Flying Ad-Hoc Networks with Electro-Chemical Nose to Detect Pathogens: Challenges and Open Problems

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Abstract

COVID19 is a contagious virus which has caused a pandemic around the whole world and into lock downs. Humans are social creatures who have to interact with each other and the environment in variety of ways. In this research, flying ad-hoc networks (FANETs) with built-in electronic nose are proposed to detect either diseases or viruses from samples of human breathes. Combining the two technologies together will provide a safer way to detect COVID19 without human contact with possible infected person(s). FANETs may be used to cover wider area and be able to take samples of human breath and analyze them with their built-in electronic nose equipped with either bio-sensors or chemical sensors. Artificial Intelligence using Neural Networks is proposed to recognize 3 different categories, namely, the COVID 19, SARS, and Other. Furthermore, FANETs may be used to further transport collected samples of viruses for further analysis and detection centers for further processing and confirmation. It also provides some open areas where further research needs to be conducted.

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Key words:
COVID 19, Ebola, Electronic nose; Neural Network, SARS, Viruses.

1. Introduction

Contagious viruses such as COVID19, SARS, EBOLA, [1] and others have been devasted the lives of people and COVID19 in particular has caused world havoc [1]. Viruses, bacteria, fungi are part of human daily life and early detection of contagious viruses are of paramount importance for early treatment and hence saving of human lives. Figure 1 shows a picture of COVID 19 virus under an electron microscope.

Humans inhale around 10,000 liters of surrounding air per 24 hours (day) and in this air there are anywhere from 100 billion to 10 trillion particles [2]. A fraction of extraordinary large number of particles get deposited on the human lung surface [11]-[17]. Disease may arise if human lung's defense mechanism does not deal with the deposited particles. As with COVID19, it is known people may be asymptomatic.

Currently drones are being equipped with sensors and use computer vision to remotely detect humans in crowds with infectious respiratory conditions such as COVID19 shown in figure 2. Drones are being used to monitor temperature, heart and respiratory rates, sneezing and coughing. The proposed FANET's system consisting of a fleet of drones are not only equipped with the current sensors and computer vision but also equipped with an electronic nose [9]-[10]. The advantage is detecting not only infected person but also detection of asymptomatic person who would be a silent spreader of virus as no normal symptoms of virus are present. The autonomous cooperation of drones in FANETs may easily help in identifying locations of virus and infected people. The possible areas to employ FANETs would be at airports, schools, colleges, stadiums, bus stops, metros, malls, music concerts and other places where human gathering is large.

One of the main importance is to detect COVID 19 in the air surrounding crowded people at congested places before it can spread to other places. Infected People exhaling their breathes into the surrounding air may become polluted with the virus in form of aerosols and it is utmost important to have a mechanism to detect the virus before the infected person shows the common symptoms.

Current research uses methods which detect infected people after they show signs of symptoms, such as sneezing, coughing, fever, chills and others, This may be considered medium to advance stage, our research is to provide an early detection method. If detection is done early enough then people may be warned of its presence. The detection will help inform the persons to avoid points of contamination with the virus or if the infected person can be detected by analyzing his/her breathe.

Currently, there are security personnel stationed at various locations such as supermarkets, hospitals, airports, to name a few, carrying devices to detect temperatures of people passing by and their aim is to sift out infected people from the crowd who shows a reading of high temperature on the hand held device, There are reports that some people do not show the usual symptoms. Our approach is similar to alcohol detection which is done by breath used by the police on patrols. Our idea is important to detect the viruses in a sample of breath taken by a drone equipped with electro-bio-chemical nose of a person who does not necessarily

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show any symptoms and the objective is detection to be in real-time (say 2 minutes to 10 minutes in duration) at the spot. Currently, swabs are being used to take samples from a person's mouth of saliva or the mucous from the nose. Our aim is two folds, one is detection by electro - chemical nose at the spot and second is the transporting of the samples of air or breathe taken by drones from congested areas with people to processing centers for further confirmation.

