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A REVIEW OF EMERGING ARTIFICIAL INTELLIGENCE AND INTERNET OF THINGS TECHNIQUES AGAINST COVID-19

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Abstract. The novel Coronavirus Disease (COVID-19) pandemic has been causing many problems in the global economy and social life since its outbreak in early 2020. As a new disease, we do not have an effective medical treatment against it and researchers have been studying intensively to find a solution to control the spread of the pandemic. However, the aggressiveness of the virus has not been decreased so far and the administrations have been adopting normalization policies which is increasing the number of confirmed cases and leading to the expectations of a second wave in the forthcoming months. As a result, there is a demand for speeding up the clinical studies in the detection and treatment of COVID-19 patients. Artificial intelligence (AI) and Internet of Things (IoT) technology have a crucial role in this stage where smart models and applications have been developed to minimize the spread as well as diagnosing the potential patients using machine learning and deep learning techniques on image and sound datasets. With this motivation, this paper covers the latest developments of the usage of AI techniques and IoT technology in the healthcare industry aiming to provide a guide for the future studies and proposes a novel algorithm that can be more effective in the control of the spread of the coronavirus.

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1 Introduction

Since the outbreak of COVID-19 pandemic, the healthcare systems are facing a global crisis. By September 2020, we have 33 million confirmed cases and around 1 million deaths caused by the novel COVID-19. Even worse, the growth rate of the disease is once again rapidly increasing and some of the countries already declared that a second wave of the pandemic emerged in their borders. Therefore, the studies for vaccination and effective treatment of COVID-19 are accelerated. However, the expectation is that we are still months away until we have a vaccine or a medicine that can be used to cure the patients.

Thus, slowing the spread of the disease is the best solution that we are able to perform at the current stage. This procedure is based on the traditional methods where the diagnosis of a patient is analyzed according to their symptoms and then confirmed by reverse-transcription polymerase chain reaction (RT-PCR) tests. As summarized in Figure 1, the traditional diagnosis procedure is based on the symptoms observed on the patients. In other words, the tests are applied when the patient is symptomatic and matching symptoms are found with COVID-19 patients. However, we know that 15% - 20% of the COVID-19 patients are asymptomatic according to latest studies. Moreover, the accuracy of RT-PCR tests are also questioned since it is presented that the accuracy of the test may change according to the prevalence of the disease

