Indonesian Journal of Electrical Engineering and Computer Science
Vol. 27, No. 3, September 2022, pp. 1635~1642
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v27.i3.pp1635-1642

Evolution of automated learning techniques for combating COVID-19: an analysis

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Article Info

Article history:

Received Mar 31, 2022
Revised Jun 14, 2022
Accepted Jul 5, 2022

Keywords:

Artificial intelligence
COVID-19
Machine learning applications
Pandemic managenet
Post vaccination

ABSTRACT

It is now more than two years that the world is battling the tiny invisible virus, COVID-19. Since its appearance, it showered humankind with shock, fear, and death. In small words, this pandemic has paused human life in all its aspects and beauties. Governments, health industry researchers and laboratories have put all their efforts to achieve a universal goal that is, overcoming the crisis and putting an end to the pandemic. However, this goal was never achievable without the smart use of automated learning, artificial intelligence, machine learning and deep learning algorithms. This review paper presents a collection of the experimental research articles tackled using real-time official datasets from hospitals and governments. These datasets are processed using automated learning (AL) algorithms in order to find suitable solutions to most of the COVID-19 related problems. This paper presents the AL applications in a story telling manner, starting from the first phases of COVID-19, when doctors had no experience dealing with the disease and had difficulty in diagnosing it, then moving to the other phases like suggesting a medicine, drug repurposing, facial mask detection, fake news detection, vaccine development, pandemic management, post vaccine statistics and lastly post COVID-19 analysis.

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1. INTRODUCTION

Before 2019, coronavirus was known as a normal cold and people were getting infected by it long years ago, however, this new coronavirus (SARS-CoV-2) known as COVID-19, has a new genetic structure. It has more serious or even fatal impacts on some groups of patients [1]. By now, it is clear that the spread mechanism of COVID-19 is through human respiratory droplets and face to face contact. Nevertheless, due to some of its dangerous features such as spreading by asymptomatic carriers, it has put humanity into fear, stress and global pandemic. 97.5% of patients carrying the COVID-19 virus show symptoms within 11.5 days, which makes its detection and diagnosis a little too late.

With its appearance, COVID-19 put the world in a big crisis, because of all the sudden changes it made to the human daily life. The large demand on oxygen supplements in the hospitals made the governments even more worried [2]. According to the official world health organization (WHO) coronavirus dashboard, up to today, 6,108,653 deaths are reported to WHO [3]. Since the beginning, WHO started guiding and advising the world with facts and steps to be taken by the governments to put a limit to the immense spread of COVID-19. Some of the taken measures were; quarantining infected people, declaring

curfew, closing schools, restrictions on movement and transportation, banning and limiting public gatherings, making mask wearing obligatory, and lately, encouraging COVID-19 vaccine intake.

Notwithstanding the good efforts and results, few could be done without the big impact of artificial intelligence in all the aspects of this pandemic management. Starting from automatic and smart detection of the COVID-19 virus, computational diagnosis, detecting fake news, detecting non-masked people, finding a treatment, drug repurposing, developing vaccines and many other applications. Artificial intelligence is the ability of computers, programs or machines to think, learn and decide in a human-like behavior.

Artificial intelligence plays a very big role in the healthcare industry since a very long time ago. Some few examples are drug discovery, patient diagnosis, medical screening, machine aided surgeries, medical care, and many more applications [4], [5]. In the next sections of this paper, many valuable research papers are discussed regarding the role of many artificial intelligence (AI), automated learning (AL), machine learning and deep learning applications in managing the COVID-19 pandemic, each supported with the dataset information, experiment details and results as well.

2. AUTOMATED LEARNING ROLE IN PHASES OF COVID-19

Since its appearance, COVID-19 spread fear amongst humanity and made millions of people lose their lives to the disease [6]. From the beginning up to discovering COVID vaccines, AI and AL played big roles in managing the pandemic and reducing its devastating impacts on human kind to a big extent [7]. Automated machine learning is the technique of making the repeated and manual process of machine learning an automated procedure [8]. It has recently become one of the trusted approaches for researchers and industrial personnel to do their findings [9], that is why it is used immensely in the researches related to the COVID-19 pandemic. There is a wide range of applications in artificial intelligence, machine learning, automated machine learning and deep learning approaches that have helped greatly throughout the worrying journey of COVID-19 [10]. Starting from detecting the disease [11], diagnosis [12], repurposing treatments, vaccine development, pandemic management [13], and up to the post vaccination statistics and findings, are all the applications of AI and machine learning for the goal of forcing the pandemic to its end.