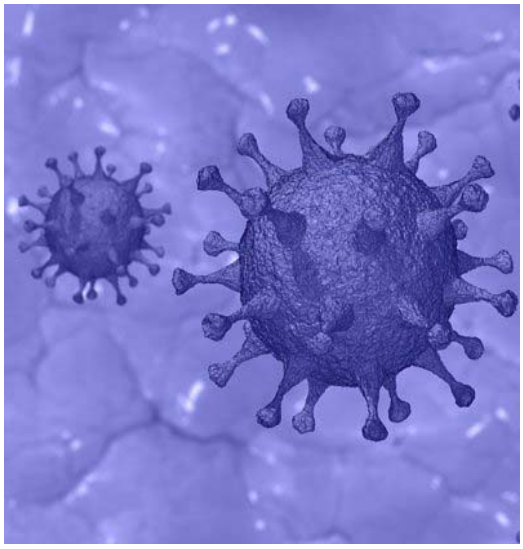


Fig. 1 COVID-19 under a microscope.

Fig. 2. Drone mounted with Camera.

Our approach is important in reducing spread of infections to people carrying out the tests as there is a high element of risk of a person taking a test to get exposed with infected persons. Our approach is to use flying drones which are unique in smelling out the virus in the breathes of people. Note again the emphasis of this research is to detect persons showing no symptoms of fever, sneeze, or coughing, yet they may be carriers of the virus.

Such devices would be useful for example at airports where passengers need to board the aircraft and there is no time to wait for the results to come from the labs, which usually take at least 24 hours.

In brief, the topic is extremely important to discover ways to detect the virus in the breath of infected people, to detect early and to early start the healing process.

The main objective is to efficiently analyze and detect COVID19 virus without human intervention. This is to have a continuous monitoring, sampling, and processing of samples of breathes of people (similar device to alcohol detection of drunken drivers) or surrounding air.

a. Detect people who may be asymptomatic and spreading the virus.
b. To study the architecture of combined technologies, namely, FANETs and electronic nose.
c. To safely transport samples of contaminated surrounding air to processing centers.

The proposed method is able to detect humans who do not necessarily show symptoms and has the following features;

a. To safely transport contagious samples to processing centers.
b. Keeping the identity of infected person confidential and private to authorities.
c. To detect the infected person early and be able to advise him/her for early treatment.
d. To facilitate the high number of tests that can be carried out on a daily basis, without human intervention, hazard, contagion.
e. Advantage of easy disinfection of contaminated drone.
f. No contact or exposure with humans and therefore avoiding transmission of contagious virus to humans

Literature survey is conducted on the current research methods in detection of viruses, in particular the COVID 19. As of current writing there does not exist any bio-sensor which completely detects the virus, although developments are being carried out by various researchers around the world. There has been progress in development of an electronic nose for detection of gases, however for the detection of viruses development of sensors is still at early stages. The main open problems are: First, to devise an efficient method to sample and collect air in suspected areas, second is to gather aerosols from the collected air for analysis, and third is the separation of RNA of the virus. Various researchers have claimed they have developed a bio-sensor, however its reliability and efficacy still has to

put to test. In the literature it is seen the theory behind the detection process is available and in most cases the process is still in infancy stages, and the practicality of the methods proposed in the literature still need to be developed.

The study on symptoms caused by the COVID 19 are also incomplete as new symptoms keep on appearing. The common symptoms of patients with mild or moderate disease so far observed are the following; headache, loss of smell, cough, nasal blockage, myalgia, asthenia, sore throat, gustatory dysfunction, rhinorrhoea, and fever [1].

The paper is organized as follows: Section 1 contains the Introduction, Section 2 the literature survey, Section 3 the proposed model, Section 4 Results and Discussion, and last Section 5 contains the Conclusion.

2. Literature Review

2.1 Optical Sensor

In [2], researchers are in the process of developing a novel optical sensor for detecting COVID 19. It can measure concentration of the COVID virus in air. The main objective is to quickly and reliably detect the virus. The idea relies on two parts to detect, safely and reliably, use of optical light and thermal sensors. They claim they have tested it with closely related SARS-CoV virus which broke out in 2003. These two viruses SARS-CoV and SAR-CoV2 are slightly different in their RNA structure. The tests showed their sensor can distinguish between the two even though having similar RNA sequences. The main advantage is that the results are ready in matter of minutes.

2.2 Virus Detection base on Color Change

In [3], scientists at University of Maryland School of Medicine have developed an diagnostic test for the virus which can visually be detected in 10 minutes. They rely on nanotechnology for quick visual detection and use plasmonic gold nanoparticles to check for color change if the virus is present. No sophisticated laboratory techniques are required and they believe it to be promising to detect the RNA material as early as beginning day of the infection. Figure 4 shows the process of visual detection of the virus in approximately 10 min time.

