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EARLY DETECTION OF COVID-19 DISEASE USING COMPUTED TOMOGRAPHY IMAGES AND OPTIMIZED CNN-LSTM

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Abstract:

Since the novel Coronavirus (COVID-19) pandemic showed up in China, it became a big problem for health authorities to counter this life-threatening disease. Early light signs such as fever and nonproductive cough give a chance for early detection of disease and appropriate treatment. Imaging features that can be obtained using computed tomography (CT) images are of the most significant aspects of COVID-19 for screening, examination, therapy evaluation, and follow-up. This paper proposes an intelligent method for early detection of COVID-19 based on CT images and deep neural networks. In the developed method, the convolutional neural network (CNN) is used for automatic feature extraction from CT images and long-short term memory (LSTM) is used for final classification. Moreover, the Harris hawk optimization (HHO) algorithm is implemented for finding the best possible value of internal parameters of CNN and LSTM, such as the number of convolution/pooling layers, size, and the number of convolution kernels with the aim of increasing the classification accuracy. The developed method tested on data collected in Mashi Daneshvari Hospital in Iran. The obtained results showed that the developed method could detect the COVID-19 with high accuracy without needing radiologist experts.

Keywords:

CNN; LSTM; Biomedical image processing; Machine-learning algorithms; Optimization

1. Introduction

Coronavirus disease 2019 (COVID-19) was firstly identified in Wuhan city, China, in December 2019, and has since been distributed around the world, which leads to a continuing pandemic. As of 24 October 2020, more than 42.4 million cases have been identified throughout 187 different countries and territories, resulting in more than 1.15 M deaths. [1]. Due to COVID-19 's strong and growing infectivity, fast and effective diagnostic methods are immediately aimed to determine, isolate, and treat patients as quickly as possible [2].

The signs of this infective respiratory disease are nonspecific, ranging from asymptomatic to severe pneumonia and death. Low-grade or high-grade fever and nonproductive cough are the most frequent medical symptoms [3]. In order to validate the diagnosis of COVID-19, a particular viral nucleic acid assay using real-time transcription-polymerase chain reaction (RT-PCR) was grown rapidly. However, some patients with a probable COVID-19 infection might just have initial negative RT-PCR results from the recently published research literature. The major reason for falsified-negative RT-PCR testing generally involves insufficient cellular material for detection and improper nucleic acid removal from clinical materials [4]. In accordance with obtained experiences through the past four months, chest computed tomography (CT) imaging may manifest abnormalities in advance of the RT-PCR approach. Currently, high-resolution chest computed tomography imaging has been included as one of the main tools for screening, primary diagnosis, and evaluation of disease severity [4].

Particularly in comparison to RT-PCR, a chest computed tomography scan may be a much more reliable, effective, and rapid technique for the classification and evaluation of COVID-19, especially in the epidemic region [5]. Nearly all hospitals have CT imaging machines; thus, the computed tomography images of the chest can be used to classify and identify COVID-19 patients in advance. The existence of infected air sacs (called alveoli) inside the lungs is usually reflected in the computed tomography images.

However, using computed tomography images for COVID-19 detection is not a perfect approach. Radiologists still find it challenging to distinguish between infected and uninfected lungs. Unfortunately, with a visual inspection, this suffers from the unavoidable human mistake and malfunction, which can be further amplified by the low quality of computed tomography images. Many researchers believe that automating computed tomography screening analyzes tends to increase the early detection rate [6].

In the recent time, thresholding [7-8], neural network [9-10], and several deep learning algorithms, especially convolutional neural networks (CNN) and long-term memory (LSTM), have been proposed for solving numerous complex tasks in all forms of image de-noising (preprocessing) and analysis, e.g., neuro, retinal, digital anatomy, abdominal, musculoskeletal pulmonary, breast, neurological, and the other medical image processing [11]. In recent years, end-to-end trained CNNs have now become the preferred approach for interpreting medical imaging [12]. If the input image is not noise-free, CNNs may derive useful and important information from it because of its noise-insensitivity. These output characteristics are expressed in a network structure that is layer by layer. As the layers in the network deepen, features are learned and represented more abstractly and concisely.

Aside from CNN, LSTM is another form of deep learning algorithm commonly used for time series analysis. It has been utilized in other applications, such as natural language processing, voice synthesis, and synthesis of handwriting [13]. The connections between the LSTM units allow information to cycle over the adjacent time-steps through a loop. This provides an internal feedback environment, which helps the network to understand the meaning of time and to learn about the temporal structure within the data presented.