2.1. Virus detection and prediction

During the early fearful days of COVID-19, there was little that doctors and health industries could do to for patients in recognizing this new disease. Here came the role of artificial intelligence to make the task easier, to a large extent. For example, many researchers, with the help of hospitals and doctors, used patient chest x-ray images to apply convolutional neural networks or deep transfer learning algorithms in detecting the virus, with a very high success rate [14]-[16]. Another example is the smart use of chest computer tomography (CT) scan datasets [17], image processing and neural network algorithm. For that, "GraphCovidNet" model is suggested to predict the COVID-19 virus with very promising results [18].

2.2. Diagnosis

After the process of detecting COVID-19 virus, AL and AI took the diagnosis stage into another level by using various machine learning and deep learning algorithms [19]. For instance, "Case Based Reasoning" is used in a research to propose an AI system that works by classifying the COVID-19 symptoms and giving the diagnosis result of each patient with the help of the doctors [20]. Knowledge based system is also a smart AI approach used to diagnose COVID by knowing the symptoms [21]. Another example of AI usage in diagnosis is the use of large number of patient cough sounds and comparing them with a database of patient cough sounds of COVID-19 and many different respiratory diseases. For this cough classification, many AI methods are used, such as deep transfer learning and deep neural networks [22].

2.3. COVID-19 treatment

With the help of AI, the big drug development industries are trying to find effective medicine to treat COVID-19 patients. Up to now, due to time limitation and the need of a rapid cure, no certain medicine is found that could be specifically used for this new virus. Nevertheless, using machine learning algorithms and drug repurposing, researchers found that some already available drugs have positive impact on curing the patients and therefore could be used as a helpful therapy for COVID-19 treatment, such as Hydroxychloroquin, Remdesivir, Azithromycin and Tocilizuma [23].

2.4. Vaccine development

The whole world was racing in developing a vaccine for COVID-19. As a result, several vaccines were produced, with different working mechanisms and different impacts on the human body. Many machine

learning algorithms, such as molecular docking and the in-silico approach, were used in the vaccine development stage in order to help humanity find the most suitable vaccine [24].

2.5. Pandemic management

All countries and governments were and still trying hard to manage this pandemic, such as controlling the spread of COVID-19 virus, declaring quarantine at many stages, reducing people's fear and psychological impacts of the virus, and lately encouraging citizens to take the vaccine. All these are done through data analysis with the big help of machine learning and deep learning algorithms. Among the many applications of these algorithms in COVID pandemic management are; detecting fake news, detecting people that are not wearing face masks in public places, smart automatic system to assist patients [25], classifying the negative opinions of people towards taking COVID-19 vaccine, automatic vaccine scheduling [26], and categorizing the population to take the right vaccine as per their medical background and gene, and many other applications.

Applying these algorithms have helped in managing the pandemic and putting it under control to a large extent [27]. For instance, in a research, a smart device is created to be used in crowed places to reduce the spread of COVID-19 by detecting non-face mask wearers, distance between people, and health condition checkup, before letting the people in. This system is created by the application of AI algorithms and internet of things, such as face detection, image processing, and Viola-Jones algorithm [28]. To force the social distancing, another research uses cloud computing, they connect their system to the cloud to make it more reliable and contactless [29].

2.6. Post vaccine analysis

After the release of COVID-19 vaccines, the role of AI and machine learning has become even more necessary in analyzing the positive and negative effects of the vaccines on different ages and classifications of people. For this purpose, many researches are conducted using machine learning algorithms. Then, statistical results are found and provided to evaluate the vaccines and guide the authorities. For instance, in the UK, medical researchers used nearly 2 million PCR test results as a dataset and analyzed it with "UgenTec FastFinder", which is a machine learning algorithm based model. The results showed that taking AstraZeneca or Pfizer vaccines reduces the infection to a noticeable range, especially after taking the second dose [30].

