An intelligent algorithm for forecasting and finding the relationship between COVID-19 outbreak and pollutants condensation

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Research

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An intelligent algorithm for forecasting and finding the relationship between COVID-19 outbreak and pollutants condensation

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Abstract

Background and Objective: Nowadays, the endemic and survival of Coronavirus disease 2019 (COVID-19) are challenging for humanity healthy, which led to death and hard or soft physical diseases and economic damages in the entire world. Durability and life span of COVID-19 are the negative feature and the problematic for transferring the virus via different ways such as environmental factors. Increasing the condensation of particulate matters ($PM_{2.5}$, the atmospheric aerosol) is also challenging for the metropolitans in autumn and winter as the critical seasons of the year.

Methods: In this paper, we propose a method for analyzing the relationship between the pollutants ($PM_{2.5}$ as an aerosol and Carbon monoxide as the pollutant gas) and the number of COVID-19 infected people (CIP) to determine the COVID-19 outbreak in the pollutant seasons. We analyzed the relationship between COVID-19 outbreak and aerosol, and COVID-19 outbreak and pollutant gas using monitoring air quality monitoring stations (AQMSs) and investigating daily statistics about the number of COVID-19 infected people. We also propose an algorithm based on neural networks that forecasts the normal or critical situation of the COVID-19 outbreak based on the previously estimated the correlation coefficient (CC) and the online reported aerosol condensation from AQMSs.

Results: Our work consists of estimating the CC based on the Kendall rank method in Tehran and Isfahan, two major cities of Iran, from February 20 to March 19, 2020. Experimental results show the correlation coefficient approximately 0.5 for aerosol and the number of CIP, and 0.21 for pollutant gas and the number of CIP in Tehran. Our analysis shows a direct relationship between increasing the condensation of $PM_{2.5}$ and the number of CIP. In addition, there is no relationship between the number of CIP and Carbon monoxide. We also forecast the situation of Isfahan according to the number of CIP using our proposed algorithm that the results demonstrate the critical situation.

Conclusion: Aerosols increase the probability of getting infected COVID-19 due to respiratory disease and the probability of transferring the virus via particulate matters. Our work can be useful to alert people about the critical situation of the city that the results can provide a prevention approach to face COVID-19.

Keywords: COVID-19; Particulate matters; Correlation coefficient; COVID-19 infected people; Neural network, Intelligent algorithm; Prevention approach;

1- Introduction

COVID-19 outbreak remains a challenge for the health of the population and the natural environment, which affects the quality of people's normal life in the entire world. The virus almost penetrates the breathing system and can lead to respiratory distress syndrome that the stage of diseases can be deadly for people with weakling lungs. Experimental results and observations demonstrated the negative impact of COVID-19 on the physical and mental health of uninfected people, such as stresses caused by managing remote working, economic damages, and increasing tedious works at home [1]. Some approaches have been proposed against the negative impact of quarantine and teleworking, whereas sunshine, fresh air, and daily physical activity have a significant effect on strengthening the body's immune system [1]. Various studies illustrated different social behaviors in different age groups and conditions (such as travel) faced by quarantine and social distance (minimum distance between two persons is 1.83 m) [2-3]. So far, social distance and self-care have been proposed to reduce the probability of getting infected the disease, and also medical sciences have not yet presented a definitive treatment and an antibody for facing the virus. However, type 1 interferons, chloroquine, and plasma have been provided as the therapies, But, these methods are not yet definitive [2], [4-5].

Nevertheless, economic damages create a limited time for quarantine due to poverty, unemployment, and hunger problems in the involved cities in the disease by deciding the governments. Social distance and self-care are temporality approaches against COVID-19. At the same time, the quarantine can only be employed as a method in order to control the virus outbreak in a short time considering the economic damages it.

The pollutants are challenging for deteriorating air quality and the health of humanity due to penetrating $PM_{2.5}$ and PM_{10} to the respiratory system that leads to weak lungs of people in the metropolitans. The case studies and observations demonstrated increasing $PM_{2.5}$ condensation considering temperature inversion phenomena in the critical seasons (autumn and winter) of the year [6]. Galindo et al. also estimated the condensation of PM_{10} as a dangerous pollutant in deteriorating air quality due to penetrating to the upper respiratory tract, which leads to infection of nose, sinuses, pharynx, or larynx. The case study illustrated increasing PM_{10} in the daytime in winter [7]. Different approaches have been proposed to improve air quality, such as controlling traffic, vehicle fuel optimization, and technical inspection, whereas the results still illustrated the increasing the condensation of particulate matters [8]. Epidemic and life span of COVID-19 are the negative feature and problematic for controlling the virus outbreak in the critical seasons of the year.

In this paper, we proposed a method for analyzing the relationship between the pollutants and the number of COVID-19 infected people. We also estimated the correlation coefficient based on the Kendall rank method between aerosol, pollutant gas, and the number of CIP from February 20 to March 19 in 2020. Our work consists of collecting air pollutant data from AQMSs, investigating the number of CIP, and computing CC between them. We also propose an intelligent two-phase algorithm for analyzing reported information from AQMSs and the number of CIP and estimating CC. Our algorithm utilizes a neural network for determining the condition (normal and critical) of different metropolitans about the probability of getting infected COVID-19 using the collected dataset and correlation coefficient. We can forecast the critical or normal situation of days ahead based on the previous estimated CC and the online reported aerosol condensation

with utilizing the proposed algorithm. Therefore, our work can alert people about the probability of getting the disease for self-caring with reporting information about the situation of the city.
The remainder of this paper is organized as follows. The second section reviews previous studies on different proposed approaches for facing COVID-19 and the negative impact of quarantine and social distance. The third section presents an overview and problem definition of this work. The fourth section discusses our method and algorithm for estimating the correlation coefficient and determining the condition of the metropolitans. Section fifth focuses on the neural network phase of the two-phase algorithm. The experimental results are provided in the sixth section, and the seventh section concludes the paper.

2- Related works

In this section, we review the related methods and case studies for facing COVID-19 and the effects of quarantine and social distance. This section also takes a quick look at the impact of particulate matters on deteriorating air quality due to the primary purpose of our work.
The spread of COVID-19 is a big problem in all of the world, considering the negative impact of the virus outbreak on humanity's healthy and economic damages. Therefore, different approaches have been proposed for facing COVID-19 include therapies, antibody, social distance, and self-caring methods. Automated detection of lung infections from computed tomography has a significant effect on traditional healthcare in facing COVID-19, whereas diagnosing the lung infection caused by the virus from other factors is essential and challenging. Fan et al. proposed a method for accurate detecting of infected tissues from normal tissues and other respiratory diseases (such as acute bronchitis) [9]. This work is a disease detection method, which helps medical staff in rapid reacting against COVID-19. Emerging critical laboratory tests affected on diagnosing infected the virus as an example c-reactive protein and plasma transfusion were reduced after following recovery and 7-days post-convalescent, which estimating c-reactive protein can determine people’s healthy situation [10]. Some therapies have been proposed to treat physical damages induced by getting infected with the disease besides provided detection methods. Sallard et al. [5] analyzed the impact of type 1 of interferons in antiviral activity in order to provide a treatment method for COVID-19. Also, Touret et al. [4] proposed chloroquine to cure the disease due to its significant effect as an antimalarial drug. Nevertheless, medical science has not proposed a definitive treatment and an antibody for facing the disease.
So far, social distance, quarantine, and self-care have been proposed as the approaches against the virus, whereas the case studies demonstrated the negative impact of these methods based on social habits and age suffering in people’s mental injury. Graves et al. [1] evaluated the negative impact of remote working, such as stress, well-being, and performance caused by being boring and increasing workload in virtually. The article proposed a proactive method for managers in order to leverage the benefits of remote working [1] fully. Quarantine, social distance, and restricted travels harmed subjective well-being and health status in which physical activities and single and safe sports (walking and cycling) can reduce the negative effects on mental health [3]. Some case studies demonstrated depressive symptoms, burdensomeness, and belongingness in adolescents caused by social isolation [2]. Nevertheless, the experimental results and observation illustrated that social isolation and quarantine had an impressive effect on controlling the

COVID-19 outbreak in dangerous locations of the city or country due to the impact of sudden, large-scale, and diffuse human migration on epidemic the virus [11].