Considering the importance of early and accurate detection of COVID-19, a simple, fast and accurate method is proposed in this study. The proposed method does not require the extraction of new features manually from chest CT images or human-based interpretation. In the proposed method, ConvNet is used for the extraction of new features from chest CT images, and LSTM is used for classification. Moreover, Harris hawk optimization (HHO) algorithm is used to find an optimal value of internal parameters of the CNN and LSTM, such as a number of convolution/pooling layers, size, and the number of the filter with the aim of increasing the classification accuracy and reducing the computational complexity. The HHO algorithm is one of the most accurate and fast nature-based optimization algorithms that mimic Harris hawk's behavior in nature [14] and it has been applied in various problems [15-19]. In recent years, nature-based optimization algorithms have been successfully used in many engineering tasks [20-24] [26-32].

2. Proposed Method

Given the important role of chest computerized tomography images in COVID-19 detection in early stages, it is significantly essential for physicians and practitioners to become acquainted with the regular features of computerized tomography images resulting from COVID-19. Despite the fact that regular and irregular computerized tomography images findings of COVID-19 are announced in the literature, the computerized tomography image features of COVID-19 overlies with those of viral pneumonia and other breathing illnesses. Consequently, it is an extremely difficult task for radiologists to make an exclusive and accurate diagnosis. Moreover, it is found that the COVID-19-infected patients show some pattern on chest computerized tomography images, which is not easily detectable by the human eye. Therefore, it is significantly important to develop an automatic method for computerized tomography images analysis for accurate detection of COVID-19. This paper proposes an intelligent method based on CNN and LSTM for chest CT image analysis and COVID-19 detection. The proposed method includes three main modules: a feature extract module, a classification module, and an optimization module.

In the case of any pattern recognition problem, extracting as much information as possible from the available data sets is crucial to creating an effective solution. Most of the time, researchers extract new features from raw data based on their experience that is called handcrafted feature engineering. This type of feature engineering has some drawbacks. First, manual feature engineering can be a tedious process. Secondly, it is boring. Moreover, the influence of human bias can lead the feature extraction process to the wrong route. These problems can be solved using CNNs. Numerous convolutional and pooling layers in the CNN structure shape a deep and rich network for extracting the fundamental characteristics form the input image.

In the feature extraction of the proposed method, we used CNNs for generating effective and abstract features from computerized tomography images that cannot be seen or detected by a human expert. The automatically extracted features lead to more accurate infection detection and classification. The LSTM network has the ability to learn chronological correlations and long-term dependencies. The LSTM network and CNN could complement each other by learning long-term dependency and local trends independently. Therefore, in the classification module of the proposed method, we used LSTM for the final classification.

