Fuzzy Logic Inference System for Identification and Prevention of Coronavirus (COVID-19)

Nitesh Dhiman, M.K. Sharma

Abstract: Now a days Novel Coronavirus named COVID-19 becomes major health concern causing severe health issue in human beings and it becomes a pandemic. It’s a kind of zoonotic that means it can transmit animals to humans. It may spread via polluted hands or metals. No specific treatment is available so far for COVID-19, so initial identification and preventions for COVID-19 will be crucial to control or to break down the chain of COVID-19. For this purpose, we have proposed a fuzzy inference system to diagnose the COVID-19 disease by taking six input factor like as: Ethanol, Atmospheric Temperature (AT), Body Temperature (BT), Breath Shortness (BS), Cough and Cold and the output factor has divided into three linguistic categories which denotes the severity level of the infected patients.

Keywords: Coronavirus (COVID-19), Gaussian Membership Function, Fuzzy Inference System, Medical Diagnosis

I. INTRODUCTION
Coronavirus is the virus that may causes Middle East Respiratory Syndrome (MERS-CoV) and Severe Acute Respiratory Syndrome (SARS-CoV). After the study it has been found that the SARS-CoV was transmitted from wild cat to human. Chang et al. [1] shows in his study that the SARS-CoV is a novel virus that may causes the emerging and reemerging infection. Few of the studies [2] & [3] described that SARS-CoV novel virus caused the first pandemic of the parasite. The novel coronavirus called SARS-CoV-2, causes the disease COVID-19 and has never been encountered/found before. It is originated from Wuhan a city of china and till now it effects more than 180 countries and territories. Currently many scientists and researchers of different countries are doing hard work to find the appropriate vaccine for COVID-19 disease. It effects more than 180 countries and territories, scientists and researchers are not certain about the origination of COVID-19. COVID-19 is the kind of zoonotic, initially it was transmitted from animals to humans [4] & [5] but now it is rapidly spreading from person to person and the spread rate of the infection increasing exponentially, according to this theory each infected person may infect more than 2 people and each may further infect more than 2 and so on. A study by Harvard T.H. Chan School of Public Health epidemiologist state that disease COVID-19 could infect major part of worldwide population and according to the world health organization (WHO) COVID-19 has affected more than 697,244 people globally with 33,257 death cases till now (by 31-03-2020). In china about 81,285 confirmed cases over 74,051 patients have recovered and about 3,295 have died. COVID-19 includes symptoms like: cough, fever, breathing difficulties and it may cause pneumonia and kidney failure or patient may death, in some cases patient might show no symptoms at all. According to the study of the Centers for Disease Control and Prevention (CDC) [6] these symptoms usually appear between two days and two weeks of exposure to the virus. Journal of the American Medical Association reports say that out of all COVID-19 patients 11-44% has fatigue, 76-82% has coughed and 98% have a fever. The severity level of the disease increases in the human of age between 28 to 85 years-old. Currently more than fifteen Italian citizens cases test have been found positive in India by March 2020. Present research paper has been divided into five sections; in the second section, we have shown the effects of COVID-19 in different types of metal. In the third section of the research paper, we have given a survey on COVID-19 and in the fourth section, we have defined some fuzzy rules as shown in tab. 3 for the proposed fuzzy expert system with six inputs as shown in tab. 2 and one output which define the severity level of the infected patient as shown in fig. 5. Fifth and last section of the research paper contains conclusion part of the work.

II. BASIC CONCEPTS
A. Effects of COVID-19 on Metals
On different kind of material and surfaces like; Steel, Aluminium, Metal, Wood, Paper, Glass, Plastic Silicon and Rubber, the coronavirus may alive or it may remain infectious from 2 hours up to couple of weeks. Kampf et al [7] summarized the persistence of the coronavirus on inanimate surfaces and this study also shows inactivation of the coronaviruses by biocidal agent through suspension and carrier tests.