In addition, increasing particulate matters remains a challenge for humanity healthy, which can lead to people's respiratory diseases in the critical seasons (autumn and winter) of the year in the metropolitans [6]. Different methods have been proposed to improve air quality, such as controlling traffic, vehicle fuel optimization, and vehicle technical inspection, whereas the condensation of PMs is still a problem in the critical seasons of the year due to temperature inversion phenomena [8].

However, our work can help people using alerting about the situation (normal or critical) of the city, in which the proposed method can reduce the probability of COVID-19 outbreak by reducing the condensation of $PM_{2.5}$ in the previously presented approach [12].

3- The Proposed method

We present an overview of the proposed method and providing a prevention approach in order to determine the situation of the city, which can be critical or normal for getting infected COVID-19, considering the condensation of aerosol. In this section, we describe the steps of our work. We also explain a problem definition of the last proposed prevention methods and the reasons for our idea for estimating the correlation coefficient and analyzing the relationship between aerosol, pollutant gas, and the number of CIP in the critical seasons of the year.

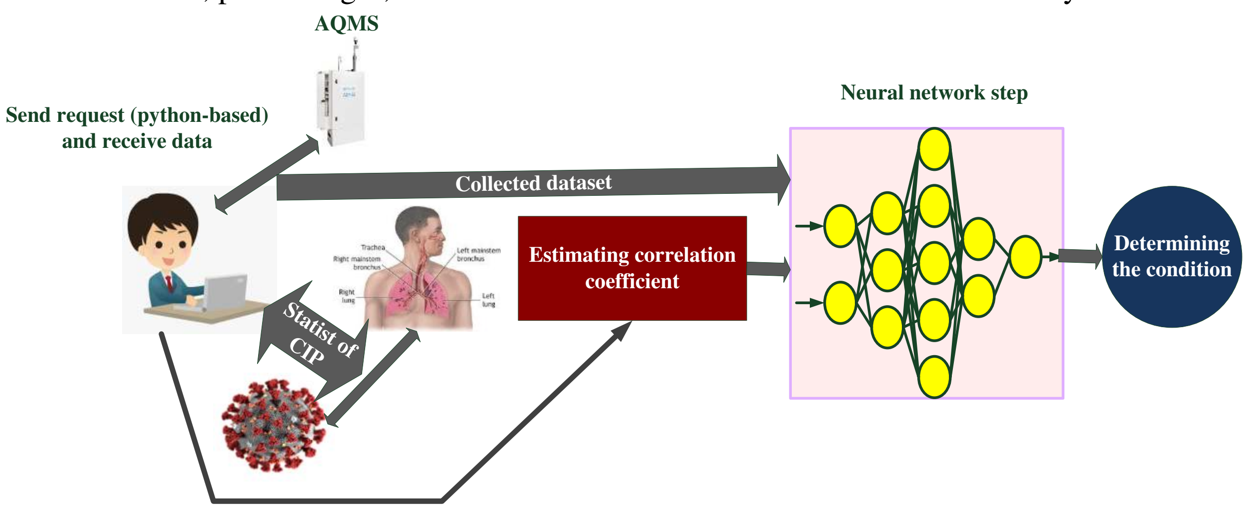


Fig.1 Steps of our work

Figure 1 shows the steps of outwork for estimating CC and determining the condition (critical or normal) of the city, considering the value of the correlation coefficient and the condensation of particulate matters. The steps of our work consist of monitoring air quality (the condensation of $PM_{2.5}$ and pollutant gas) from AQMSs, investigating the number of CIP, computing CC, and making decisions about the condition of the city considering aerosol and the estimated correlation coefficient.

The pollutant impact on the probability of getting infected COVID-19 and the relationship between aerosol, pollutant gas, and the number of CIP are invisible in last case studies and observations, whereas increasing $PM_{2.5}$ condensation remains a challenge for humanity healthy due to penetrating PMs to the upper and lower respiratory tract. Therefore, we focus on analyzing this relationship because of the negative impact of particulate matters on the weakening of the respiratory system.

Problem definition

The case studies examined and determined various effective parameters in the spread of COVID-19 that demographic, cultural, ethnic, and individual habits had a significant effect in reducing or increasing the probability of getting the disease and its epidemic. Different control and management approaches have been proposed to guide and inform people in order to reduce the negative impact of these habits and regarding the rules of social distancing and self-caring against the virus outbreak. Some provided approaches consist of presenting intelligent applications on cell phones, responsible forces' alerting, social networks, and national media. Nevertheless, the specific characteristics of the virus and lack of providing definitive treatment or antibody lead to its sustainability in all of the world in now and ahead years that have to consider all negative condition and parameters in order to confront the disease epidemic and preventive management for critical seasons (Autumn and Winter).

According to introduce the negative impact of $PM_{2.5}$ in deteriorating air quality and weakening of the respiratory tract in the metropolitans in the critical seasons of the year, we focus on finding a relationship between the number of CIP, pollutant gas and aerosol in order to help the government for the crisis management caused by the disease epidemic in the critical seasons in metropolitans. Our observations consist of monitoring the situation of two metropolitans (Tehran and Isfahan) in critical seasons (February 20-March 19) in Iran according to start the first peak of the virus outbreak in these seasons of the year and the exponential growth in the number of the patients with COVID-19 in the Tehran and Isfahan (two metropolitans). Our purposes of investigating the issue include:

- The disease's sustainability in the environment and threat to people's health in all of the world in ahead years
- Lack of providing a definitive treatment or antibody
- Dependency between confronting the disease epidemic and some habits
- The negative impact of aerosol ($PM_{2.5}$) on humanity healthy due to its penetration into the respiratory tract and weakening people's lower respiratory system in the critical seasons of the year in metropolitans
- The probability of virus particles transmission by aerosol
- Increasing the condensation of $PM_{2.5}$ in Autumn and Winter in the metropolitans due to temperature inversion phenomenon and heating systems
- Increasing the probability of getting the disease for people with background diseases such as respiratory system syndromes
- Reporting the situation of Tehran and Isfahan as two metropolitans in Iran in the first peak of the virus outbreak according to their the exponential growth in the number of patients with COVID-19

- Achieving the relationship between the probability of getting the disease and the condensation of aerosol and pollutant gas can help to crisis management in the following years

4- The correlation coefficient and the proposed intelligent algorithm

This section describes our method for estimating the correlation coefficient based on the Kendall rank method and also explains our proposed two-phase algorithm for determining the condition about the probability of getting infected with the virus (critical or normal) of the city.

Correlation coefficient

We first collect a dataset including the reported information from AQMS (ground-level ozone, $PM_{2.5}$, PM_{10}, SO_2, NO_2, and CO) and the number of CIP and modify the values of the dataset. We employ the Kendall rank method for estimating the correlation coefficient between aerosol, pollutant gas, and the number of CIP considering the non-normal distribution of the COVID-19 outbreak curve. Equation (1) describes the Kendall rank method, which $\daleth$ and n are CC, and the number of samples, respectively [13].

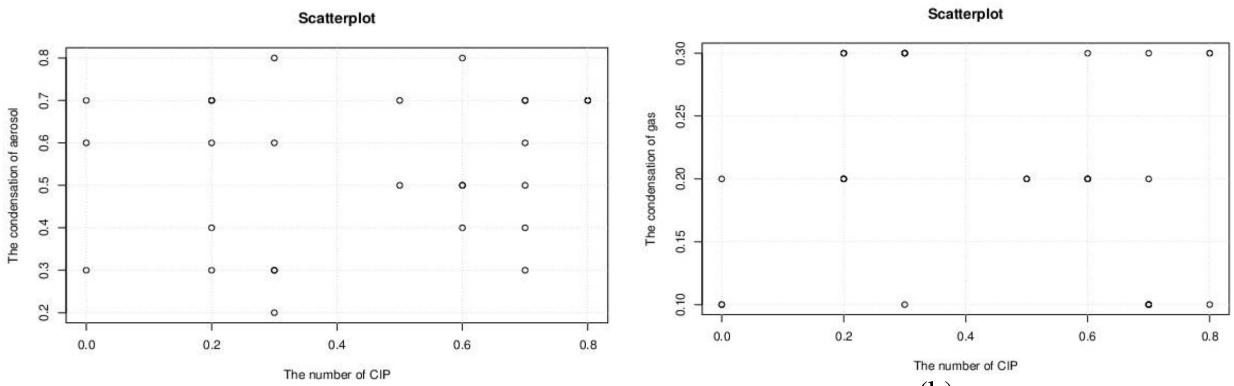
$$\daleth = \frac{(number\ of\ concordant\ pairs) - (number\ of\ discordant\ pairs)}{\binom{n}{2}} \qquad (1)$$

Table 1 demonstrates the definitions of the Kendall rank CC method, which is described in Equation (1).