2.3 Usage of holography and AI to detect virus

In [4], researchers at UCLA are using biosensing method based on holography and Artificial Intelligence based on deep learning methods to detect the presence of viruses. These biosensing technique relies on characterization of specific analytes, for example as bacteria, viruses, proteins. It is based on analyte forming clusters and the process of monitoring and characterization of particle clusters indicate whether the target analyte is present and in what concentration.

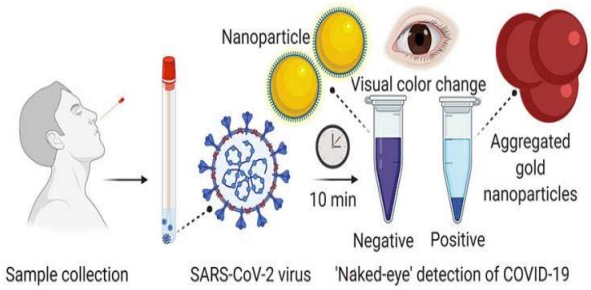
2.4 Using Ultrasound with AI to detect virus

In [5], researhers at Eindhoven University of Technology (TU/e) and from the University of Trento have developed a software with the help of lung specialists. The software uses Ultrasound with Artificial Intelligence to detect whether the lungs are afffected by COVID 19 or not. Comparison with the swab test the ultasounds based test takes only minutes

2.5 Use of Computer models based on AI and Computer Vision to detect COVID 19 from X-rays

In [6], Cranfield University students designed computer models which can identify the COVID 19 virus in X-rays. AI and computer vision are used to study the X-ray images. It is based on information classification from the X-ray images.

Fig. 3. Typical places such as airports [1]



. Fig. 4 Visual detection of virus by observation of color change.

3. Proposed Method

The array of signals from sensors are fed into the computer which runs a pattern classifier or pattern recognition algorithm based on neural networks. The objective is to train neural network with a set of input patterns to assign the correct target classes. Once the neural network is trained it can be used to classify patterns which it has not observed before. The dataset is used to create a neural network that can classify viruses in 3 classes, COVID, SARS-Cov2 as shown in fig 4, and Other based on constituents found in chemical analysis. Based on array of sensors utilized in the chemical analysis, assume a 14 x 180 matrix of 14 attributes of 180 virus samples as input the neural network. The output is a 4 x 180 matrix classified in 3 types of viruses as COVID, SARS, and Other. The Matlab was used to simulate the dataset and the Neural network [9]. The following algorithm was used on the virus dataset.

Algorithm:

[x, t] = virus_dataset;

Net = patternet(10);

Net = train(net, x, t);

View (net);

Y = net (x);

The Neural network is first trained with a dataset divided into 3 parts, one for training, for validation, and for testing. The results for a hypothetical data set are shown in the figures below. The data set was formulated based on generating vectors with close distances and not easy to differentiate viruses such as SARs and COVID. The purpose is to study the neural network's capabilities in learning to differentiate such close distances and testing its accuracy. The neural networks in predicting correctly between SARs and COVID are studied with the results presented.

Figure 5 shows an analogy between biological nose and an electronic nose. The sensors are used to pick out the virus characteristics and then fed into preprocessing phase then placed in a database. From the database the vectors are input to a neural network where pattern recognition is performed by a trained neural network and the resultant output classified into one of the 3 classes.

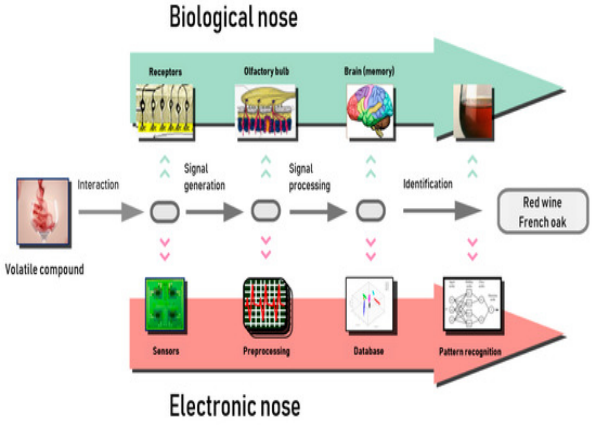


Fig. 5 Analogy between a biological nose and the electronic nose.

