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Feature extraction with capsule network for the COVID-19 disease prediction though X-ray images

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A B S T R A C T

Past couple of years, the world is going through one of the biggest pandemic named COVID-19. In the mid of year 2019, it is a very difficult process to predict the COVID-19 just by viewing the images. Later on AI based technology has done a significant role in the prediction of COVID-19 through biomedical images such as CT scan, X ray etc. This study also implemented the deep learning model for the prediction of COVID-19 through X-ray images. The implemented model is termed as XR-CAPS which consist of two models such as U-Net model and the capsule network. The U Net model is used for performing the segmentation of the images and the capsule networks are applied for performing the feature extraction. The XR-CAPS model is applied on the X-ray images for the prediction of COVID-19 and the evaluation of the model is done by three parameters that are accuracy, sensitivity and specificity. The model is compared with other existing models like ResNet50, DenseNet121 and DenseCapsNet, this has achieved an accuracy of 93.2%, sensitivity of 94% and specificity of 97.1% which is better than other states of the art algorithms.

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1. Introduction

With the end of 2019, COVID-19 has started to spread worldwide and created an alarming situation around the globe. The disease has already become a problem. In December 2019, the virus originated in Wuhan, a city in eastern China [1]. The World Health Organization (WHO) declared it a "international emergency of public health" in 2020, and the disease it was considered to be a pandemic by March 2020 [2]. Around 118, 7 million people have been affected, and by March 2021 2.6 million deaths have been confirmed. Other symptoms, like fatigue, dry cough, and fever, are caused by pneumonia. The RT-PCR (reverse transcription polymerase in China) is one of the primary methods for coronavirus testing and test results are achieved within a few hours or two days. This detection method is time-consuming and costly [2]. Consequently, it is an important challenge for researchers to design other virus detection methods. In particular, no specific therapy for COVID-19 has been conducted up to now.

Automatic diagnosis of many diseases is today based on artificial understanding that has demonstrated its efficiency and high level of performance through various methods of automatic image classification. Moreover, machine learning defines models with great quantities of input data examples that can learn and make decisions [3]. Artificial intelligence calculates and predicts based on input data analysis and then carries out tasks requiring human intelligence like spoken recognition, translation, visual perception and more. Deep learning is a combination of machine learning methods which mainly focus on automatic imaging and grading and have showed great success in numerous applications, in particular in the field of health care [4]. Deep Learning model has produced better results in case of cancer classification. Deep learning models are already applied on various types of cancer datasets such as colon, breast, prostate, lungs and many more.

Now there are many models based on deep learning for COVID-19 classification using chest X-rays, and through the use of computed tomographic images (CT). Additional work on COVID-19

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based upon pulmonary datasets has been detected and diagnosed, such as in addition, some studies employed CNN data sets for the classification and detection of COVID-19 from X-ray images of the chest. Several studies also focused on COVID-19 detection and differentiation from other chest diseases such as pneumonia, authors have shown that in the early stages a chest X-ray has less momentum although a Chest CT scan can be helpful even before symptoms occur. The potential overlap between COVID-19 diagnosis, pneumonia and chest cancer is one of the problems associated with Chest CT or X-ray images, particularly when people diagnosed with low experience or if the patient's history file is currently not available [5]. This requires the automation of such a process so that one of those three diseases can be accurately confirmed.

This paper has presented an ensemble deep learning based approach for the prediction of COVID-19 disease through the X-ray images. Before performing the classification, an image preprocessing is done by applying the feature selection approach using U Net model and the capsule network.

The remainder of this paper is organized accordingly: Previous work done in the area of COVID-19 prediction using artificial intelligence approach is discussed in Section 2. Section 3 illustrates the datasets and methods, including the selected study data sets, data pre-processing and the suggested deep-learning models. The experimental results of comparisons are explained in Section 4 for the experimental parameter and efficiency metrics for our classifications model. Section 5 draws conclusions with possible future work followed by reference section in the last

2. Literature survey

Prior to now, the method employed for COVID-19 prognosis was real-time RT-PCR (reverse transcription-polymerase chain reaction). Once the CT and X-ray scans are completed, the information is used to forecast COVID-19. Early studies indicate inaccurate results while the method is being tested, but when the method is refined with artificial intelligence approaches, the outcomes will improve.