B. Fuzzy Logic in Medical Diagnosis
Fuzzy logic is a kind of computational archetype which gave us a mathematical tool for human reasoning for handling the various type uncertainties. The capability of fuzzy logic provides us to express the human knowledge in linguistic way. The framework of fuzzy logic used in different kind of disease diagnosis [8, 9, 10] in which the physicians and expert’s knowledge is represented on the behalf of symptoms and diseases. In which we can frame the different type membership function for the symptoms depending upon the trend of the patient data and they have used to form a suitable fuzzy expert system.
III. A SURVEY ON COVID-19

According to the Ministry of Health & Family Welfare [12] (by 30-03-2020) the spread rate of coronavirus in different states of India like: Maharashtra, Kerala, Delhi, Uttar Pradesh, Karnataka, Ladhak, Telangana, Rajasthan, Jammu and Kashmir, Andhra Pradesh, Gujrat, Punjab, Chhattisgarh, Odisha, Puducherry, Chandigarh, Uttarakhand, West Bengal has been shown by chart 1. and chart 2. shows that the spread rate of COVID-19 in different countries like; Armenia, Australia (New South Wales, Australia – Australian Capital Territory, Australia – Western Australia, Australia – Victoria, Australia – South Australia, Australia – Tasmania), Austria, Bahrain, Belarus, Belgium, Brazil, Canada – National lab, Canada, China – Guangdong, Colombia, Costa Rica, Croatia, Czech Republic, Denmark, Faeroe Islands, Estonia, Finland, France, Germany, Hong Kong, Hungary, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Japan, Kuwait, Kyrgyzstan, Latvia, Lithuania, Malaysia, Malta, Mexico, Netherlands, New Zealand, Norway, Pakistan, Palestine, Panama, Philippines, Poland, Qatar, Romania, Russia, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, Turkey, Ukraine, United Arab Emirates, United Kingdom, United States – CDC samples tested, United States and Vietnam.
Table 1: COVID-19 Checklist by IAF Med Services

|   | International History or Contact History | More than 14 days | Less than 14 days | Direct contact with confirmed cases |
|---|----------------------------------------|------------------|------------------|-------------------------------------|
| 1 | Fever                                  | No               | More than 14 days | Less than 14 days                   |
| 2 | Breathing Difficulty                    | 98-100F          | 100-102F         | 102-104F                            |
| 3 | Body Pain                               | No               | Mild             | Moderate                            |
| 4 | Fatigue                                 | No               | Mild             | Moderate                            |
| 5 | Sore Throat                             | No               | Mild             | Moderate                            |
| 6 | Cough                                   | No               | Mild             | Moderate                            |
| 7 | Diarrhoea                               | 1-2 episodes (in last 24 hours) | 3-5 episode | 5-7 episodes | more than 7 |
| 8 | Other Medical Conditions                | None             | High BP          | High BP & Diabetes                   |
| 9 | Status (last 48 hours)                  | Improved         | No change        | Worsened                            |
| 10| Age                                     | 15-50 years      | 5-15 years       | 0-5 years                            |

Weekly spread rate of COVID-19 has shown by chart 3, between three different countries Italy, Iran and India. This chart shows that spread rate of COVID-19 increases rapidly in Italy as compare to Iran and India. As COVID-19 cases increases in India Indian Air Force (IAF) recently creates many quarantine facilities at its nodal bases [13] across the country and the interpretation given by the various sections of tab. 1 which has divided into three different color section in which green color indicates the Safe Zoon amber indicates Caution Zoon and red indicates Danger Zoon.

Chart 4: Currently available list of private laboratories in India to test COVID-19 developed by Indian Council of Medical Research

- Lal Path Labs, Block -E, Sector 18, Rohini, Delhi
- Dr Dangs Lab, C-2/1, Safdarjung Development Area, New Delhi
- Laboratory Services, Indraprastha Apollo Hospitals, Sarita Vihar, New Delhi
- Max Lab, Max Super Speciality Hospital, Saket, New-Delhi 5.
- Sir Ganga Ram Hospital Clinical Lab Services, Sir Ganga Ram Hospital, Delhi
- Oncquest Labs Ltd, 3-Factory Road, New-Delhi

- Unipath Speciality laboratory limited, 102, Sanoma Plaza, Opposite Farimal Garden, Besides JMC House, Ellis bridge, Ahmedabad
- Supratech Micro path Laboratory & Research Institute Pvt Ltd, Kedar, Ahmedabad
- SN Gen Lab Pvt Ltd, President Plaza A, Near Mahavir Hospital, Nanpara, Surat
- Pan genomics International Pvt Ltd, Ellis Bridge, Ahmedabad 3, Haryana (3) 1. Strand Life Sciences, A-17, Sector 34