Table 1: The definitions of Equation (1)

Variable	Definition	Decision
x	The value of the number of CIP sample	-
y	The value of aerosol or gas sample	-
i	Index for determining sample number which i<j	-
j	Index for determining sample number which j>i	-
(x_i, y_i)	Ordered pair with i index	-
(x_j, y_j)	Ordered pair with j index	-
$(x_i, y_i), (x_j, y_j)$	If both $x_i < x_j$ and $y_i < y_j$ or $x_i > x_j$ and $y_i > y_j$	Concordant pair
$(x_i, y_i), (x_j, y_j)$	If both $x_i < x_j$ and $y_i > y_j$ or $x_i < x_j$ and $y_i > y_j$	Discordant pair
$(x_i, y_i), (x_j, y_j)$	If both $x_i = x_j$ or $y_i = y_j$	Neither concordant nor discordant

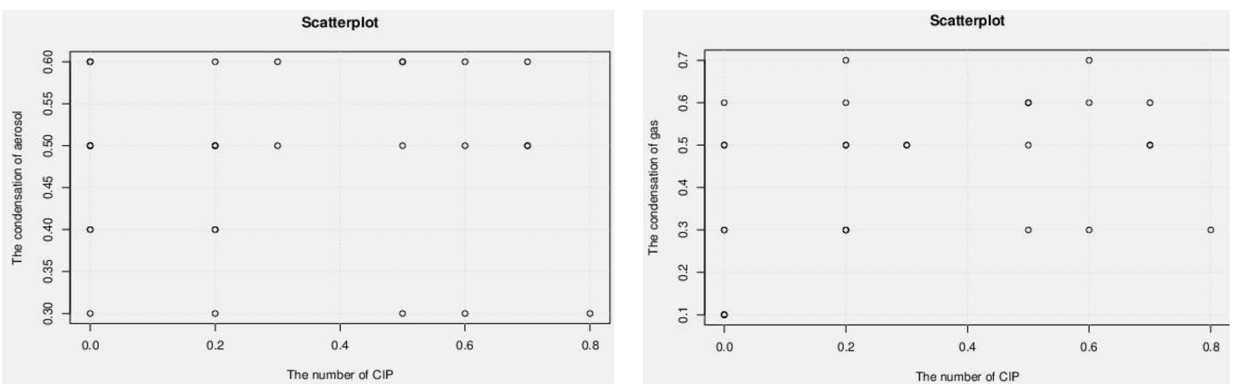
Figures 2 (a)-(b) show the scatterplots of the estimated CC based on the Kendall rank method between the number of CIP, aerosol, and the number of CIP pollutant gas, respectively.



(a) (b)

Fig.2 The scatterplots of estimated correlation coefficient based on the Kendall rank method in Tehran (a) scatterplot of estimated CC between the number of CIP and aerosol (b) scatterplot of estimated CC between the number of CIP and pollutant gas

We also evaluate dependency between the virus outbreak, aerosol, and pollutant gas with computing correlation coefficient based on the Kendall rank method in February 20 to March 15 in order to employ the estimated CC for forecasting days ahead in Isfahan. Our observations demonstrate a direct relationship between increasing the condensation of aerosol ($PM_{2.5}$) and the number of CIP whereas pollutant gas and the number of CIP are independent in Isfahan. Figures 3 (a)-(b) show dependency between aerosol and the number of CIP, and independency between pollutant gas and the virus outbreak using the scatterplots in Isfahan, respectively.



(a) (b)

Fig.3 The scatterplots of estimated correlation coefficient based on the Kendall rank method in Isfahan (a) scatterplot of estimated CC between the number of CIP and aerosol (b) scatterplot of estimated CC between the number of CIP and pollutant gas

The correlation coefficient illustrates a direct relationship between increasing the number of CIP and aerosol condensation, whereas its value demonstrates independence between the number of CIP and pollutant gas.

The proposed intelligent algorithm and its functionality

We proposed an intelligent two-phase algorithm for analyzing observations and determining a condition for a metropolitan.

In phase 1, our evaluation illustrates the spread of COVID-19 by increasing the condensation of $PM_{2.5}$ in the critical seasons of the year in the metropolitans, as shown in Figure 4. The proposed algorithm decides the relationship between the number of CIP, aerosol, and pollutant gas using estimating CC. We should determine a situation of the city based on computed correlation coefficient and aerosol condensation in order to help people facing the virus and also should not limit specific metropolitan such as Tehran or Isfahan in Iran.

Algorithm 1 Forecasting and Finding the relationship between COVID-19 outbreak and Pollutants condensation Mapping (AFCP)

procedure AFCP

//**Start phase 1** // *monitoring the condensation of aerosol and pollutant gas, and the number of CIP, and estimating correlation coefficient (CC)*

Selecting the metropolitans with the maximum number of patients with COVID-19 in the first peak

Monitoring the daily number of CIP for the selected city using the reported statistics of new cases

Monitoring the condensation of aerosol and pollutant gas from fourteen days ago to one day before the virus outbreak in the selected cities

Computing CC between the number of CIP and aerosol for fourteen days ago to one day before the virus Outbreak (CC_A)

Computing CC between the number of CIP and pollutant gas for fourteen days ago to one day before the virus outbreak (CC_G)

Finding the maximum value of the estimated CC_G and CC_A in fourteen days (CC_{GMax} CC_{AMax})

Determining threshold's value for CC (CC_{Thr})

if ($CC_{GMAX} \geq CC_{Thr}$) *//evaluating the relationship between pollutant gas and the number of CIP*

$CC_G=CC_{GMax}$; *//demonstrate a direct relationship between pollutant gas and the number of CIP*

End if;

if ($CC_{AMAX} \geq CC_{Thr}$) *//evaluating the relationship between aerosol and the number of CIP*

$CC_A=CC_{AMax}$; *//demonstrate a direct relationship between aerosol and the number of CIP*

End if;

if ($CC_G \geq CC_A$) // *determining maximum correlation coefficient*

$CC=CC_G$; *//maximum dependency between pollutant gas and the number of CIP*

else

$CC=CC_A$; *//maximum dependency between aerosol and the number of CIP*

End if;

Return

// **end phase 1;**

Fig.4 Phase 1 of AFCP for finding the relationship between the number of CIP and pollutant gas, and aerosol

Our work also proposes a prevention method to forecast the situation of the city using providing an intelligent two-phase algorithm due to the need to inform people about the probability of

COVID-19 outbreak based on the previous estimated CC in Autumn and Winter in the metropolitan. In phase 2, we employ a neural network method for determining the situation about the probability of getting infected with the disease for various metropolitans that its stages are demonstrated in Figure 5. We introduce a value as CC threshold (CC_{Thr}), which its value determines dependency or independency between the number of CIP and aerosol. We forecast the situation of the city using a neural network when
$CC \geq CC_{Thr}$ is met. We consider CC_{Thr}=0.5 based on evaluating estimated correlation coefficients for the metropolitans when the number of patients with COVID-19 increases, exponentially. The threshold's value is determined according to monitoring the condensation of aerosol and pollutant gas, and the number of CIP on consecutive days of the first peak of the virus outbreak in the critical seasons (February and March).

```
// Start phase 2 // Employing neural network for forecasting COVID-19 outbreak
    Designing a neural network include one input layer, three hidden layers, and one output layer
    Training neural network two inputs, including reported daily aerosol condensation (X) and estimated
    CCs in phase 1 (Z), to achieve estimated CC (Y)
    if (Y ≥ CC_Thr) // Investigating the situation of the city
        The situation of the city is critical // as an example for one day ahead in Isfahan
            else
        The situation of the city is normal // as an example for one day ahead in Isfahan
    End if;
    Return
// end phase 2
end procedure
```

Fig.5 Phase 2 of AFCP for forecasting the normal or critical situation of the city using a neural network

5- Details of neural network phase

In phase 2, we employ a neural network method in order to decide the critical or normal situation of the city for informing people. At first, we train the neural network based on the gradient distance method after the inference phase, in which the situation is determined after training.

