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How deep learning techniques are relevant in a COVID-19 world

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Abstract. The diagnosis of COVID19 using neural networks has established itself as a promising field within the modern world of applying deep learning algorithms to problems we are currently facing. Most research has been based on feeding Computed Tomography (CT) scan images into an image classification AI to find pneumonia caused by the disease. Within recent months, the research regarding the diagnosis of COVID19 with AI has substantially broadened, with new ideas and applications proving success. Despite these studies showing incredible success, there has been little review or external support in order to verify this research and potentially lead it into clinical trials. In this study, we review one of the earlier studies on CT diagnosis, and compare this to the relatively new studies that use Chest X Rays (CXR) and the auditory samples. We not only introduce the relevance and significance of several recent models but also conclude several potential challenges for the task and the field as a whole.

Keywords: Deep Learning, Neural Network, COVID-19

1. Introduction

Since the discovery of the SARS CoV 2 and the following global pandemics 603 million have been reported as of September 1 2022. Despite the previous outbreaks posing significant threats to health infrastructure and the public and a complete eradication of the virus nearly impossible. The possibility of our current health systems being overwhelmed is no longer likely. With suitable methods of response already widely used,the issue of COVID-19 no longer lies in preventing a global crisis but rather in our inefficient approach to combating the virus.

One of the most notable examples of this issue lies in the expensive and time-consuming process of diagnosing the virus. Since the start of the pandemic China has administered more than 11.5 billion covid tests and if the government is to continue their current approach of 48 hour testing, the total costs could rise to an estimated 1.74 trillion RMB, approximately 1.5 percent of China's GDP in 2021[1]. Generally, governments test large quantities of the public in order to prevent large outbreaks. Currently, polymerase chain reaction (RT-PCR) tests are commonly used for COVID19. Despite being commonly accepted as the gold standard of COVID testing, RT-PCR testing is both expensive and slow. Most tests take more than 24 hours for a result to come out, adequate time for the virus to spread and potentially leak into a large outbreak.

[1] These predictions were made by Soochow Securities Co, a chinese Capital market company based in SuZhou

This approach simply isn't feasible in the long term especially when considering the majority of developing nations still struggling with the economic fallout from the initial pandemic and not only lack the ability to spend large portions of their GDP on testing, but also can't afford to deal with a potential outbreak caused by delayed action. This paper aims to demonstrate how applying Machine Learning algorithms in order to aid the diagnostic process of COVID19 promises to reduce cost, human resources and most importantly the time required for an accurate diagnosis could essentially solve all of these issues.

Currently, the majority of research bearing successful and promising results utilises Machine learning algorithms. These algorithms are capable of finding logical connections and links beyond the capacity of human knowledge and logic. Hence they are often used to make unique yet remarkable contributions towards pushing the respective fields they are applied in. Traditionally the development and utilisation of Artificial intelligence (AI) has been centred around mimicking human behaviour, algorithms manually find features recognised by the original programmer, paired with the sheer speed of modern computing systems, the successful implementation of such an algorithm simply relies on how accurate the algorithm is. With artificial neural networks (NN) taking the scene from 1958 to the early 21st century, the issue of computing speed inherently became an issue. The use of millions of neurons to complete tasks slows computing speed dramatically. An example of how NNs would become impractical is guessing the number of termites in a mound by viewing an external image. With complete and absolute knowledge, doing so to a certain degree would be possible, however, the NN would have to consider relatively fine details, exponentially increasing the time necessary to finish the computation.

Recently new forms of neural networks have once again allowed new possibilities to be explored in complex fields such as image processing. The most basic yet revolutionary innovations lie in Convolutional Neural Networks (CNN). The technology allows for image processing specifically centred around allowing the NN to focus on what was general is based on pre-programmed human knowledge of the specific field and also simplification optimised by the NN itself before the application of the main NN[2]. In addition to this, tools such as Support Vector Machines (SVM), dilated convolutional networks and the optimisation of CNN hyperparameters have further increased the efficiency. Hence, it is only logical that we put into effect the far more efficient systems of dealing with COVID19 that have only recently become feasible.

While impressive leaps and achievements have been made within the field of machine learning in combating COVID19, efforts have largely been distributed across abstract fields with ideas often vastly unique from each other. This research, while abundant in potential, hasn't faced adequate criticism or support essential for large scale application to begin. Therefore, this paper aims to organise the efforts, integrating the efforts within newly created research articles and also articles within a broader range and that have contributing findings. Hence we help paint an accurate image of how different aspects of current research in the field are developing, one capable for the general public to understand. The paper aims not only to benefit related researchers, but also researchers in related medical and technical fields as well as the general public.

