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Deep learning applications to combat the dissemination of COVID-19 disease: a review

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Abstract. – Recent Coronavirus (COVID-19) is one of the respiratory diseases, and it is known as fast infectious ability. This dissemination can be decelerated by diagnosing and quarantining patients with COVID-19 at early stages, thereby saving numerous lives. Reverse transcription-polymerase chain reaction (RT-PCR) is known as one of the primary diagnostic tools. However, RT-PCR tests are costly and time-consuming; it also requires specific materials, equipment, and instruments. Moreover, most countries are suffering from a lack of testing kits because of limitations on budget and techniques. Thus, this standard method is not suitable to meet the requirements of fast detection and tracking during the COVID-19 pandemic, which motived to employ deep learning (DL)/convolutional neural networks (CNNs) technology with X-ray and CT scans for efficient analysis and diagnostic. This study provides insight about the literature that discussed the deep learning technology and its various techniques that are recently developed to combat the dissemination of COVID-19 disease.

Key Words:
Artificial intelligence, Coronavirus pandemic, AI, SARS-CoV-2, Machine learning, Big data, COVID-19.

Introduction

Novel coronavirus disease (COVID-19), which particularly affects the lungs and causes pneumonia, was identified for the first time in Wuhan, Hubei Province, China, in late December 2019[1]. Although the Chinese government has adopted timely and effective measures, such as wearing masks at public locations, frequently washing the hands, maintaining the social distancing policy, quarantining COVID-19-positive cases, and reporting the latest symptom information to regional health centers, in order to prevent and control the spread of COVID-19. Despite these procedures, the scope of the COVID-19 outbreak has developed widely and rapidly[2]. On January 30, 2020, the World Health Organization (WHO) announced that the outbreak of COVID-19 has become a public health emergency of international concern, and the situation has evolved quickly; on March 11, 2020, the WHO declared COVID-19 as a pandemic[3]. Today, COVID-19 is spread in all countries, and the number of infected cases and deaths rapidly and significantly increases; furthermore, efficient measures and treatments have yet to be developed to control this pandemic, severely affecting every aspect of our daily lives[4].

The long incubation period of the virus, which may take more than 2 weeks in some cases and may not cause symptoms in other cases, is one of the most important causes of the rapid spread of this pandemic[5]. Therefore, the early diagnosis and quarantine of COVID-19-positive cases can save numerous lives. Reverse transcription-polymerase chain reaction (RT-PCR) is known as one of the primary diagnostic tools for the identification of infection on people to separate them. In addition, computed

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tomography scan (CT scan) and X-ray images are alternative diagnostic tools for detecting COVID-19. Doctors image lungs and look for signs of COVID-19 deformations on the CT or X-Ray images. However, this process requires a certain amount of time for correct pneumonia type classification among various groups of coronaviruses, COVID-19, SARS, and MERS. Therefore, the doctors are looking for novel and fast leading-edge technologies to track, monitor and restrict the dissemination of COVID-19 disease[6,7]. AI is one such parallel technology that can provide support against this virus by population screening, medical help, notification, and suggestions about infection control. AI is also implemented in the field design through inception of learning-prediction model and performs a swift virtual screening to accurately display the congruent outputs. Thus, doctors can employ artificial intelligence techniques on X-ray and CT scans for analysis. Moreover, AI can be used to screen drugs that have potential to fight minacious diseases such as COVID-19. Being an evidence-based medical tool, this technology has the potential to improve drug discovery, planning, design treatment and outline follow-ups of the COVID-19 patients.

Machine Learning, which is normally presented as artificial intelligence, refers to the intelligence exhibited by computers. Deep Learning (DL) is an enhanced and flexible extension of Machine Learning (ML) to improve learning algorithms' structure and make them easy to use. Being a subset of ML, DL is immensely used with very large data with simpler framework to deploy any complex model. DL along with Convolutional Neural Networks (CNNs) has been tremendously applied in several computer vision researches. The major advantage of DL has the potential to support huge amounts of data during learning. As an obvious impact, the accuracy will increase automatically by a considerable margin. The key contribution of this study is to discuss the most promising fields of research based on recent studies regarding the various applications of DL that are recently developed in detection and diagnosis of COVID-19 disease.

The remaining parts of this paper are organized as follows. Section 2 describes the progress in machine intelligence. Section 3 discusses the deep learning/CNNs applications to combat COVID-19. Section 4 concludes the work with recommendations.