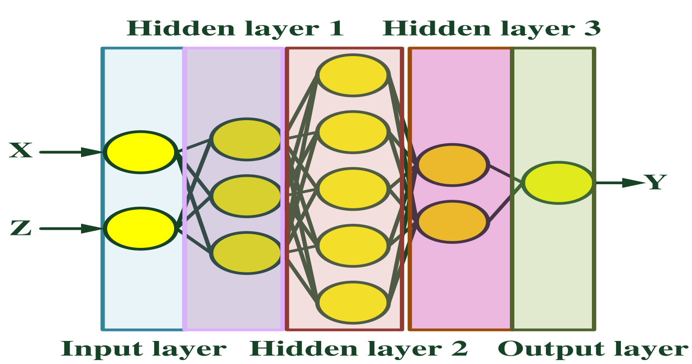


Fig.6 A schematic of a fully-connected neural network for determining the critical or normal situation

Figure 6 shows a fully-connected neural network includes one input layer (with two neurons), three hidden layers with ten neurons, and one output layer with one neuron. We have not always access to the number of CIP for estimating CC and have to use the last computed CC ($CC \geq CC_{Thr}$) as one of two inputs (Z). We can online monitor air quality (the condensation of $PM_{2.5}$) from AQMSs and employ its reported information as another input (X) for determining the situation (Y) of the city. We describe the normal and critical situations based on the conditions of $Y< 0.5$ and $Y\geq 0.5$. We train the neural network with two inputs, including reported daily aerosol condensation (X) and correlation coefficients (Z), to achieve estimated CC (Y) as a value for forecasting the normal or critical situation of the city. While we do not have access to statistical data of the number of CIP and we have to alert people about the situation of the city for self-caring. The output of the neural network is a predicted CC that determines the normal ($Y<0.5$) or critical ($Y\geq 0.5$) situation of the city.

6- Experimental results

We explained the proposed method to analyze the relationship between the number of CIP, aerosol, and pollutant gas which the results demonstrate respectively correlation coefficient approximately 0.44 and -0.07 for COVID-19 outbreak and aerosol, pollutant gas and spread of the virus on February 20 to March 19 in Tehran. In this section, we discuss our experimental results and observations considering the different presented charts. Our results consist of analyzing the relationship between pollutant gas, aerosol, and the number of CIP, estimating CC and forecasting the normal or critical situation in Tehran and Isfahan as two metropolitans in Iran.

We first collected a dataset include reported information (ground-level ozone, PM2.5, PM10, SO2, NO2, and CO) for one critical month from February 20 to March 19 in Tehran from AQMSs that monitored air quality using a python-based program and the number of COVID-19 infected people. Then, we registered the information and shared the dataset on GitHub (https://github.com/yasamanhosseini/COVID-19-project/tree/master). The dataset of reported information from AQMSs is an average from the information of twenty-one stations of monitoring air quality in Tehran.

We also modified the values of the dataset due to variety and sparsity in the number of CIP, aerosol condensation, and pollutant gas that their values are different for determining normal and critical situations of air quality and COVID-19 outbreak. We standardized these values in order to better analyzing and deciding about the critical or normal situation.

We compute the correlation coefficient for analyzing the relationship between aerosol, gas, and the number of CIP that the estimated CCs are approximately 0.5 and 0.21 for Aerosol ($PM_{2.5}$) and COVID-19, Carbon monoxide gas (CO) and the virus, respectively. Our studies and observations consist of monitoring aerosol condensation ($PM_{2.5}$) and pollutant gas (CO) from fourteen days before the daily number of CIP and also estimate the correlation coefficient between them. Table 2 demonstrates aerosol condensation from seven days (February 13-March 18) before the daily number of the virus-infected people (February 20-March 19) in Tehran. Finally, we consider the maximum value of the estimated CCs of fourteen days ago due to the occurring acute symptoms of the disease after three to fourteen days of getting infected. The results determine three estimated CCs for three, two, and one days ago that can be considered as the acceptable correlation coefficients ($CC\geq 0.5$) in Tehran.

As shown in Figure 8, we consider estimated CC for three days ago and demonstrate the relationship between aerosol, pollutant gas, and the number of CIP which the reported CO condensation is related to three days ago. We select the computed CC for three days ago according to the probability of occurring acute symptoms of COVID-19 after three days of getting the disease.

Table 2. Aerosol condensation from seven days ago and the daily number of CIP

Date (daily)	The number of CIP (daily)	Aerosol (daily)	Aerosol (7 days ago)	Aerosol (6 days ago)	Aerosol (5 days ago)	Aerosol (4 days ago)	Aerosol (3 days ago)	Aerosol (2 days ago)	Aerosol (1 day ago)
2/20/2020	0	0.6	0.2	0.3	0.2	0.2	0.3	0.3	0.6
2/21/2020	0.2	0.3	0.3	0.2	0.2	0.3	0.3	0.6	0.6
2/22/2020	0.2	0.6	0.2	0.2	0.3	0.3	0.6	0.6	0.3
2/23/2020	0.2	0.7	0.2	0.3	0.3	0.6	0.6	0.3	0.6
2/24/2020	0.2	0.7	0.3	0.3	0.6	0.6	0.3	0.6	0.7
2/25/2020	0.2	0.7	0.3	0.6	0.6	0.3	0.6	0.7	0.7
2/26/2020	0.2	0.4	0.6	0.6	0.3	0.6	0.7	0.7	0.7
2/27/2020	0.3	0.2	0.6	0.3	0.6	0.7	0.7	0.7	0.4
2/28/2020	0.3	0.3	0.3	0.6	0.7	0.7	0.7	0.4	0.2
2/29/2020	0.3	0.8	0.6	0.7	0.7	0.7	0.4	0.2	0.3
3/1/2020	0.6	0.8	0.7	0.7	0.7	0.4	0.2	0.3	0.8
3/2/2020	0	0.7	0.7	0.7	0.4	0.2	0.3	0.8	0.8
3/3/2020	0	0.3	0.7	0.4	0.2	0.3	0.8	0.8	0.7
3/4/2020	0.7	0.3	0.4	0.2	0.3	0.8	0.8	0.7	0.3
3/5/2020	0.3	0.3	0.2	0.3	0.8	0.8	0.7	0.3	0.3
3/6/2020	0.3	0.6	0.3	0.8	0.8	0.7	0.3	0.3	0.3
3/7/2020	0.5	0.7	0.8	0.8	0.7	0.3	0.3	0.3	0.6
3/8/2020	0.7	0.5	0.8	0.7	0.3	0.3	0.3	0.6	0.7
3/9/2020	0.6	0.4	0.7	0.3	0.3	0.3	0.6	0.7	0.5
3/10/2020	0.6	0.5	0.3	0.3	0.3	0.6	0.7	0.5	0.4
3/11/2020	0.7	0.7	0.3	0.3	0.6	0.7	0.5	0.4	0.5
3/12/2020	0.8	0.7	0.3	0.6	0.7	0.5	0.4	0.5	0.7
3/13/2020	0.8	0.7	0.6	0.7	0.5	0.4	0.5	0.7	0.7
3/14/2020	0.8	0.7	0.7	0.5	0.4	0.5	0.7	0.7	0.7
3/15/2020	0.7	0.4	0.5	0.4	0.5	0.7	0.7	0.7	0.7
3/16/2020	0.6	0.5	0.4	0.5	0.7	0.7	0.7	0.7	0.4
3/17/2020	0.7	0.7	0.5	0.7	0.7	0.7	0.7	0.4	0.5
3/18/2020	0.7	0.6	0.7	0.7	0.7	0.7	0.4	0.5	0.7
3/19/2020	0.5	0.5	0.7	0.7	0.7	0.4	0.5	0.7	0.6
Estimated CC		**0.4**	**0.1**	**0.27**	**0.14**	**0.04**	**0.5**	**0.95**	**0.75**

Figure 7 shows the relationship between aerosol condensation for three, two, and one day ago, and the daily number of CIP that is illustrated maximum dependency between aerosol for two days ago and the daily number of getting the disease in Tehran.