2. Background

It is inherent that we point out the various leaps in applying deep learning to image analysis that have recently emerged. The use of CNN was first popularised in the 2010s, with companies such as Amazon reporting performance increases such as doubling speed while increasing accuracy by 30% [11]. The application of Deep Learning algorithms using CNN has also gained prevalence within the broader medical field with studies such as [12], demonstrating the ability of CNNs to identify lung cancer. While multiple other efforts have been made in unique fields using multiple approaches, the applications in regards to COVID19 are often less diverse, considering the relative scarcity of contributions. When it comes to COVID19 in particular the use of Deep Learning algorithms and CNN has been most

[2] Within the context of the example above, bushes and nearby shrubbery could be removed with colours also being removed based on relevance.

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commonly used to diagnose COVID19, or in other circumstances where efforts are no longer centred around preventing cases, detecting severe cases of COVID19. The majority of efforts across both fields have shown effective results. A study in 2021 [13], showed certain models having a 98.08% to diagnose COVID with (CXR). These newer efforts, despite using more convenient CTR instead of complicated and expensive CT scans, have several underlying issues which bring forth doubt on whether or not they will be applicable in the field. One example would be the inability of these newer studies to access large datasets for both training or testing3 despite efforts potentially making this possible in the future. This issue manifests itself in studies such as [3] which somehow boost accuracy several times higher than other studies despite not having datasets or applications outside of the lab.

Earlier studies have however been made since 2020 in hospitals across China. [10] Shows diagnostic accuracy results all above 90%, a similar value to that of traditional PT-PCR tests mentioned above. The majority of studies, like this one also focused on CT scans due to the increased detail available in each image. However, the neural networks in this study were inputted CT scans instead of CTR. Hence, the application and training of this program was dependent on the access of thousands of slices made by an expensive and slow CT scanner. Other proposed substitutes to traditional COVID19 testing often lie in more abstract yet unverified methods. These studies focus on impractical circumstances in which they become applicable, while others, [14] propose methods so radical and logically questionable that they bring up obvious issues in other fields. Despite various issues being present within the current research and little verification and access to appropriate training sources and databases, The majority of studies within this field have shown reasonable accuracy and potential. The constant flow of new ideas and applications have shown considerable success and lead the way forward for similar studies harbouring more success and resulting in confirmatory, similar results. However, the impracticality of many proposals in certain circumstances is certainly still an issue.

3. Recent researches

Maram Mahmoud A. Monshi et al. [13] provides research on one of the most optimised computer algorithms within this field. The algorithm, like many others, is claimed to be capable of diagnosing COVID19 using CXR. Unlike many other Deep learning algorithms which this study openly references and is based on, this paper focuses on the optimisation of the image processing network. The algorithm is stated to have SVM and KNN, using the optimiser called Adam in order to achieve a very high standard with much more flexible circumstances. Lighting, zoom, perspective, and the removal of certain indiscriminate portions of the input are all tested to create a more concise image processing layer of the CNN. Such measures are inherently necessary considering the reduced standards of the actual image itself. Unlike the high resolution CT scan slices, the study exclusively used CXR images. As mentioned by the paper, CXR images were prone to being taken at the wrong angle or taken at a low resolution and definition due to the broader spectrum of X Ray system quality. Despite the numerous issues at hand, their research does report surprisingly good results. After only using 960 images to train their algorithm, their final accuracy result was 95.82% accuracy, 15.19% above the original algorithm that did not feature image processing optimization. Despite claiming to have an accuracy comparable to PT- PCR COVID19 tests used currently in the field, we would like to point out some potential issues with their findings. As the paper partially alludes to, the imbalance of the dataset is also an issue which plagues all studies researching the use of CNN algorithms. In reality, the vast majority of people in the world simply don't have pneumonia. In the US, only 1.5 million cases of pneumonia were documented in 2018, compared to a relative total population of 326.8 million at the time. The majority of studies within this field create patient groups proportionate to each other, causing the algorithm to favour actually diagnosing the individual with an illness in the first place. The CNN image processing network may have a weak grasp on the multitude of unique cases present in individuals without pneumonia and hence be inaccurate when dealing with these cases. While lacking in clinical trials, the research promises

[3] The majority of well trained and tested programs were government funded and originated in East Asia.

potential feasibility of using CNN in the field and also the importance of image processing algorithms and utilising modern deep learning techniques.