Computer Tomography may be utilized as a screening tool for a sensitive lung diagnosis diagnostic equipment for COVID-19 [5]. After finding a high concentration of COVID-19 in the lungs of subjects receiving radiation therapy, evidence of the most serious respiratory illness appeared after 14 days. A high percentage of false-negative tests have been reported to doctors, both with medical testing and with chest CT scans, in order to help diagnose illness by medical tests or chest CT scans. In places like Turkey, where there were few cases of COVID-19 at the start of the epidemic, CT was employed for the diagnosis. The idea is that comparing the clinical imaging results to laboratory test results will help in early detection of COVID 19. In COVID-19 patients, radiographic images provide useful diagnostic information. Preclinical tests reportedly indicated a possible improvement in the condition before the administration of COVID-19 based on chest x-rays and CT scans. Other researchers in the COVID-19 imaging study also made great strides. Ground-glass opacity on the right side was described by Kong et al. in the COVID-19 box.

A few days after Wang and Wong [6] proposed the COVID Net deep learning model that characterizes groups as conventional, non-COVID, and COVID-19 with 92.4% accuracy, the groups became regular, non-COVID, and COVID-19. A deep learning pattern was established utilizing 224 COVID-19 verified pictures. Images of the chest were produced by Narin et al. [7], and ResNet50 identification of X-ray signals showed a 98% CO_2 signal detection rate. Haque and Abdelgawad compared the CNN model for a COVID-19 positive patient [8]. This technique successfully finds and identifies patients who have Coronaviruses with almost no time or effort. This is also investigated in their work, which compares the CNN models of COVID-19.

To strengthen virologists, AI researchers, and politicians involved in the COVID-19 epidemic, Rasheed et al. [9] brought a medical and technical research article into being. Another method used in the COVID-19 is highlighted in the paper. During the research, it was discovered that many AI techniques were proposed to help the COVID-19 pandemic, including a number of techniques for early detection to image diagnoses, as well as models that aid to explain COVID-19 outbreaks and predict new locations of future outbreaks. Advances in medical imaging such as radiography have recently become critically important to physicians as a source of predictive diagnostic approaches for machine learning. Accumulated depth in a particular area of artificial intelligence (AI) facilitates the construction of end-to-end algorithms to accurately anticipate outcomes by utilizing input data without the intervention of human intelligence. Several COVID-19 discovery approaches have been put up, including CNN, COVIDScreen, and COVINet. An advanced machine learning technique has been submitted. This approach used a combination of efficient, secure, and effective methods for CT scans and X-rays.

Sethy and Behera [10] used an X-ray image feature set to create a support vector machine (SVM) model. ResNet50 and SVM classification yielded the best results in this study. In some recent COVID-19 trials, various deep learning methods were applied. Gomati et al. [11] has performed the Pattern analysis that predict the COVID-19 pandemic in India using AutoML.

Using deep learning methods, Hemdan et al. [12] employed COVID-19 X-ray images to diagnosis the 7 CND models COVIDX-Net, and therefore proposed a network of 7 CND models with COVID-19 as a member One of the three individuals in the study of Yoon et al. was discovered to have a nodular opacity in the lower left lung area. While the other two individuals showed a deviation in the hardness between the four and five lung regions, the first showed no abnormality. Additionally, Zu et al. [13] observed that about one-third of chest CT images are able to distinguish pulmonary illumination that is not sharp.