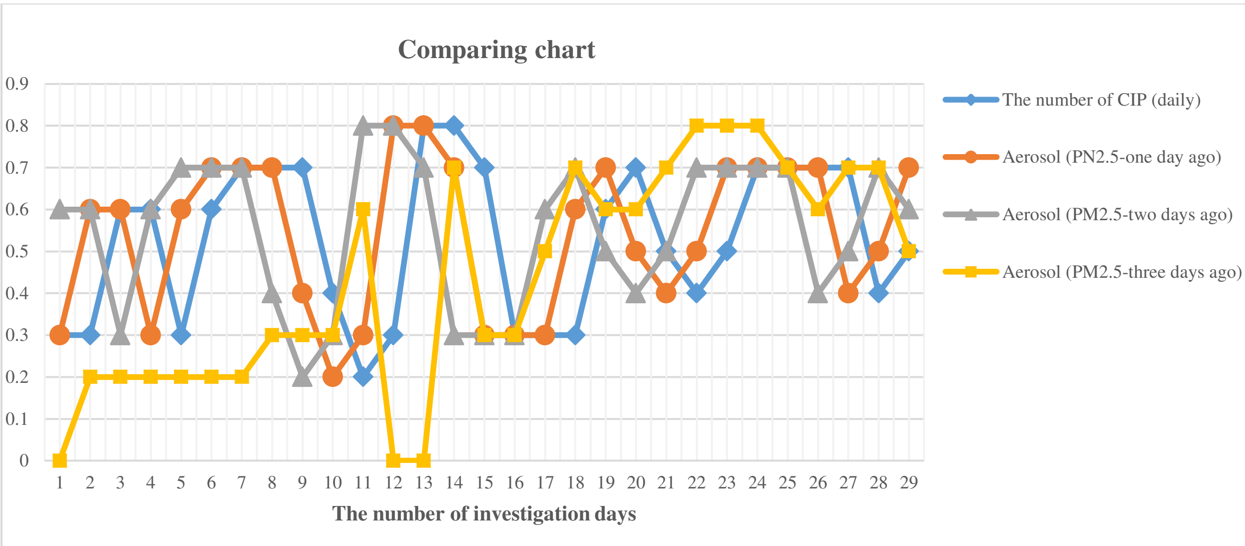


Fig.7 The relationship between the daily number of CIP, aerosol for three, two, and one day ago gas in Tehran

Our observations and estimated CC demonstrate a direct relationship between the number of CIP (February 20-March 19) and aerosol (February 17-March 16), and illustrate independence between the spread of the virus and gas (February 17-March 16), as shown in Figure 8.

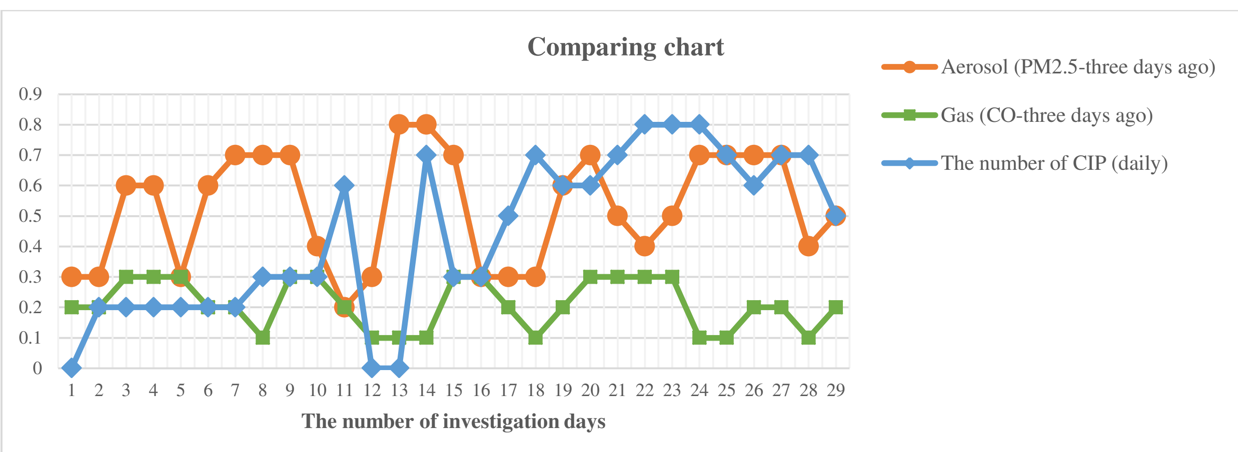


Fig.8 The relationship between the number of CIP, aerosol, and pollutant gas in Tehran

We likewise analyze the correlation coefficient of aerosol, pollutant gas, and the number of CIP in different metropolitans, which Figure 9 shows the relationship between them from February 20 to March 15 in Isfahan. Our algorithm employs the Kendall rank method for the computing correlation coefficient of the first twenty-five days (February 20 to March 15). It forecasts CCs and the situation of Isfahan for the days ahead (March 16 to March 19) based on previously estimated CC (the first twenty-five days) and online reported aerosol, and gas condensations that utilizes the neural network for predicting. As shown in Figure 9, the results demonstrate the COVID-19 outbreak with increasing the condensation of aerosol in Isfahan, whereas estimated CC also illustrates this dependence. Our analysis consists of monitoring aerosol condensation ($PM_{2.5}$) and pollutant gas (CO) from fourteen days ago to one days ago in order to determine the maximum estimated CC between aerosol, pollutant gas, and the daily number of CIP in Isfahan. Therefore, we consider the estimated CC between aerosol and CO for four days ago (February 15-March 10), and the daily number of CIP (February 20-March 15) in Isfahan. We computed the correlation coefficient based on the Kendall rank method, which CC is approximately 0.93 and 0.06 for COVID-19 outbreak and aerosol, pollutant gas, and the number of CIP in Isfahan.

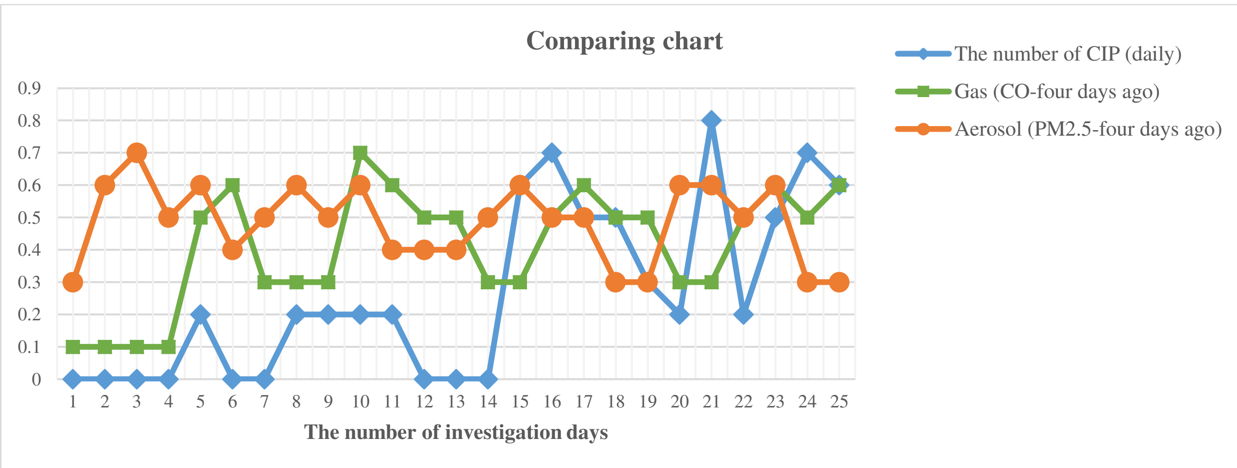


Fig.9 The relationship between the number of CIP, aerosol, and pollutant gas in Isfahan

The results demonstrate that the situation of days ahead is critical in Isfahan where predicted CC ≥ 0.5 is met as the condition for determining the situation, as shown in Figure 10. Our algorithm decides about the situation based on estimated CC between aerosol and the number of CIP because the computed CC is approximately 0.06 for pollutant gas and COVID-19 outbreak that the estimated CC is less than 0.5 and the condition of $CC \geq CC_{Thr}$ is not met from February 20 to March 15 in Isfahan.