Progress in Machine Intelligence: Machine Learning vs. Deep Learning

Machine intelligence, which is normally presented as artificial intelligence, refers to the intelligence exhibited by computers. ML is the best tool so far to analyse, understand and identify a pattern in the data. ML uses data to feed an algorithm that can understand the relationship between the input and the output. When the machine finished learning, it can predict the value or the class of new data point. However, when moved into the era of 'big' data, ML approaches evolved into deep learning (DL) approaches, which are a more powerful and efficient way to deal with the massive amounts of data. DL is the new state of the art in term of AI. DL is a computer software that mimics the network of neurons in a brain, which uses neural networks to learn from the data. Figure 1 summarises progress in machine intelligence. Moreover, Table I provides a brief comparison between ML vs. DL.

Deep Learning Applications to Combat COVID-19

The early diagnosis and quarantine of COVID-19-positive cases are among the most effective solutions to combat the COVID-19 pandemic. RT-PCR is used as the standard method for the classification of respiratory viruses. Although efforts have been devoted to improving this technique for detecting SARS-CoV-2[8,9], RT-PCR is costly and time-consuming; it also requires specific materials, equipment, and instruments[10]. Moreover, most countries are suffering from a lack of testing kits because of limitations on budget and techniques. Thus, this standard method is not suitable to meet the requirements of fast detection and tracking during the COVID-19 pandemic. The use of AI methods in image processing, specifically for medical-related images, is a low cost, fast, and simple way of identifying and diagnosing COVID-19. Nevertheless, studies have described AI and deep learning in medical image analysis as common solutions[11,12].

DL along with Convolutional Neural Networks (CNNs) has been tremendously applied in several computer vision researches. The major advantage of DL has the potential to support huge amounts of data during the learning. Accordingly, CNNs might be used for faster and better diagnosis of COVID-19 based on CT scans. Several studies have shown that X-ray images and CT scans can be widely used as input of DL algorithms, which can enhance the detection capabilities of

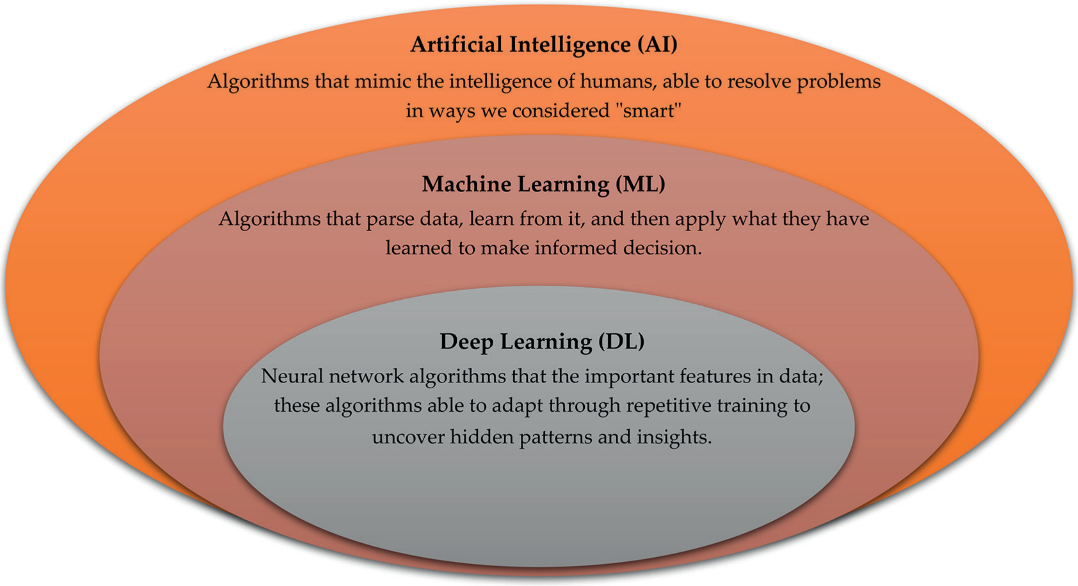

Figure 1. Machine intelligence technologies.

COVID-19-associated infections[13-18]. The performance results show that these models are close to human-level accuracy. These models also result in high classification performance in medical image classification.

CNNs include AlexNet[19], GoogleNet[20], VGG[21], MobileNetV2[22], ResNet[23], and DenseNet[24]. Loey et al[25] utilized a deep learning model in conjunction with a GAN model for COVID-19 and pneumonia detection on X-Ray images. The proposed methodology builds on generating synthetic image and training convolutional neural networks on the generated data. Authors use AlexNet, GoogleNet, and RestNet-18 convolutional neural networks to detect COVID-19, healthy, pneumonia bacterial, and pneumonia virus. He et al[26] proposed a sample efficient convolutional neural network for detecting COVID-19 on CT scans. The authors achieved a sample-efficient model by introducing a new transfer learning strategy. They fine-tune VGG-16, ResNet-18, ResNet-50, DenseNet121, and DenseNet-169 models to classify CT images. Authors also propose a new CNN architecture which includes three convolutional layers and one classification layer. This CNN model builds on a small set of CT scans and