Xiang li et al. [1] further explores the possibilities within the field of diagnosing COVID19 with Xray images. The study focuses the image processing aspect and optimisation within the actual neural network system itself. Using a series of Coevolutionary layers and pooling layers, the DL algorithm can effectively summarise the most important aspects of the image, instead of randomly testing alterations. The paper focuses on the use of two methods, the first being dilated convolution. Features of the images are extracted via dilated convolution, immediately reducing the size and number of kernels in the image, while still keeping its details and structures uniform. This reduces the time taken for the model to train and function, while also being generally applicable instead of case specific. Aiming to mimic human visionary focus and increase intuition, by using Gradient weighted Class Activation Mapping (Grad-CAM), they can alter the final data fed into the classifier. Grad-CAM Image processing essentially alters the image and creates a priority of different sections and their contributing weight. This allows the algorithm to focus on specific parts of the lung that normally show signs of COVID19. Through application of dilated convolution and Grad-CAM, the study was able to increase the overall accuracy or their initial model. In order to test these systems within the context of the actual task, Two models were made to compare the accuracy and also the internal values (DDCNNC-I and DDCNNC-II).

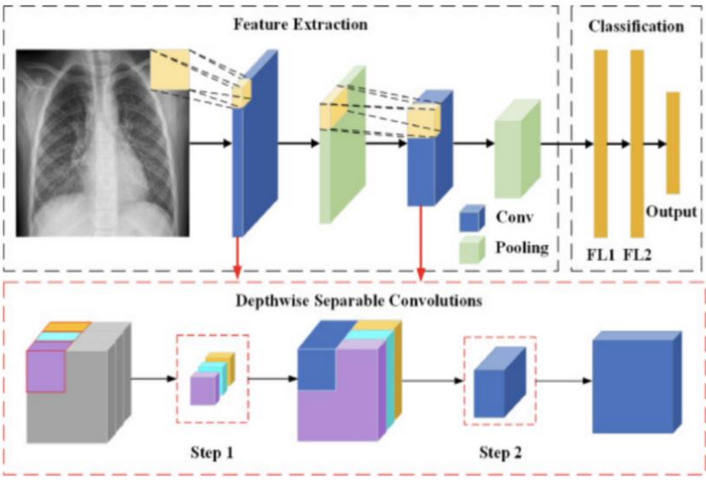

Figure 1. A visual interpretation of the CNN process and analyse the patients CXR image.

Essentially, "DDCNNC-I" contained more dilated convolutional neural layers and featured heavier application and focus on Grad-CAM image processing. In contrast, "DDCNNC-II" contained only one dilation layer and less optimisation of the grad-CAM processing. "DCNNC-III " was also created as a third diagnosis algorithm, featuring only Grad-CAM processing without dilated CNN layers. After training the dataset with around 5500 images from a medical dataset called kaggle, tests were made on the remaining CXR 1390 images in the dataset. DDCNNC-I showed a maximum overall accuracy of 93.63%, 0.37% higher than DDCNNC-II. The operating speed of DDCNNC-I was also 3.6 to 10.96 seconds faster than DDCNNC-II. When analysing the actual computer interpretation of the grad-CAM results, DDCNNC-I highlighted important features like the lungs and airway more distinctly and definitively than DDCNNC-II, which gave an unclear result. Overall these results helped show the clear benefit and importance of using efficient image processing algorithms and integrating them with the neural network. This not only increases accuracy but also speed. DDCNNC-III however, gave a strange result, while it was predicted that the strengthened use of Grad-CAM would prioritise important details and shrink the time needed to diagnose, it also has a higher accuracy around 0.3%higher than DDCNNC-II. The paper leans this on the fact that despite not having dilated convolutional layers, DDCNNC-II only had 1 and hence didn't have an inherent advantage over DCNNC-III. While lacking clinical trials like the majority of studies exploring the use of CXR images to diagnose COVID19, the paper is also

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one of many that sheds light on image processing aspects within this field and the sheer multitude of possibilities for improvements open in such an important yet difficult field of study.

Ali Imran et al. [2] proposes perhaps one of the most ambitious and visionary ideas actually proven with research. In short, the study focuses on the possibility of a mobile device app diagnosing COVID19 by analysing an input of a cough sample from a continuous stream of audio. The primary basis is that this increases the number of COVID19 cases that can be detected and diagnosed (far more than the cases that explicitly cause pneumonia). The study aims to create a phone app capable of aiding the personal tracking of potential COVID19 infections. The app informs individuals if they are likely to be infected with COVID19 and gives a recommendation on whether formal testing should be done.The paper argues that during the beginning of the pandemic, the inability to test large portions of the population lead to the rapid transmission of COVID19 via individuals with minor symptoms. In our current efforts against COVID19, this is even more so the case, as individuals with minor symptoms are not only more infectious, but also make up a larger portion of the infected population as mortality rates drop. The study relies on the idea that COVID19, unlike other respiratory diseases, causes unique pathomorphological changes within the individual infected.