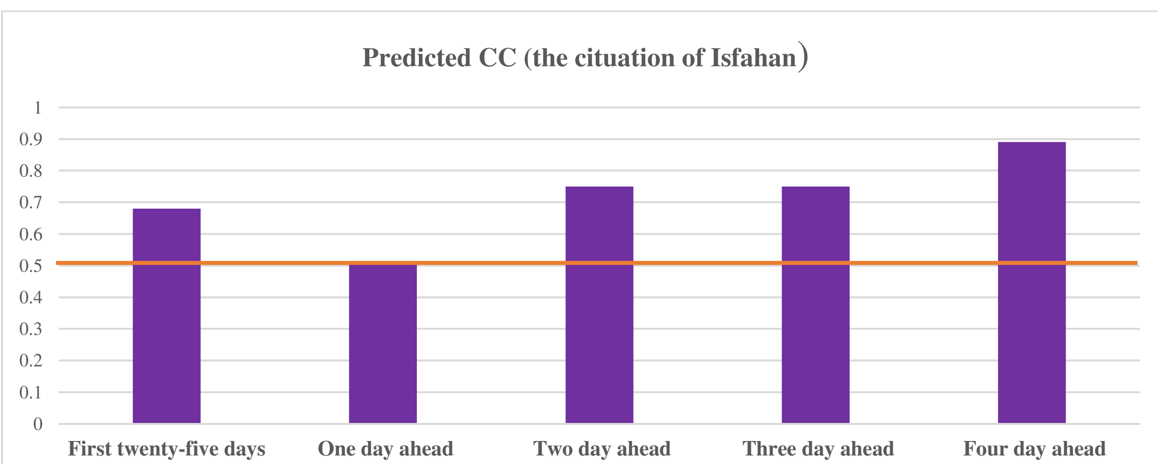


Fig.10 Forecasting CCs and the situation of Isfahan for days

The experimental results and observation demonstrate the high impact of increasing aerosol condensation on the spread of the virus and the probability of being infected with the disease, which can lead to a problem in winter the metropolitans. The virus can transfer via aerosol considering the characteristics of COVID-19 In durability on surfaces and period. Therefore, the probability of the disease outbreak in the metropolitans is more than other cities due to the increase in the condensation of particulate matters caused by vehicles and temperature inversion phenomena. We report the condensation of aerosol $PM_{2.5}$, considering its most negative impact in deteriorating air quality compared to PM_{10} in the critical seasons of the year. Our results demonstrate the relationship between CO (as the pollutant gas) and the virus outbreak due to its more negative effect in deteriorating air quality than other pollutant gases (SO2, NO2, and ground-level ozone) in autumn and winter in Tehran and Isfahan. Our work can help people against the disease by alerting the critical situation of a city considering estimated CC and the condensation of aerosol.

7- Conclusion

COVID-19 outbreak remains a challenge due to its epidemic and life span features, which can lead to survival in a long time in the entire world. COVID-19 is an infectious disease that penetrates the upper and lower respiratory tract. The virus is a severe health threat for people with background diseases such as the failure of respiratory, chronic heart, diabetes mellitus, and kidney, which increases the probability of being infected the acute disease and death in the people. Increasing daily particulate matters is challenging for humanity healthy due to their penetration in the respiratory system, which is caused by heating devices and temperature inversion phenomena in critical seasons of the year in metropolitans. Therefore, we proposed a method for analyzing dependency between the number of COVID-19 infected people, aerosol, and pollutant gas using estimating the correlation coefficient based on the Kendall rank method between them. Also, we presented an intelligent algorithm to decide the critical or normal situation of the city, considering the previous computed CC and the online reported condensation of aerosol. Our experimental results illustrated a direct relationship between increasing the condensation of aerosol and the virus outbreak in the metropolitans such as Tehran and Isfahan. We focused on investigating the situation of the city due to the negative impact of $PM_{2.5}$ on weakening people's lungs and the probability of transferring the virus via aerosol.

Declarations

- Ethical Approval and Consent to participate: Not applicable

- Consent for publication: Not applicable

- Availability of supporting data: https://github.com/yasamanhosseini/COVID-19-project/tree/master

- Competing interests: The authors declare that they have no competing interests

- Funding: No funding was received

- Authors' contributions: All authors have contributed equally. All authors read and approved the final manuscript.

- Acknowledgements: Not applicable

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Figures

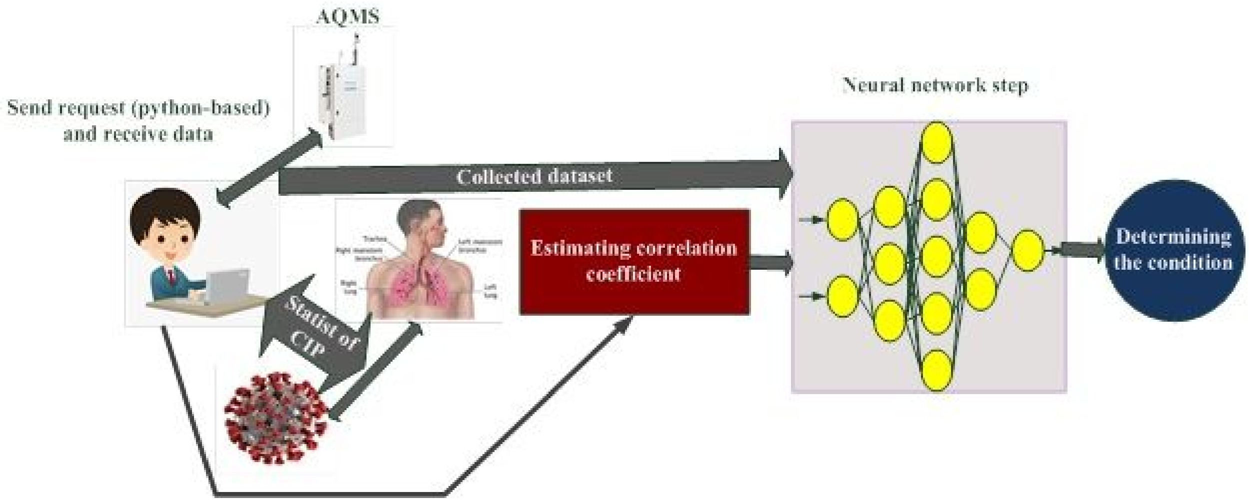

Figure 1

Steps of our work

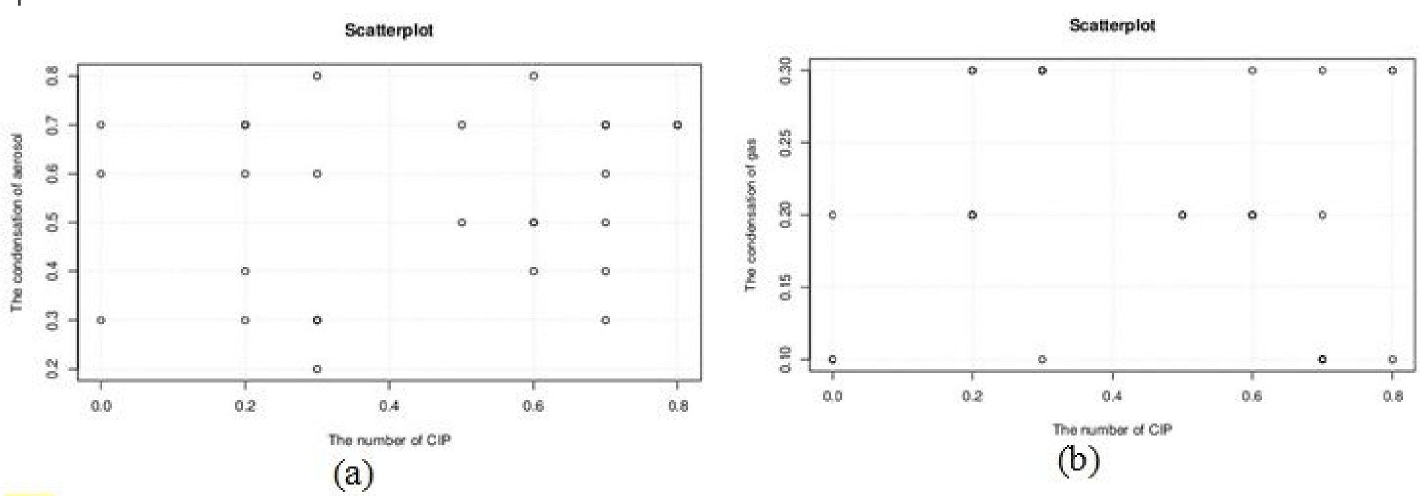

Figure 2

The scatterplots of estimated correlation coefficient based on the Kendall rank method in Tehran (a) scatterplot of estimated CC between the number of CIP and aerosol (b) scatterplot of estimated CC between the number of CIP and pollutant gas