3. ANALYSIS OF AUTOMATED LEARNING APPLICATIONS IN COVID-19 PANDEMIC

This chapter presents many experimental research papers applying AL algorithms to fight COVID-19 problems, from the first phases of COVID, to the last ones. All the necessary information of each paper are provided in Table 1 (see in appendix). Such as, the application type, author or paper information, dataset reference (if available), the experiment details including the AL algorithms and methods, the results and outcomes claimed by the authors, and finally, the challenges or limitations of each application.

4. DISCUSSIONS AND CONCLUSIONS

Out of a sudden, the coronavirus COVID-19 appeared and put human race in an unexpected threat. The whole world put their efforts together to overcome this global epidemic as fast as possible. AL, AI, machine learning, and deep learning applications were undoubtedly the key factors into making the long fight shorter, the high death rate lower, and the battle winning against COVID-19 more guaranteed.

Without all the smart AI applications, this process would have required much more time, price, energy, and even human souls. This paper presents the very useful AL applications for combating COVID-19 from the perspective of the recent experimental research papers. Those papers are the fruit of collecting substantial real-time datasets of COVID-19 patients. Data is mostly gathered officially from hospitals and government datasets. Then, they are classified and processed with the use of AL algorithms.

This paper presents these applications and analyzes them in a story telling way, from the early stages of COVID-19 when detection and diagnosis where the most difficult tasks for the health sectors. Then moving to suggesting treatments, drug repurposing, pandemic management, vaccine development and lastly, post vaccine analysis and effectiveness. The optimistic research results and outcomes show the valuable impact of technology in general and AL in specific in the fight against COVID-19. Upon concluding this paper, it is worth to mention that amongst all these advantageous AI methods, image processing, text mining, and natural language processing are the most frequently used throughout the phases of COVID-19 pandemic. Although COVID-19 threat has calmed down recently, the valuable researches and experiment results done on the use of AI applications to battle a pandemic of this size, will always stay a good achievement. All the good techniques could be reused and enhanced for other future health problems that might face humanity.

APPENDIX

Table 1. AL applications in COVID-19

No.	COVID-19 AL Applications	Author	Dataset	Experminet details	Outcomes	Challenges and limitations
1	Virus detection	[31]	Dataset is gathered from 3 different sources [32]-[34]	Research uses patient X-ray images as data, among them are 180 COVID-19 and 200 non-covid x-ray images. The images are resized to 224 × 224. Then, deep feature extraction and fine tuning methods are applied on them, alongside many pre-t raining CNN models and classifiers.	Best result is achieved when using ResNet50 model and SVM classifier with an accuracy score of 94.7% in detecting COVID-19 x-ray images.	The major limitation is with the fine-tuning training, it is requiring too much time compared to the other deep feature extraction methods.
2	Virus detection	[35]	COVID Chest Xray Dataset [36]	This experiment uses text mining to detect the virus. The dataset is 212 patient X-rays, and has 24 columns. Such as name, id, gender, age and oxygen supplement need, but only the needed features are used for classification.	The authors state an accuracy of at least 90.6% in detecting the COVID-19 virus from the used dataset.	Lack of bigger datasets in the experiment time makes the accuracy less. Larger datasets might help in getting improved results.
3	Virus prediction	[37]	Dataset is from the patients of the Hospital “Israelita Albert Einstein” at Sao Paulo Brazil, [38],	The dataset consists of 111 laboratory findings. From which the most related 18 fields are used in this experiment. Number of patients is decreased from 5644 to 600. Six different deep learning models are trained, such as artificial neural network, convolutional neural networks, and long-short term memory. The clinical findings are then fed into the models in order to do the COVID-19 predictions.	This research indicates the best result when using the Long-Short Term Model, with an accuracy of 86.66% in predicting COVID-19 among the other clinical data.	The biggest limitation of such a predictive system is the data being in limited size and also unbalanced. Many fields should be deleted in order to get a dataset that can be used properly.
4	Diagnosis	[39]	Two datasets are gathered from 7 China hospitals, one is a COVID-19 dataset of n=1266, and the other one is EGFR dataset of n=4106	Total of 5372 CT scan images collected from 7 cities are used. Total of 4106 of the CT scans are used for training the deep learning algorithm, and the other 1266 are used for classification as COVID-19, or as other pneumonia such as lung cancer and other diseases. They use CT scan lung segmentation to classify COVID-19 from the other diseases.	Research indicates classification rate of AUC 0.88 for COVID-19 and AUC 0.86 for the other pneumonia. This DL system Automatically finds abnormality area without human intervention.	One limitation is that there is no unified CT image slice thickness, which reduces the system performance.
5	Diagnosis	[40]	Piczak [41] data set is used, together with the cough sounds gathered from the “AI4COVID-19” smartphone app.	This research uses cough sounds of patients to differentiate between COVID-19 and other respiratory diseases. They have created a smartphone app named AI4COVID-19. It takes 3 seconds of cough sound and processes it to help diagnosing COVID and non COVID patients by the sound frequency and deep transfer learning.	Many different classifiers are used, each showing different accuracy rates. For COVID-19 diagnosis using deep transfer learning and multi-class classifier, accuracy is 92.64% for the limited data available.	Number of training data is the biggest limitation. Also, it is difficult to decide based on cough voice alone, knowing that several diseases have similar cough sounds.
6	Diagnosis	[42]	Three public datasets of chest X-rays are used for training, [43] for previous chest diseases and normal lungs, while [44], [45]	The datasets are trained by creating a deep neural network architecture. Network segmentation is applied then 5 classifications are created, such as normal, bacterial pneumonia, viral, TB and COVID-19.	Different segmentations methods and networks are created, so there are more than a result. Taking U-Net as example, the accuracy is 85.9 while for the FC-DenseNet103,	Limited training dataset.