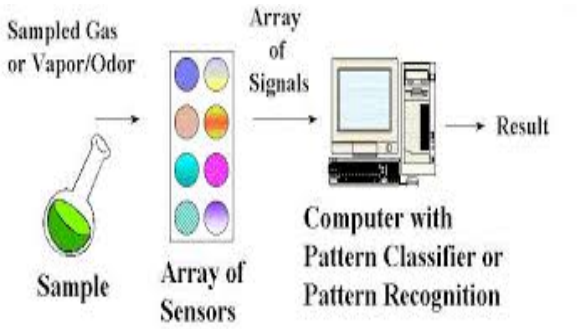


Fig. 6 Array of sensors signals being classified by the computer.

Figure 6 shows the setup of the proposed method which breathe odor is input to an array of sensors using chemicals which in turn produce an array of signals having certain patterns and the computer program is then utilized to classify the patterns into classes.

Figure 7 shows the performance of training, validation, and testing phases of the neural network. Note, the validation occurring at epoch 8 after which the performance starts to degrade.

Figure 8 shows the gradient and validation checks versus the epochs. The gradient has a value of 0.00082 at epoch 15 and validation checks at 6 at epoch 15. Figure 9 shows the error histogram for each of the phases, ie., training, validation, and testing.

The confusion matrix shows the results for predicted and actual values. It is seen the results of training confusion

matrix showing accuracy of 100, this indicates the overfitting.

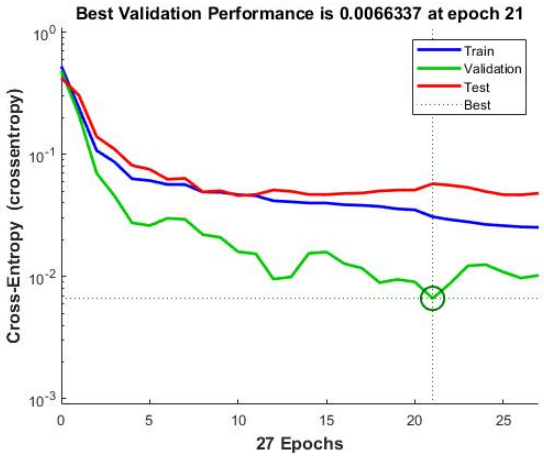


Fig. 7 Best validation performance at epoch 21.

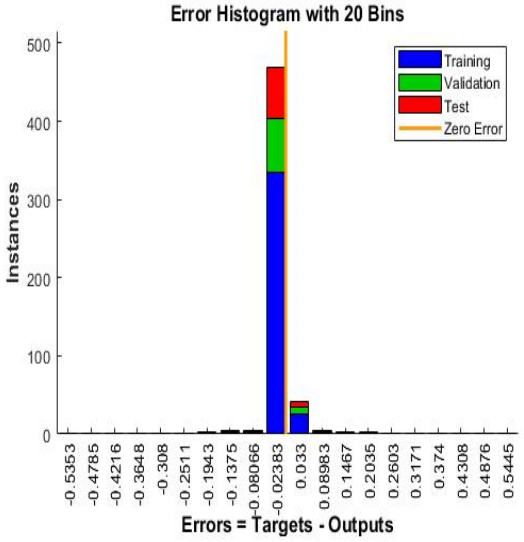


Fig. 9 The errors between targets and outputs.

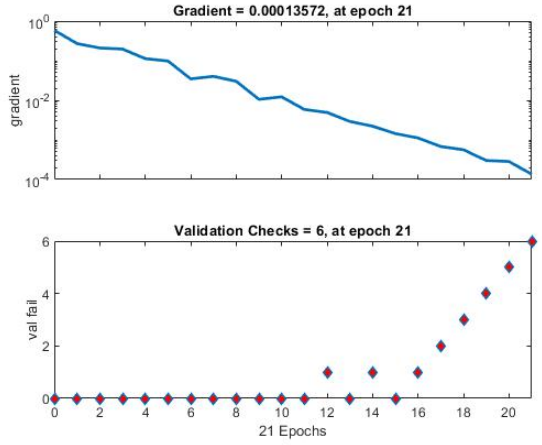


Fig. 8 The gradient and validation checks at epoch 21.