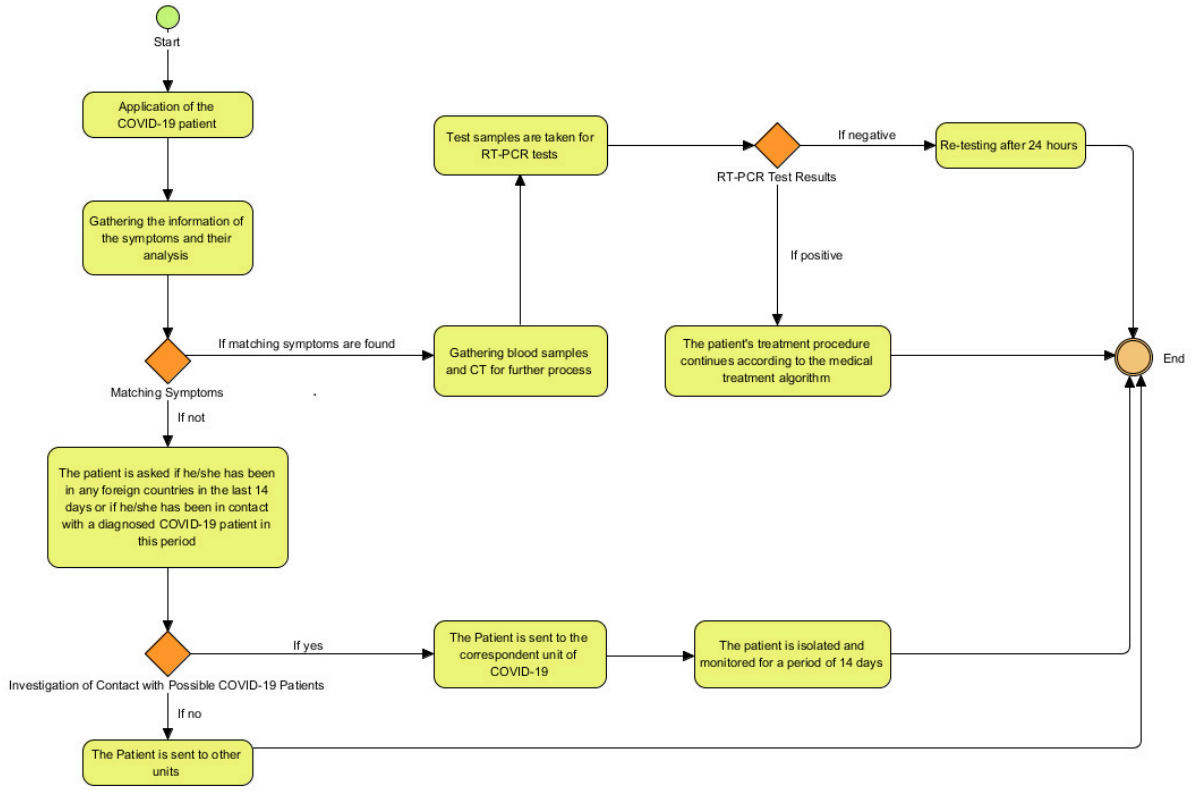

Figure 1: The general flowchart of the diagnosis algorithm applied in Turkey (TR MoH Algorithm, 2020)

(Floriano et al., 2020) and the process is time consuming. Alternatively, Computer Tomography (CT) has gained much attraction by the medical experts as a more reliable and faster method in the diagnosis of COVID-19 patients. However, the performance of CT based diagnosis is based on the performance of the radiologists (Ardakani et al., 2020). As the number of confirmed cases is increasing rapidly, this also increases the work load of the radiologists and decreases the success of the CT based diagnosis. Therefore, the healthcare system needs alternative solutions in order to control the spread of the disease to prevent the collapse of the system due to the rapidly increased number of patients requiring medical treatment.

Artificial Intelligence (AI) and Internet of Things (IoT) technologies are considered as essential factors for providing effective solutions. In the latest studies, Machine Learning and Deep Learning Algorithms are employed in the assessment of testing kits to improve the early detection of potential COVID-19 patients (Vaishya et al., 2020; Javaid et al., 2020). Likewise, some countries introduced IoT based applications that perform indoor safety monitoring (Yonghe Cardinal Tien, 2020) or Global Positioning System based applications to provide the infection rate information to their citizens showing the number or density of the infections observed in their region (TR MoH Algorithm, 2020). Therefore, the potential patients can be isolated or healthy people can secure their social distance with the infected people. Moreover, the usage areas of AI and IoT based applications are still increasing and people around the world are trying to adapt to the new normalization approach introduced by their administrations. Thus, in such a pandemic that is said to be seen once in a hundred years, it is likely that the application areas of such innovative approaches will increase due to their potential for reducing the spread of the virus.

In this work, state-of-the-art AI and IoT studies used in the early detection of COVID-19 patients are investigated. This paper also covers the recently introduced applications and gives a sight about their potential as well as their drawbacks. Finally, this paper offers an algorithm

by combining novel approaches with the traditional diagnosis procedures to provide resources for dynamically changing needs for the fight against COVID-19 including other types of tests and computer aided applications.