No.	COVID-19 AL Applications	Author	Dataset	Experminet details	Outcomes	Challenges and limitations
			datasets are used to get COVID-19 Chest X-ray images.		accuracy is 88.9.	
7	Treatment	[46]	COVID-19 patient reports of 6 hospital emergency departments in the US are used as the test data.	290 positive COVID-19 patients are included in the study to observe the effect of hydroxychloroquine medicine in their treatment by creating a machine learning algorithm. Factors included age, sex, oxygen saturation, previous medical history, used medications and many others.	Survival rate was increased by 31.4% for COVID-19 patients that used hydroxychloroquine.	Lack of biological data of the patients, small size of dataset, varying follow up times between the patient groups and many other limitations.
8	Treatment	[47]	The tested drugs are commercially available. The amino acid sequences, SARS-CoV-2 genome and the other necessary data are taken from the National Center for Biotechnology Information Database (NCBI).	A deep learning model called Molecule Transformer-Drug Target Interaction (MT-DTI) is used in this research that identifies and detects the impact of available drugs on the genome of SARS-Cov-2, and has a positive healing impact on the patients.	Experiment shows that Atazanavir is the top one effective drug with Kd of 94.94 nM, second is remdesivir, with Kd of 113.13 nM, then third is efavirenz with Kd of 199.17 nM.	Research result is not supported yet by other researches to evaluate the positive impact of these drugs on COVID-patients.
9	Vaccine development	[24]	NCBI [48] Dataset from the "National Center for Biotechnology Information" is used.	250 COVID-19 Genome sequences are used. The S, M and E proteins are found, then candidate vaccines are suggested against them, using molecular docking and the in silico approach, which is a deep learning method used in vaccine and drug development.	The research result suggests CoV-RMEN as the most effective vaccine, with a coverage around 90.0% on the world's different ethnicity groups.	Lack of a big COVID-19 genome sequence dataset is a major limitation. Also, the positive effectiveness of the suggested vaccine should be further studied and tested in terms of boosting the immunity against COVID-19.
10	Pandemic management by identifying fake news.	[49]	Zhou *et al.* [50] dataset is used. It consists of 2304 news about COVID-19 from different reliable and unreliable sources, including information about title, author, body-text, country and many others.	From the dataset, the only information used are the body text and title of the news to identify whether it is fake or not. Firstly, natural language processing is applied. Secondly, after cleaning the data and classifying it, text mining is applied using Python and then decision tree classifier is used.	Accuracy rate of 72% is indicated in identifying fake news when applying the algorithm on the news titles.	There is not enough words to train the model more appropriately.
11	Pandemic management by detecting facial mask.	[51]	Kaggle [52] website is used for the dataset which consists of images of random people, some wearing facial masks and some are not.	A set of 1315 images, 142 images and another 194 images are used as data. They are classified as mask and non-mask categories. This research uses convolutional neural network deep learning algorithm to train the model together with image processing algorithms. It detects people wearing mask and non-masked people.	99% accuracy rate achievement is claimed by the authors when applying FDS models.	Because of the precise image data patterns, this research requires high quality images, computer machines with very high GPU, and very good internet bandwidth.
12	Pandemic management by suggesting appropriate candidate	[53]	Dataset from "vaccine adverse event reporting system" [54] is used.	Machine learning algorithms such as adaboost, decision tree, logistic regression and random forest are used to classify vaccine takers into	Adaboost ML algorithm shoes the highest accuracy rate in detecting the appropriate vaccine,	The dataset contains USA data only, the experiment can be applied on any