Table I. Brief comparison between ML *vs*. DL

Requirement	Machine Learning	Deep Learning
Dataset dependencies	Small/medium	Big
Training dataset	Small	Large
Training time	Short	Long
Approach used	A large problem is subdivided into several small tasks and at the end are combined to build the ML model.	Several layers of neurons
Execution time	From few minutes to hours	More time is needed. Neural Network needs to compute a significant number of weights
Interpretation	Some algorithms are easy to interpret (logistic, decision tree), some are almost impossible (SVM, XGBoost)	Hard to interpret the process of solving the problem. Because, several neurons collectively solve the problem

the model parameters initiated on the ImageNet dataset. Mei et al[27] proposed to use the Resnet-18 convolutional neural network in conjunction with support vector machines for COVID-19 detection. In this work, the CNN model allows prediction on the CT image, while SVM provides COVID-19 prediction on non-image data. Authors combine ResNet-18 and SVM outputs to detect COVID-19. Harmon et al[28] utilized DensNet-121 deep learning architecture for classification of COVID-19 and pneumonia. The proposed method train and tested on a multi-dataset for performance evaluation. Bhandary et al[29] use AlexNet in conjunction with support vector machines to classify Covid-19 and cancer on X-Ray and CT Scans. Authors also compare the SVM based AlexNet with AlexNet, VGG16, VGG19, and ResNet50. Butt et al[30] use ResNet-18 deep learning model for the classifying COVID-19, viral pneumonia, and normal CT scans. This method builds on creating 3D volumes of the CT scans and then extracting paths from these regions. Then, these images were used as inputs to the ResNet-18 model for differentiating COVID-19, viral pneumonia, and normal CT scans.

Combining CNN and a Generative Adversarial Network (GAN) models is another way of achieving data efficient models. GAN models[31-33] are known as creating synthetic images from a given set of images. This model architecture includes generator and discriminator networks. The generator is responsible for synthetic image generating while the discriminator compares real and synthetic images during this process. A review[34] reported all proposed GAN models. Authors mainly utilize vanilla GAN, Deep Convolutional GAN (DCGAN), pix2pix, and CycleGAN models for medical applications. DCGAN, WGAN, and PGGAN models allow medical image synthesis while CycleGAN and pix2pix models allow modality transferring of the medical images. First, the authors proposed[31] vanilla GANs, which consists of a fully connected generator and discriminator networks. Another study introduced DPGAN models. This model is comprised of convolutional neural networks instead of fully connected layers. Two recent works[25,32] combined CNN and GAN based methods for detecting Covid-19 on X-Ray images. Waheed et al[32] proposed CovidGAN convolutional neural network for classification of Covid-19 on X-Ray images. Authors generated synthetic images using the GAN technique and use these images in conjunction with augmented images for the proposed model training. The proposed approach showed that training CNN model both synthetic and augmented images improve the detection accuracy on the X-Ray images. Loey et al[25] also improve convolutional neural networks using generative adversarial networks. This study classifies COVID-19, normal, bacterial pneumonia, and viral pneumonia on X-Ray images.

Conclusions

This study highlighted the promising fields of research on DL for the diagnosis of COVID-19. Data-efficient convolutional neural networks are proposed for COVID 19 detection on CT scans. The proposed methods build on a small number of CT scans of COVID19-CT. This method allowed to increase the number of available CT scans using augmentation techniques and synthetic images. Augmented images are obtained by rotation images, while the generation of synthetic images is achieved using deep convolutional generative adversarial networks. Both classic deep learning methods and proposed data-efficient methods are compared. The AlexNet, VGG, ResNet-18, ResNet-50, MobileNetV2, and DensNet-121 deep learning models are used for modeling both augmented and synthetic images. The proposed models are all fined-tune on the Imagenet dataset to achieve robust classification accuracy on both COVID19-CR and Mosmed dataset. The best performing CNN models on COVID19-CT and Mosmed datasets are Resnet-18 and mobileNetv2, respectively. ResNet-18 model built on augmented and synthetic images of COVID19-CT data outperforms the ResNet-18 model, which builds on only augmented data. This augmented, and synthetic data-based models also outperform all outer modes. MobileNetV2 model built on augmented and synthetic images of Mosmed images outperforms MobileNetV2 mode, which builds on only augmented data. This augmented, and synthetic data-based models also outperform all outer methods. This ResNet-18 and MobileNetV2 models provided 0.89% and 0.84% ROC values on the COVID-19-CT and mosmed datasets respectively. Moreover, the GAN based deep learning model provides higher performance than classic deep learning models for COVID-19 detection.

Conflict of Interest

The Authors declare that they have no conflict of interests.

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