2 Artificial Intelligence and Internet of Things Applications in the Fight Against COVID-19

Artificial Intelligence is a discipline aiming to create machines and applications that can make smart decisions to solve a specific problem. Therefore, the machine actually imitates the human behavior and able to perform human-like actions including visual perception, speech recognition, self-learning or decision-making under specific circumstances. As a roof to many concepts, AI can be divided into many subtopics according to the specific action that the machine performs. Machine learning (ML), Deep Learning (DL), Natural Language Processing (NLP) are some of the subtopics of AI. ML refers to the concept of self-sufficient learning ability of a machine using the previous experience that has been gained without the intervention of a human. Basically, the machine works on a provided classified data, analyzes it and makes predictions for the future phases. DL is referring to a similar concept. However, it operates on large datasets and the machine is also able to discover new features to be used for classification which has to be given by the human in ML. In both of these concepts, they use Artificial Neural Networks (ANN) to perform self-learning behavior which was designed similarly to the human neural network. Finally, NLP refers to the applications that machines are able to read and understand human languages. It is also important that these concepts are multidisciplinary which means we can build hybrid systems using multiple AI techniques or we can use other subjects of computer science including computer vision, image processing or IoT together with AI concepts.

In our fight against COVID-19, AI concepts became popular to provide solutions that were mentioned in the previous section. One of the application areas of AI techniques to improve the accuracy of chest CT data. Ai et al. (2020) presented that chest CT data is more reliable compared with the RT-PCR tests. However, the accuracy of CTs is based on the performance of radiologists as explained by Ardakani et al. (2020). Therefore, AI techniques are proposed to be used on CT data to reduce the work load on radiologists where the machines can be able to detect a potential COVID-19 patient by extracting patterns observed in CTs (Vaishya et al., 2020; Gozes et al., 2020; Li et al., 2020). These studies propose that deep learning algorithms operate successfully on CT data and diagnose the patient correctly. A Convolutional Neural Network (CNN) which is a specific type of neural network working on visual images, can train the machine if the system is provided with sufficient amount of data collected from non-COVID and COVID patients. With the improved CT analysis using Deep Learning, Ardakani et al. (2020) introduces that an AI based model is capable of reducing the rate of false-positives (patients initially tested by RT-PCR). It is even possible to improve the effectiveness of the detection models using image processing techniques (removing noise, increasing the brightness) to increase important aspects of CT data (Ucar and Korkmaz, 2020) that can be used to train CNNs in a more efficient way.

Another application area of AI techniques is the vaccination and effective medicine development procedures. Ahuja et al. (2020) and Vaishya et al. (2020) introduced that AI programs are capable of generating trillions of synthetic compounds and decide on which can be good candidates in the vaccine development. This can have a major impact on accelerating the vaccine development process that can be reduce the rates of deaths by increasing the immunity of the people against the virus. It can also be applied on the existing medicine dataset to analyze which of the drugs may be used against the novel coronavirus as well as the people that may have a higher risk due to their genetic structure (Alimadadi et al., 2020).

Some countries are employing NLP based applications to reduce the work load of the medical employees. An NLP based app operating on phone lines, is capable of understanding the

complaints and symptoms of the potential patients and checking them in their database. Therefore, the app may decide if the person calling is a candidate COVID-19 patient and explain the next step to be followed in the process (Koronabot, 2020). Another study was conducted on the analysis of inhibitors that was performed by Ge et al. (2020). According to their results, they found that CVL218 is a good candidate for the treatment of COVID-19 patients. The NLP program found that result processing on the Pubmed database, and matching the results of the studies based on other types of viruses that may have similar effects with the novel coronavirus. Moreover, Madurai Elaravasan and Pugazhendhi (2020) presented a model that can automatically analyze and label the regions that have a huge infection rate.

IoT is another popular concept in computer science that describes a network of physical objects that are connected through an internet connection and able to communicate and share data with each other. As it is explained in the previous paragraph, IoT can be used with AI techniques which brings the advantage of supporting necessary image, sound or signal data that can be used by the machine to make smart decisions for a specific problem. Using high resolution cameras, microphones or any other types of sensors, the IoT concept provides a huge collection of data for AI based applications.