Fig. 10 The training, validation and test confusion matrices.

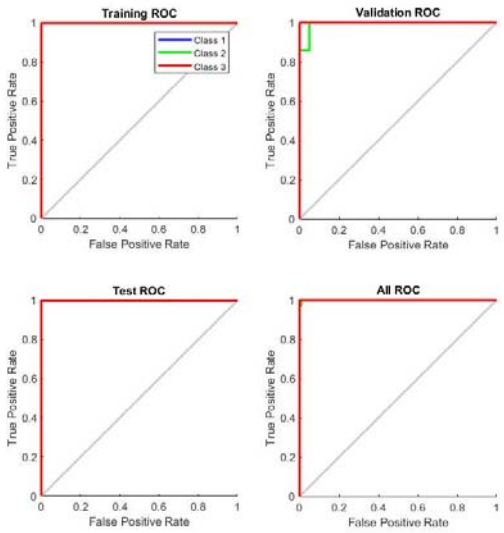


Fig. 11 The ROC graphs.

4. Results and Discussions

The results indicate there is a lack of sensors in the market which can efficiently and accurately detect the COVID 19 virus. It is seen from the literature survey that many researchers are working on detecting the virus using variety of techniques. All the methods being proposed in literature aim for rapid and accurate testing. Most of them are aiming in obtaining results in minutes rather than the 24 hours normally taken by the swab testing method. Simulations indicate the neural networks may be utilized to predict the viruses into classes provided the sensor technologies are manufactured with the capabilities of reliable and accurate detection.

The results indicate there are quite a number of challenges and open problems that remain to be solved. Some of the these are the following:

Challenges and Open problems:

1) Bio-Sensors: using nanotechnology, need to be thoroughly developed and tested.
2) Chemical-Sensors: using nanotechnology, need to be thoroughly developed and tested.
3) Use of Artificial Intelligence: matured technology, need to integrate or interfaced with bio-sensors or chemical-sensors.
4) Accuracy of testing methods: accuracy of each method should be close to 99.5 to 99.9 range
5) Computer Vision: mature technology need to incorporate with chemical sensors, as visual detection is usually employed. In analysis of x-rays, computer vision algorithms need to be enhanced.
6) Security of Flying drones and the of people: flying drones need to be flown autonomously and therefore need to be secure, so no tampering or malicious intentions are done to them while in flying motion.
7) Safety of Flying drones and safety of the people: flying drones should not in any way hurt the people, in motion or when in collection mode.
8) Reliability of drone communication, of tests, of sensors, of hardware: the communication of flying drones should be secure using encryption algorithms, the tests should give reliable results, the sensors should be reliable to produce reliable results from machine learning for example.
9) Duration of test, some can take 2 minutes, 10 minutes, 24 hours, etc. on spot tests, in lab tests: the results of the test should be achieved in minimum time possible.
10) Pinpointing location of place of contamination: once the sample of air is detected to contain the virus, the location of the sample should be able to be traced precisely.
11) Disposal of contaminated items, self-cleaning of drone if contaminated: after each collection of air sample and/or detection of the virus, the drone should be able to self-clean (dis-infect) itself either through passing through disinfectant center.

The quantity of air sampling is unknown and needs to be practically calculated for the feasibility of the method. The path motion of the flying drone and exact locations to sample or draw in the air need further study.

5. Conclusion and Future Direction

It is seen COVID 19 is a very contagious virus and drones can be used to detect areas of contagion. It is proposed to use electronic nose mounted on drones to take samples of air in crowded areas such as concert halls, stadiums, airports, shopping malls, etc. The usage of a drone equipped with electronic nose helps in several ways, avoids virus exposure to the person who would normally be checking public and taking samples, helps safely transport the contaminated samples to testing centers for further analysis. The proposed method using artificial intelligence and sensors which can reliably sift out the signatures of the viruses are yet to be manufactured. The neural networks are trained on COVID 19, SARS, viruses and able to detect and recognize which type of virus is present if any. Further work is required in the area of more efficient sampling of the virus using sophisticated array of chemical sensors to be able pick up the fingerprints of the type of viruses.

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