No.	COVID-19 AL Applications	Author	Dataset	Experminet details	Outcomes	Challenges and limitations
	vaccine types for different people.			two candidate vaccines, Pfizer and Moderna, according to some variables, such as age and gender. The aim is to suggest the suitable vaccine for the suitable vaccine taker.	which is 98.1%, followed by Random Forest 97.8%, Logistic Regression 97.31% and Decision Tree Classifier 97.3%.	other similar dataset for other countries as well.
13	Pandemic management by analyzing people's attitude for taking covi-19 vaccine.	[55]	Social media posts, and specifically Twitter, are used as dataset.	18,440 tweets are used as dataset, terms like "COVID vaccine" are detected in the posts in the Indian community. Then, the behavior, thinking, mentality and fear of people are analyzed toward taking COVID vaccine. ML techniques used in this experiment are sentiment analysis, natural language processing, and latent dirichlet allocation.	The results indicate that only 35% of the posts are positively talking about vaccine taking, while 47% are in natural tone and the other 17% are in a negative tone. As time passes, the results show more positive and less negative tones.	No limitation is stated.
14	Post vaccine analysis, side effect analysis of Pfizer, AstraZeneca, and Sinopharm vaccines in Jordan.	[56]	Dataset is created from a Google form online survey, consisting of a thorough questionnaire of many sections, such as the vaccine takers' medical status and demographic data, together with pre and post vaccine perception.	Survey answer of 2213 participants is used for the study. Many ML techniques such as eXtreme gradient boosting, K-Star, multilayer perception, and random forest algorithm are used to study the severity of each vaccine side effect on the Jordanian people.	Research states that only 10% of the participant vaccine takers got severe side effects, while the others only felt some temporary common side effects, such as dizziness, fever and headache. Result also showed that a small percentage of 5% got infected with the virus after getting vaccinated.	The fact that this study uses self-reporting information and online survey, is the biggest limitation because that might present misinformation and biased data.
15	Post vaccine analysis of the side effects of COVID-19 vaccine from the view of Indian citizens.	[57]	Dataset is prepared by analyzing twitter posts of Indian citizens by using the Python Library Twint.	Only English posts from certain locations are used, through the geographical filtrations of the Twint Library. Using 189,888 tweets, the words "COVID vaccine" and "side effects" are detected. After data cleaning, sentimental analysis and latent dirichlet allocation are applied.	Results show that 33.6% (63.848 tweets) are mentioning side effects in the positive way, 44.9% (85,407 tweets) are in neutral tone, and 21.3% (40,6330 are in the negative tone.	This study uses Indian people perspective only, regardless of the different cultures and cultural effect on the population mindset.
16	Post vaccine analysis of Sinovac and Pfizer in Indonesia	[58]	Dataset is collected from Bahasa Indonesia tweets on twitter, the phrase "vaksin (COVID or corona)" are detected using Tweepy and Search-tweet api python libraries to gather the data.	A collection of 76,708 tweets are gathered, then labled into "vaksin sinovac" and "vacsin pfizer" manually. After that, it's pre-processed using case folding, document filtering, tokenizing, stop word removal, normalization and stemming. Next, feature selection, modeling, and label prediction are applied to the data.	Sinovac research results are 77% positive, 19% negative, and 4% neutral. Pfizer results are 81% positive, 17% negative and 3% neural. Pfizer shows more positive feedback than Sinovac.	More evaluation on the normalization, classification, and modeling steps can enhance the performance and better results.

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