They utilise analysis from CML-MC, DTL-MC and DTL-BC4, combing the techniques in order to create a final conclusion for diagnosis. Their first classification technique turns the audio input into a mel spectrogram. The study then uses a CNN to analyse the spectrogram image, classifying whether the cough sample is COVID-19, pertussis, bronchitis or nothing of medical concern. Their use of (CML-MC) directly analyses features of the audio through MFCC and PCA based feature extraction5. The researchers feed this data into a SVM which classifies the cough audio into the four categories mentioned above. Their third classifier essentially operates on the same principle as the first, only that the algorithm is only trained to distinguish between whether the individual has COVID19 or not.

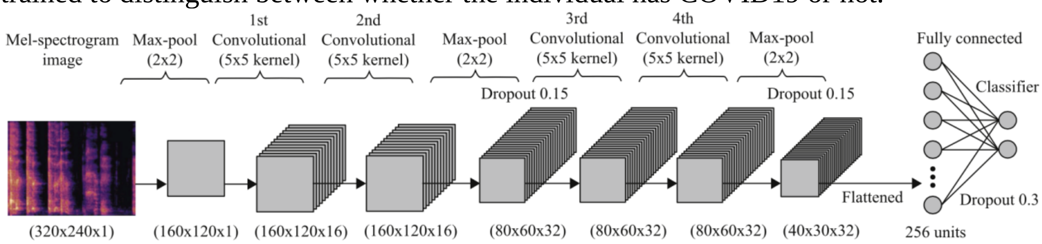

Figure 2. A visual representation of the CNN used to identify coughs as sounds.

To accommodate the small dataset, the algorithm is trained with transfer learning, as not only does it reduce the likelihood of overfitting, but it also yields higher results. The individual results featured an accuracy of 92.64%, 88.76% and 92.85% respectively. On the surface level, these values may indicate a sufficient accuracy, yet 38.7% of the results are returned as inconclusive, considering the lack of a large enough database to train their model, it is unlikely that the final results are accurate. We see this in the fact the line between accuracy during training and accuracy during validation shows substantial overfitting until the model is eventually fine tuned. The paper of course, agrees that clinical trials and application are clearly not possible, but aiding the population as an optional health monitor, at any degree would help keep the public informed on their own situation and what they should do, thus helping efforts against the pandemic.

4. Challenges

When it comes to using AI to diagnose COVID19, the current state of this field ranges from thousands of practical studies that researched the applications of Diagnosing COVID19 with CT scans to unique applications and ideas that while not having clinical trials, have shown considerable potential from a

[4] Classical machine learning multi classification, Deep learning multi classification and Deep learning binary classification respectively.

[5] Principal Component Analysis (PCA) and Mel Frequency Cepstral Coefficients, are both speech feature recognition techniques often used together.

technical perspective. Existing review papers have largely focused on what the vast majority of research is aimed at achieving.However, they struggle to encompass the progression and direction changes that may be more relevant at our current stage of the pandemic. Most of the research within this field was conducted in China in order to face the earlier stages of the pandemic. Despite proving the astonishing ability of AI and its numerous techniques to function within this field, lack of direction and practicality has slowed research within recent months. Like all research within the field of COVID19, the sheer speed at which circumstances change has been the main force in slowing research or completely nullifying it. Nevertheless, the advent of using AI to deal with COVID19 still has a basis in relevance and very well may prove useful in the future given that it receives increased support.

5. Conclusion

As the situation of the COVID19 pandemic continues to change and shift, the field of using computer algorithms to diagnose COVID19 will inevitably do so as well. Research has shifted due to a virtue of not only practicality but also possibility. Research in diagnosis via CT scans is getting phased out with research into diagnosis via CXR images. This has been of course made possible due to, in part, independent contributions made within the field of neural networks and deep learning such as CNN. These techniques are getting continuously verified and recently tested in the field to help create practical algorithms, advancing both the field of deep learning as a whole but also supporting the medical fight against the pandemic. While it is no longer realistic that the advent of using deep learning algorithms to combat COVID19 will completely solve the issues of the pandemic nor is it vitally necessary any more, it is likely that AI will eventually serve as another tool in the medical field that can be used to aid efforts against the pandemic.

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