Highly trained problem-solving Deep Learning approaches have all been efficiently applied to specific tasks, such as arrhythmia detection, skin cancer diagnosis, breast cancer identification, surgical diagnosis, pneumonia pathology, fundus segmentation, and pulmonary segmentation. The fast expansion of the COVID-19 pandemic has necessitated expertise. Automated detection systems using AI techniques have seen increasing popularity in recent years. Because there are only a few numbers of radiologists at each hospital, this new technology is challenging for specialist clinics. As a result, it will be easier to fix this issue by giving AI models that are fast, precise, and fast to use to patients. The ability to apply AI technology for radiological use is an advantage, but due to their significant field experience, radiological usage is still vital. Additionally, AI techniques can avoid the issues of lack of RT-PCR test kits and the expense of test procedures. Moreover researchers are proposing various protocols in the field of healthcare [19–24] and vehicle communication [25–32] to protect the information exchanged among various devices to devices.

3. Datasets and methodology

Dataset is one of the major components required for the analysis purpose. This study has also used the dataset consist of X-ray Images that are used for the prediction of COVID-19 disease. Images contains large number of features and some of the features are not needed for the analysis purpose, so feature extraction is needed before performing any prediction or classification. In the case of image analysis, feature extraction is the essential process through which important features can be extracted. This work will focus on feature extraction using capsule networks that contains number of convolutional layer.

3.1. Datasets

The dataset contains X-ray images of 896 patients with different number of normal, pneumonia and COVID patients. Images having some similarities and dissimilarities on the basis of which they are classified into these 3 classes.

3.2. Methodology

The implemented method has been take from Heidarian et al. [5]. They have applied the method on the CT scan dataset and termed as CT-CAPS, but in this study the method is applied on the X-ray dataset and termed XR-CAPS. The CT-CAPS method has performed the feature extraction before performing the analysis. To perform the feature extraction, U-net model and Capsule network has been applied then these extracted features are passed through max pooling layer with fully connected layer for the prediction purpose.

3.2.1. Chest X-ray segmentation

UNet is U-shaped symmetric neural network developed for biomedical image segmentation [14]. There are two paths in UNet, and the first path is also referred to as an encoder that is essentially a set of convolution, activation and bundling layers for the input image to capture the context. In the expansion path, the output of the coder is smaller than the input. The expansion path or the decoder allows accurate location with transposed turns. The expansion path combines high-quality characteristics and spatial information with the corresponding characteristic maps from the contracting path through a sequence of ups and connections. As the encoder's low-level feature maps contain better spatial information useful for analysing complex scenes with multiple objects, intermediate low-level characteristic maps from Efficientnet are combined with intermediate high-level UNet decoder feature maps. Many feature channels allow the network to spread context information in higher resolution layers in the upsample part (see Fig. 1).

3.2.2. Capsule network

Fig. 2 shows the XR-CAPS pipeline architecture, it's a capsule network which first segment the X-ray images into sliced images and then perform the feature extraction using the capsule layer. A stack of 4 convolutionary layers and batch normalization, and a max-pooling level are created to create this network, as illustrated in Fig. 2. The convolutionary layer is then used to provide the following capsules for the extraction by the routing process. After that, two other capsule layers are added to the model, in which the last amplitude is the probability of the input in each target class age. Next, we add slice-level characteristics extracted from the described network via intermediate layers to move into the patient level area. In that respect, a representative slice characteristic map is used in the capsule layer before the last one. The results (presented later in Article 4) show that this model can distinguish COVID-19 from non-COVID images efficiently. Moreover the model consist of different layers, size ranges from 16×32 to 1 *2.

The layers and the process used in the proposed model are as follows:

1. Chest X-ray Segmentation – The chest X-ray image is segmented through the U Net model that provides small slices of the processed image.