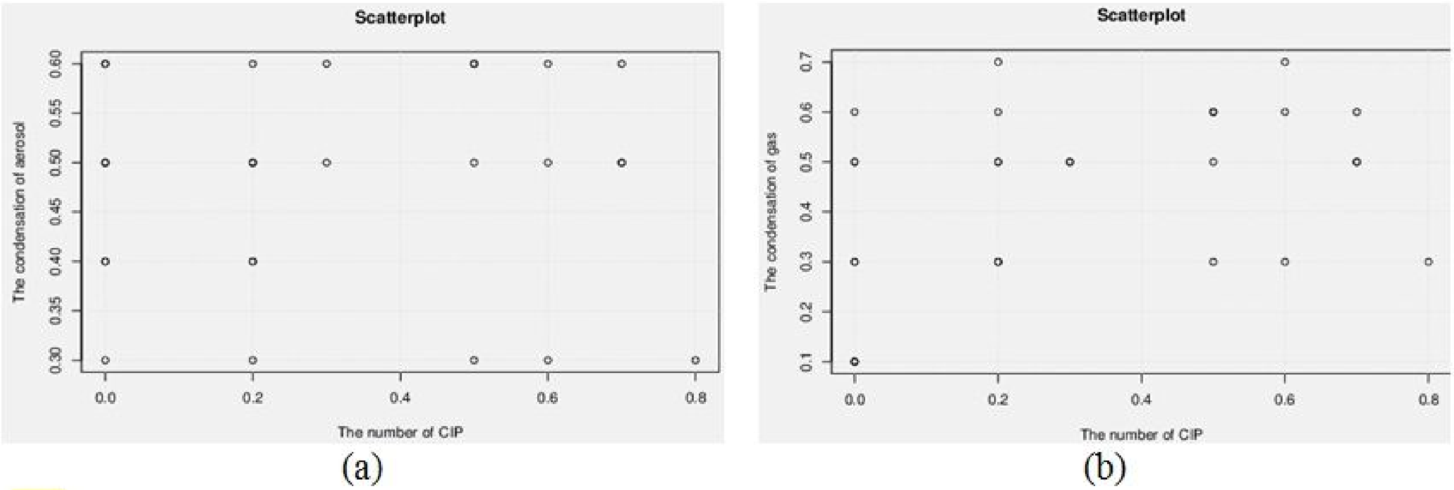

Figure 3

The scatterplots of estimated correlation coefficient based on the Kendall rank method in Isfahan (a) scatterplot of estimated CC between the number of CIP and aerosol (b) scatterplot of estimated CC between the number of CIP and pollutant gas

Algorithm 1 Forecasting and Finding the relationship between COVID-19 outbreak and Pollutants condensation Mapping (AFCP)

```
procedure AFCP
//Start phase 1 // monitoring the condensation of aerosol and pollutant gas, and the number of CIP, and estimating
        correlation coefficient (CC)
    Selecting the metropolitans with the maximum number of patients with COVID-19 in the first peak
    Monitoring the daily number of CIP for the selected city using the reported statistics of new cases
    Monitoring the condensation of aerosol and pollutant gas from fourteen days ago to one day before the virus
    outbreak in the selected cities
    Computing CC between the number of CIP and aerosol for fourteen days ago to one day before the virus
    Outbreak (CC_A)
    Computing CC between the number of CIP and pollutant gas for fourteen days ago to one day before the
    virus outbreak (CC_G)
    Finding the maximum value of the estimated CC_G and CC_A in fourteen days (CC_GMax CC_AMax)
    Determining threshold's value for CC (CC_Thr)
      if (CC_GMAX ≥ CC_Thr) //evaluating the relationship between pollutant gas and the number of CIP
        CC_G=CC_GMax;    //demonstrate a direct relationship between pollutant gas and the number of CIP
      End if;
      if (CC_AMAX ≥ CC_Thr) //evaluating the relationship between aerosol and the number of CIP
        CC_A=CC_AMax;    //demonstrate a direct relationship between aerosol and the number of CIP
      End if;
      if (CC_G ≥ CC_A) // determining maximum correlation coefficient
        CC=CC_G; //maximum dependency between pollutant gas and the number of CIP
          else
        CC=CC_A; //maximum dependency between aerosol and the number of CIP
      End if;
    Return
// end phase 1;
```

Figure 4

Phase 1 of AFCP for finding the relationship between the number of CIP and pollutant gas, and aerosol

```
// Start phase 2 // Employing neural network for forecasting COVID-19 outbreak
    Designing a neural network include one input layer, three hidden layers, and one output layer
    Training neural network two inputs, including reported daily aerosol condensation (X) and estimated
    CCs in phase 1 (Z), to achieve estimated CC (Y)
    if (Y ≥ CC_Thr) // Investigating the situation of the city
          The situation of the city is critical // as an example for one day ahead in Isfahan
                else
          The situation of the city is normal // as an example for one day ahead in Isfahan
      End if;
    Return
// end phase 2
end procedure
```

Figure 5

Phase 2 of AFCP for forecasting the normal or critical situation of the city using a neural network

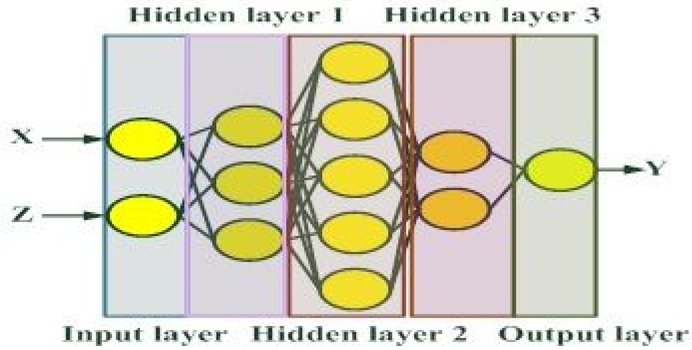

Figure 6

A schematic of a fully-connected neural network for determining the critical or normal situation

