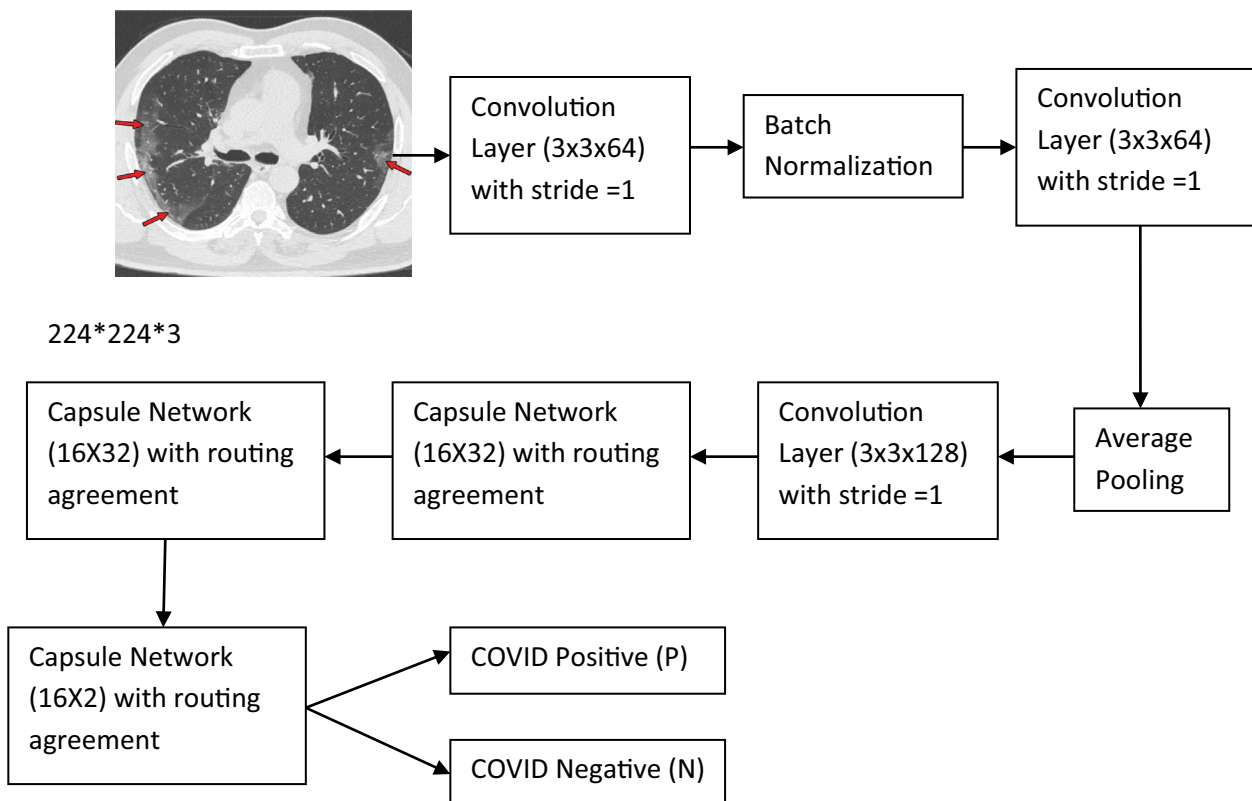

224*224*3

Fig. 1. Flowchart of Capsule Network for the classification of CT scan images.

Table 1
Compares existing models of the proposed model.

Method	Accuracy (%)	Specificity (%)	Sensitivity (%)
Li et al. [34]	–	96	90
Xu et al. [35]			86.7
Wang et al. [36]	73.1	76	67
Light CNN [37]	85.03	81.95	87.55
DOCN (Detail oriented capsule network)	98	98.4	81

sules replace the last layer of the capsules to adjust the model with the COVID 19 data set. All other capsules are switched smoothly, and conventional layers are fixed before weight exercise. The following changes are performed in comparison to the original Capsule Network [33], some of the highlighted work are as follows:

- The network of Capsules presented in the previous study [33] initially works on a dataset of black-and-white digital numbers and are small in size as compared with CT scan image. We extend the capsule layers and routing procedures for the Capsule network to extract complete patterns from the CT scanner to make them applicable to the problem.
- The dataset that was originally used to develop the Capsule Network is fully compatible with each label. However, as COVID19 is a new problem, COVID-19 is restricted to very unbalanced data sets. We have changed the original loss margin to give more penalties to misclassified positive cases to account for this unbalanced data set.
- Our Capsule Network is pre-trained to make the small data set available. A 5-class external data set is the pre-training system that is reflected in five final capsules. The five capsules collapse into two capsules and finish in the main COVID-19 data set with all layers of the capsules. For Adam Optimizers, we have used a learning rate of 10^{-3}, 100 epochs and 16 batch sizes. As described in section 4, we have two training sets (80%) and validations sets (20%) divided into training sets for model training and validation set for selecting the best model. The model chosen is tested on the test set for the final evaluation. The following three metrics are used: Accuracy, sensitivity, specificity. We will subsequently present the results obtained.

4. Implementation details

The proposed work is carried out in the programming language Python 3 with some of the required libraries such as TensorFlow, Scikit learn, and many more. Exactness, specificity, and sensitiveness are the parameters discussed in the evaluation of the models. Table 1 compares existing models of the proposed model, showing that the proposed DOCN model outperformed other state-of-the-art algorithms.

5. Conclusion and future work

This work is aim to find out the effective model for the prediction of COVID-19 disease. In this work we have implemented the capsule network for the analysis. But the dataset used for the analysis is comparatively small in size. So we cannot assure that the model which has developed can be used for clinical purpose, still we are working continuously to get more accurate results. The study has used the different number of capsule networks with number of convolution layers and the work has achieved better results than the existing models. In the future we will focus on the processing time of the model. Because in this model more number of capsule networks and convolution networks can take

more time for the prediction, so to reduce the processing time, a new model has to be implemented in the future.

CRediT authorship contribution statement

Shraddha Modi: . **Rajib Guhathakurta:** . **Sheeba Praveen:** . **Sachin Tyagi:** . **Saket Narendra Bansod:** Validation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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