Moreover, IoT based applications emerge to reduce the risk of contamination (Yonghe Cardinal Tien, 2020; TR MoH Algorithm, 2020) or to provide decision making for a monitored patient (Petrović & Kocić, 2020). (Yonghe Cardinal Tien, 2020) installed a hybrid system in their hospital for indoor safety monitoring. The people inside the building are monitored by a 2-in-1 detection device that checks if the personnel are wearing masks or they are having an abnormal body temperature. Thus, the system may label the people as "highly risky" where these people may be isolated from the others and tested for the diagnosis. Turkish Ministry of Health introduced an app named as *"Hayat Eve Sığar"* or *"HES"*, which has a direct access to the database of the infected people and checks their current location using the GPS information provided by their cell phones. Therefore, any Turkish citizen can check whether they are in a high risk area. The same application is also used for the entrance to the public buildings and people who are either infected or have a contact with a COVID-19 patient is not allowed to minimize the risk of contamination among the healthy people. IoT based applications can also organize the production supply chain including the precauotinary items such as masks and face shields which is important during the ongoing pandemic (Javaid et al., 2020).

A crucial development in newly proposed methods is the detection of COVID-19 patients through cough samples. As a novel approach, Imran et al. (2020) introduced an app that collects the cough samples of the app users using and an AI model analyzes these samples using signal processing techniques. Their motivation is coming from the fact that COVID-19 affects the respiratory system uniquely and the studies show that cough analysis may be a key factor in the diagnosis of respiratory diseases. Therefore, this novel approach turns every cell phone into test kits and may be an alternative solution for the lack of RT-PCR test kits and time consumed by RT-PCR tests. In addition, CTs are reliable alternatives for RT-PCR tests. However, similarly it is not possible to test each individual by CTs and CTs also impose a considerable amount of radiation which is also debated among the medical experts. Therefore, this novel approach is promising due to its capability of accessing a significant number of people and has no cost compared with other testing kits.

As it can be seen, with an increasing number of usage areas of AI and IoT based techniques against COVID-19, it is possible to end the ongoing pandemic with minimal losses. However, we are still away to find an effective medical treatment against COVID-19 and the economic recession is causing an unrest among the people around the world. Moreover, the social depression is becoming a huge problem in the society and people are becoming more ignorant about social distancing which also increases the work load of the medical employees. Therefore, it becomes crucial to change the traditional diagnosis algorithm which is lacking to detect all the possible infections. In this manner, the next section will introduce a novel algorithm that

combines the traditional algorithm with newly proposed approaches. Thus, it will be easier for administrations to control the spread of the virus until an effective medicine or vaccine is introduced. Nevertheless, it is still experimental at the moment and more samples are needed for the training of the AI model. Similar approaches are also carried out by Coughvid (2020); Covid-19 Sounds App (2020); Breathe for Science (2020).

3 A Novel Algorithm in the Detection of Potential COVID-19 Patients

In this section, a novel algorithm is proposed for the control of COVID-19 infection rate. The applications are taken via an NLP based system to reduce the work load of medical staff. The symptoms and complaints are taken similarly with the traditional algorithm. Then, if matching symptoms are found, the system directs the applicant to the novel cough diagnosis tool. As the probability of infection increases for an individiual, the algorithm directs the individual to widely used CTs and RT-PCR tests. Otherwise, the applicant is either isolated or sent to the corresponding units. The proposed algorithm can be seen in Figure 2.