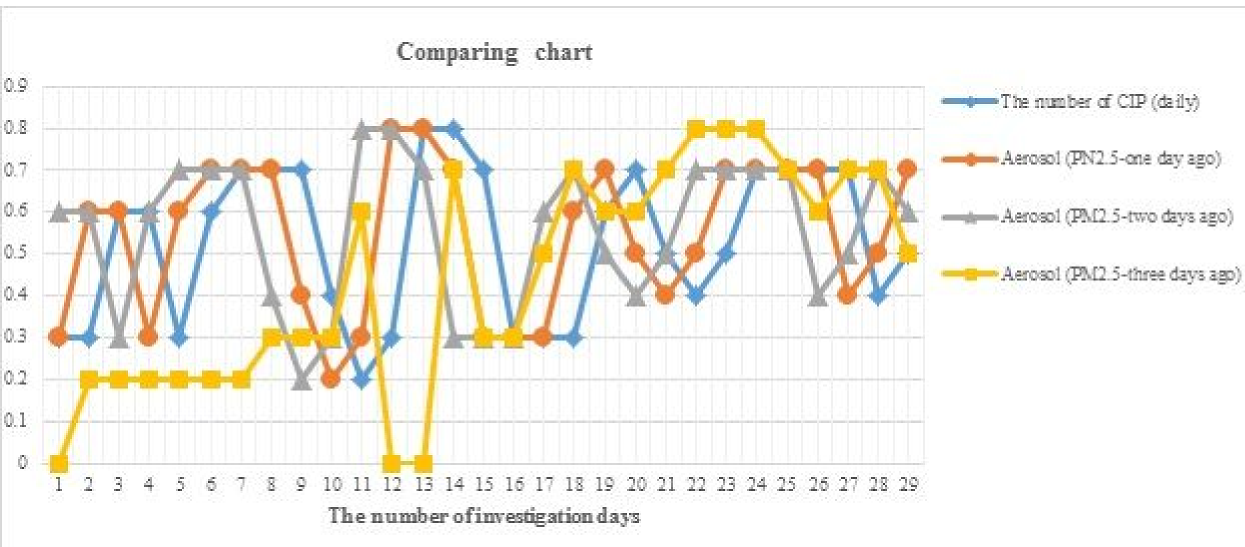

Figure 7

The relationship between the daily number of CIP, aerosol for three, two, and one day ago gas in Tehran

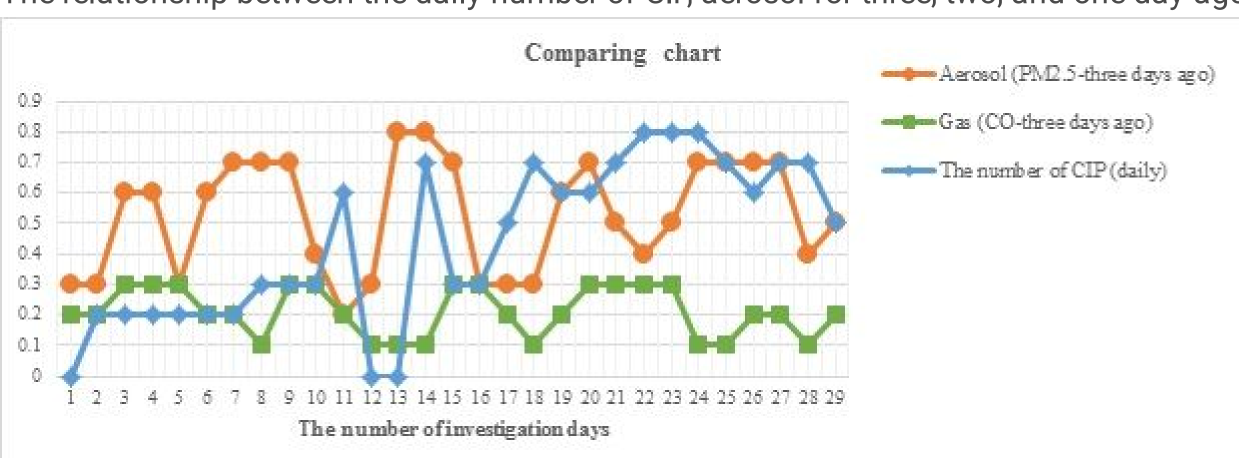

Figure 8

The relationship between the number of CIP, aerosol, and pollutant gas in Tehran

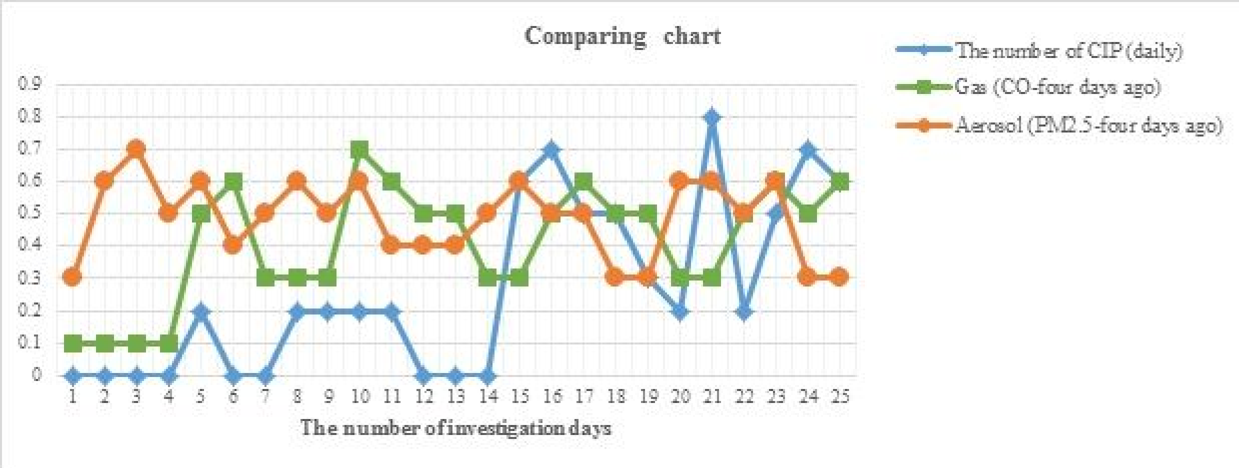

Figure 9

The relationship between the number of CIP, aerosol, and pollutant gas in Isfahan

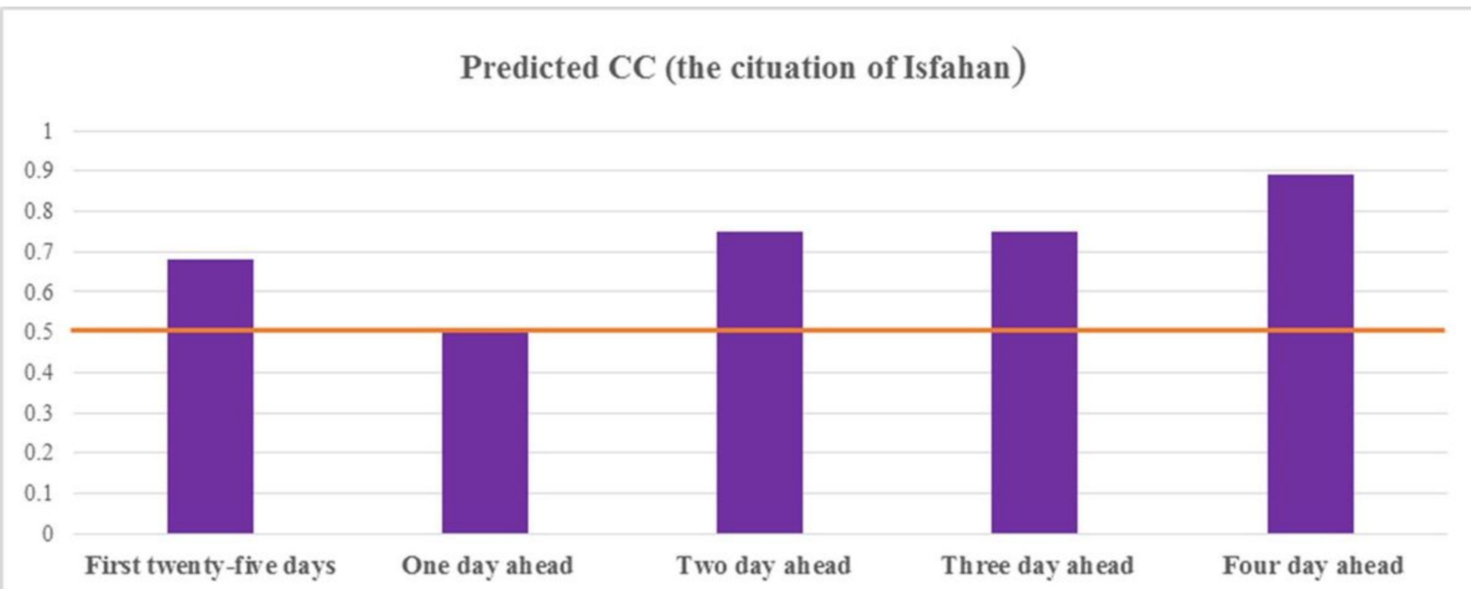

Figure 10

Forecasting CCs and the situation of Isfahan for days