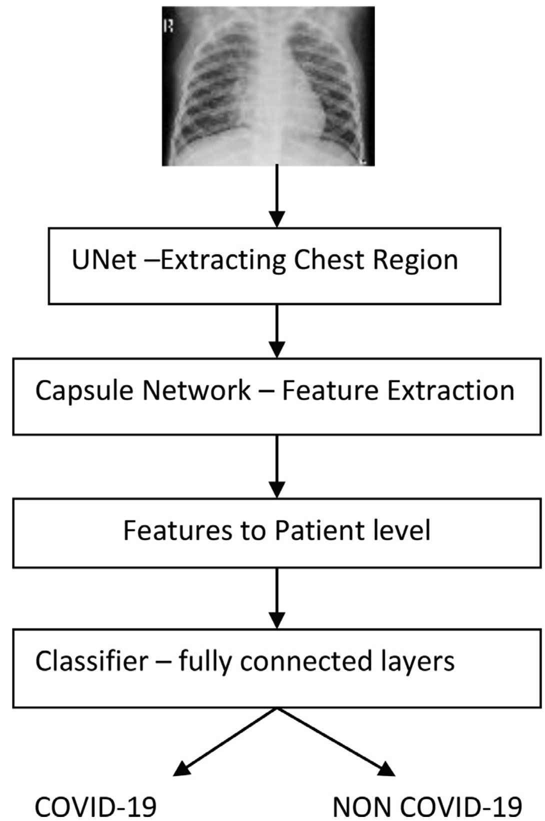

Fig. 1. Flowchart of the proposed model.

2. Convolution layers – Mainly three convolution layers are used in the model of size 3x3 with stride equals to 1.
3. Capsule layers – Overall there are four different size capsule layers are implemented in the model with routing by agreement. Routing by agreement is performed because in this model there are multiple capsule layers in which higher level capsule transfers the information is passed to the lower capsule layer. Finally the last capsule layer with size 1x2 is applied for the prediction of the disease.
4. Batch Normalization – Batch normalization is applied to form the mini batch of the images [15].
5. Max pooling – This technique is used for the discretization purpose which helps in dimensionality reduction and more informative features are generated [16].
6. L2 Normalization – L2 normalization are the regularization method which are basically used to make the model less complex.

4. Result analysis

The work is implemented by using Python programming language. Python libraries such as keras, pandas and matplotlib are used for the analysis purpose [18]. The parameter used for the evaluation of the model are accuracy, sensitivity and, specificity. 627 images are used for the training purpose and 269 images are used for the validation purpose.

Above Table 1 and the Figs. 3–5 has shown how the implemented model XR-CAPS has performed better than the existing models.

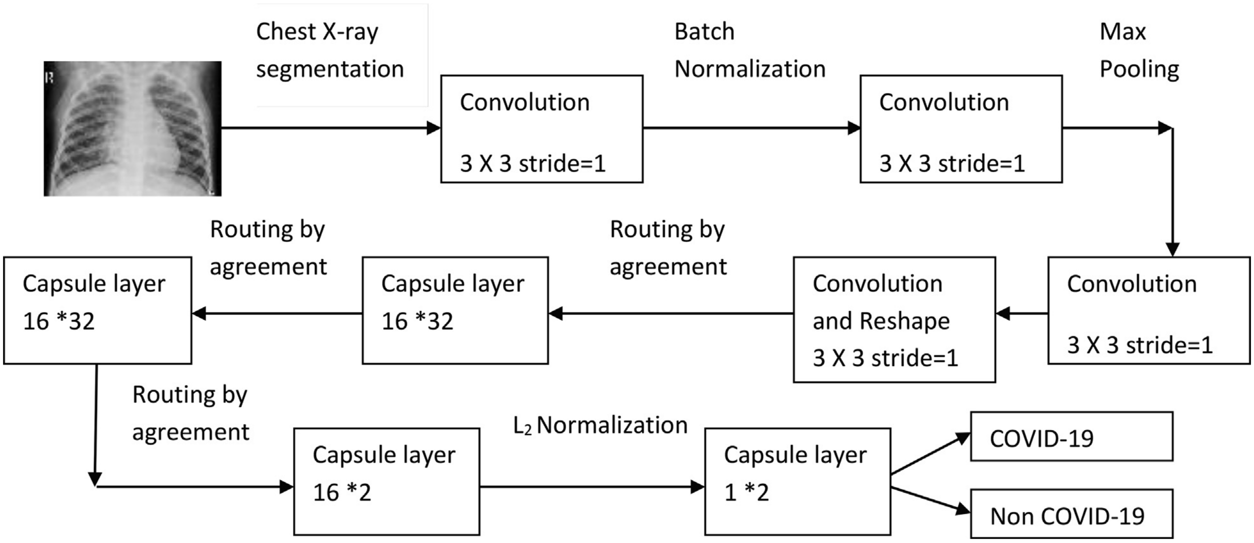

Fig. 2. Architecture of the deep learning model XR-CAPS.