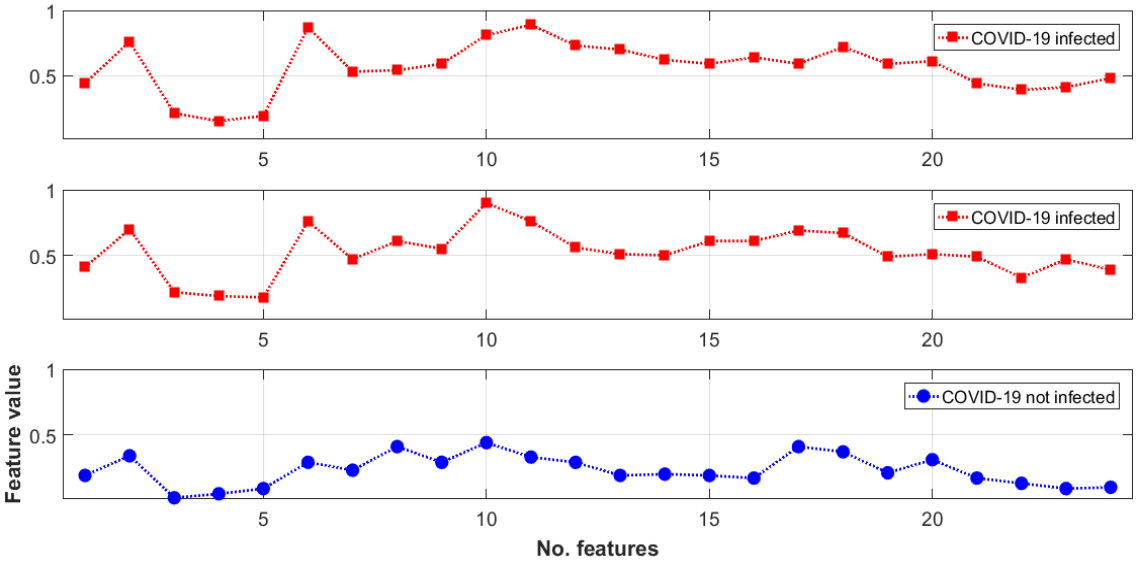

Fig.1 Extracted features from CT images by CNN

One great obstacle for implementing CNN and LSTM networks on a new problem is that it requires the amount of considerable experience and skill to select fitting hyper-parameters such as activation function type in CNN, number of convolution, and pooling layer in CNN and number of memory blocks in LSTM network. Since these hyper-parameters have internal relations, their tuning is notably expensive and time-consuming. These hyper-parameters are the number of layers, learning rate, activation function type, number and size of kernels zero-S, P, pooling method type, size of kernels in pooling layer, stride, and the number of memory blocks in LSTM. This paper proposes the application of the HHO algorithm for finding the optimal value of hyper-parameters in CNN and the LSTM network.

3. Results

3.1. Dataset

In this study, the chest CT images dataset collected in the National Research Institute of Tuberculosis and Lung Diseases (NRITLD), Daneshvari Hospital, Tehran, Iran, is used for evaluation of the developed method [25]. The dataset is collected by three experienced radiologists with 15, 10, and 17 years of clinical experience between March 2020 and May 2020. From the 315 cases, 174 cases are patients confirmed with COVID-19, and 141 cases are patients with other respiratory diseases such as Pneumonia, Emphysema, and Asthma that are confirmed by an experienced radiologist. Table 1 lists the details of a dataset.

Table 1 Details of dataset

Class	Gender	No. cases	Age range
COVID-19	Male	93	[18 73]
	Female	81	[23 79]
Other respiratory diseases	Male	73	[19 75]
	Female	68	[20 74]

We used K-folds cross-validation with K=4 to split our data into training and test subsets. All the simulations are performed using a personal computer with core i7 processing cores and 16 GB RAM and Python programming language.

3.2. Performance of the proposed method

In this subsection, the performance of the proposed method is evaluated. For this purpose, hyper-parameters are selected using the optimization algorithm. In the HHO algorithm, 30 hawks are generated randomly in the search space, and the optimization process is iterated 100 times. The selected hyper-parameters using HHO algorithm are listed in Table 2. According to the HHO algorithm, CNN with five layers (NL=5) and learning rate equal to 0.0018 and LSTM network with 43 memory blocks (NMB=43) leads to the highest accuracy.

Figure.1 shows the extracted features by convolution layers with optimal structures. It can be seen that the input CT images are converted to a vector with 24 arrays. Each array in the feature vector indicates the deep feature of CT image. Using CNN, 24 effective features were extracted and used as the input of LSTM. The simulations showed that the proposed

method, CNN-LSTM optimized by the HHO algorithm, could classify the COVID-19 with 99.37% accuracy.

Table 2 Optimal configuration

	T_{Act}	NK_c	SK_c	S_c	Z	$T_{pooling}$	SK_p	S_p
Raw data	–	–	–	–	–	–	–	–
Layer 1	RReLU	64	5×5	1	1	L_p	4×4	1
Layer 2	PReLU	128	4×4	2	1	L_p	3×3	1
Layer 3	PReLU	256	4×4	1	2	Mixed	3×3	2
Layer 4	PReLU	32	3×3	2	2	L_p	2×2	1
Layer 5	RReLU	32	3×3	1	1	L_p	2×2	1

4. Conclusion

The number of cases of COVID-19 continues to rise in Iran and around the world. In this condition, timely diagnosis of the disease in the early stages can help physicians to adopt the right decisions and choose appropriate remedies methods, and ultimately increase the chances of survival of the patient to a very high level. According to the importance of the issue, in this study, a new hybrid method was presented to process a CT scan of chest images and diagnosis of COVID-19 disease. In this method, CNN was used for the automatic extraction of characteristics and the LSTM network for the final classification of images. Also, the HHO algorithm was used to select the optimal parameters of CNN and the LSTM neural network. The proposed method can diagnose the disease with an accuracy of 99.37%. The results showed the superiority of the proposed method over other techniques available in the literature.

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