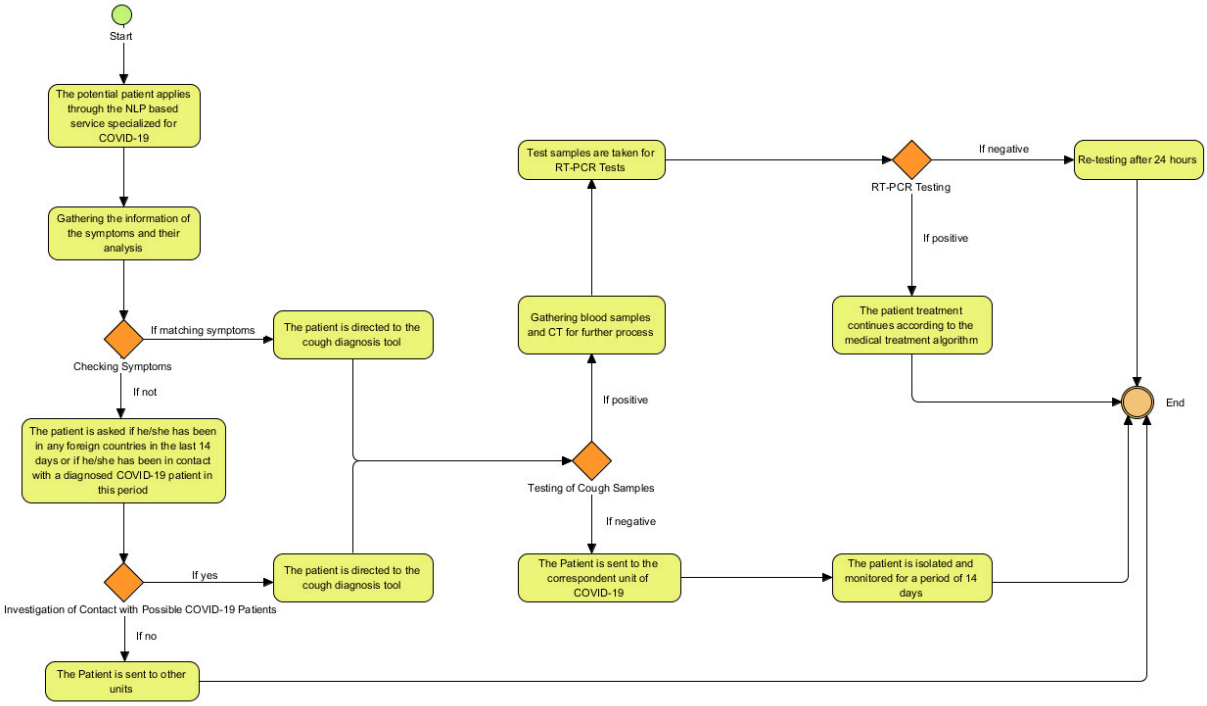

Figure 2: The general flowchart of the proposed novel algorithm

The main difference of the novel algorithm is based on using the innovative approaches in the detection of the infected patients which were previously discussed. The current traditional approach is totally based on RT-PCR tests and CTs. However, we know that there is a daily test capacity and lack of time as the infection rate is rapidly increasing and the traditional approaches cannot find a solution to that problem. It is also a fact that even the uninfected applicants may get infected as they apply to the hospitals to have a RT-PCR test and the risk is increasing as they are getting closer to the real infected people. Therefore, the novel algorithm introduces the cough diagnosis tool as a first step in the testing of the applicants which may be applied anywhere using a regular smart phone. Therefore, the risk of getting infected may be minimized and it may be possible to test as many people as possible. The results of tests can also be transferred to *"HES"*, for better monitoring of the infected people. Moreover, the map

of the infected people shown in the app will also be more accurate since the system would be fed with more data.

4 Conclusion

In this paper, state-of-the-art Artificial Intelligence and Internet of Things approaches for COVID-19 has been presented and discussed in detail. As it can be seen, the work load on the medical staff is a major problem in the detection and treatment of COVID-19 patients. The bottlenecks and risks in the traditional algorithm has been expressed from different perspectives. Therefore, a novel algorithm is proposed to reduce the work load that introduces the usage of smart applications for analyzing the symptoms of the patients and a novel cough diagnosis tool to increase the number of tests to reduce the infection rate. Moreover, the novel algorithm can be enhanced by promising techniques which will not have an affect on the work load.

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