Table 1
Comparison analysis of the XR-CAP model with other deep learning models.

Models	Accuracy (%)	Sensitivity (%)	Specificity (%)
ResNet50 [17]	87.3	89	93.7
DenseNet121	90.7	91	95.3
DenseCapsNet	92.7	93.3	96.4
XR-CAPS	93.2	94	97.1

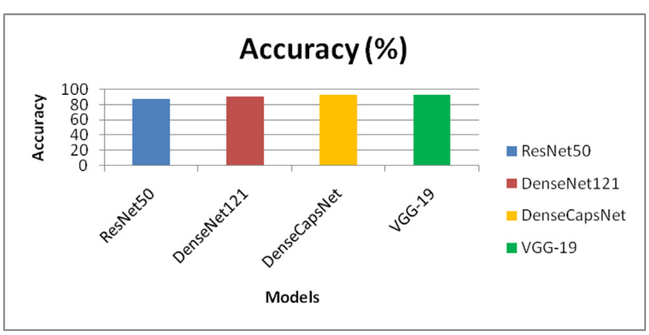

Fig. 3. Accuracy comparison graph of XR-CAP model with existing deep learning models.

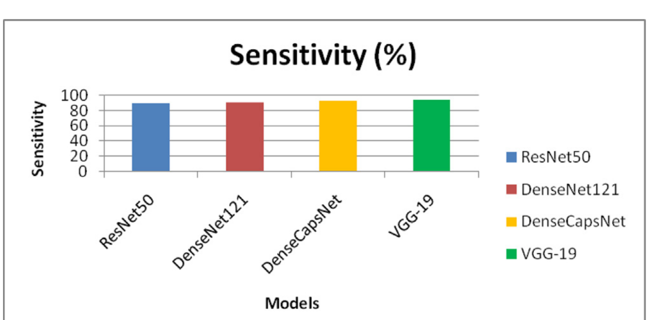

Fig. 4. Sensitivity comparison graph of XR-CAP model with existing deep learning models.

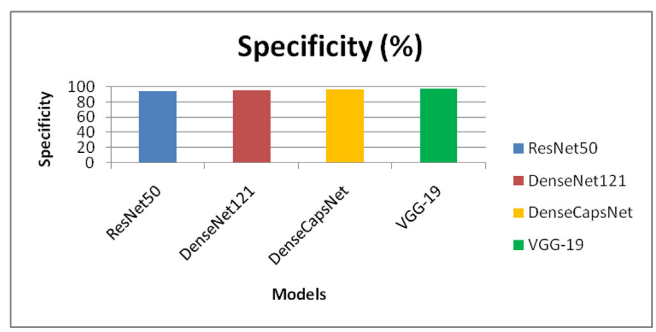

Fig. 5. Specificity comparison graph of XR-CAP model with existing deep learning models.

5. Conclusion

In this study, the focus is on the feature extraction of the images. To perform this, the chest X-ray images are segmented using the U net model, and slices are formed. These slices are further processes through different convolution layers and capsule layers for the prediction purpose. This model is termed as XR-CAP model, which can be considered as an ensemble deep learning model. The parameters used for the evaluation of the models are accuracy, sensitivity, and specificity. The model has achieved an accuracy of 93.2% for the prediction of COVID-19 through X-ray images. In the future, the focus will be on some more transfer learning approaches so that more accuracy and performance can be achieved.

CRediT authorship contribution statement

Pinesh Arvindbhai Darji: Conceptualization, Data curation, Formal analysis, Funding acquisition. **Nihar Ranjan Nayak:** Investigation, Methodology, Project administration. **Sunny Ganavdiya:** Investigation, Methodology, Project administration. **Neera Batra:** Resources, Software, Supervision. **Rajib Guhathakurta:** Writing – original draft, Writing – review & editing.

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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