- Sir Ganga Ram Hospital Clinical Lab Services, Sir Ganga Ram Hospital, Delhi
- Oncquest Labs Ltd, 3-Factory Road, New-Delhi

- Strand Life Sciences, A-17, Sector 34, Gunugram
- ShL Limited, GP26, Sector 18, Gunugram
- Modern Diagnostic & Research Centre-Lab, 363-364/4, Jawahar Nagar, Gurgaon
- Neuberg Anand Reference Laboratory, Anand Tower, #54, Bevering Hospital Road, Bengaluru
- Canucyte Technologies Pvt Ltd, Sri Shankara Research Centre, Bengaluru

- Thyrocare Technologies Limited, D37/1, TTC MIDC, Turbhe, Navi Mumbai
- Suburban Diagnostics (India) Pvt. Ltd., 306, 307/F, 3rd Floor, Sunshine Bl., Andheri (W), Mumbai
- Metropolis Healthcare Ltd, Unit No. 409-416, 4th Floor, Commercial Building-1, Kothinoor Mall, Mumbai
- Sir H.N. Reliance Foundation Hospital and Research Centre, Molecular Medicine, Reliance Life Sciences Pvt. Ltd., R-282, TTC Industrial Area, Rabale, Navi Mumbai
- ShL Limited, Prime Square Building, Plot No 1, Gourav Industrial Estate, SV Road, Goregaon, Mumbai
- A.G. Diagnostics Pvt Ltd, Nayantara Building, Pune
- Kokilaben Dhirubhai Ambani Hospital Laboratory
- InfeXn Laboratories Private Limited, A/131; Thirukkovel Compound, Road No 23, Wagle Industrial Estate

- Dept of Lab Services, Apollo Hospitals, Bhubaneswar
- Dept. of Clinical Virology, CMC, Vellore
- Department of Laboratory Services, Apollo Hospitals Enterprise Ltd, Chennai
- Neuberg Ehrlich Lab Pvt Ltd, 46-48 Masilamani Road, Balaji Nagar, Chennai
- Sri Ramachandra Medical College & Research Institute, Porur, Chennai

Chart 4 shows that the list of currently available private laboratories in different states of India to test COVID-19 [14].
IV. FUZZY INFERENCE SYSTEM (MAMDANI)

We have designed a fuzzy inference system (as shown in fig. 1) to diagnose the COVID-19 disease by taking six input factors like as; Ethanol, Atmospheric Temperature (AT), Body Temperature (BT), Breath Shortness (BS), Cough and Cold with one output factor which has further divided into three linguistic categories which denotes the severity level of the patient. We will construct membership functions for the included factors. In this article, we propose a structure of fuzzy inference system which is based on fuzzy rules for the inference.

A. Structure of fuzzy inference system

![Figure 1: Structure of fuzzy inference system with six inputs and one output](image)

| Including Factors | Linguistic ranges |
|-------------------|------------------|
| Atmospheric Temperature (AT) | Low (°C) | Medium | High |
| Breath Shortness (BS) | 1 Yes | 0 No |
| Ethanol | Low (mg/dl) | Medium | High |
| Body Temperature (BT) | Low (°F) | Medium | High |
| Cold | 1 Yes | 0 No |
| Cough | 1 Yes | 0 No |
| Severity | Less-Severe | Normal | Severe |

B. Fuzzy rules for Inference

Table 3: Fuzzy rules for inference system with six input and one output

| Rule | Conditions | Severity |
|------|------------|----------|
| 1. | If (AT is High) and (BT is Low) and (Ethanol is Low) and (Cold is No) and (BS is No) then (Severity is Less Severe) |
| 2. | If (AT is Low) and (BT is High) and (Ethanol is Low) and (Cold is Yes) and (BS is Yes) then (Severity is Severe) |
| 3. | If (AT is Low) and (BT is Low) and (Ethanol is Low) and (Cold is No) and (BS is Yes) then (Severity is Less Severe) |
| 4. | If (AT is Medium) and (BT is Medium) and (Ethanol is Medium) and (Cold is No) and (BS is No) then (Severity is Normal) |
| 5. | If (AT is High) and (BT is Medium) and (Ethanol is High) and (Cold is Yes) and (BS is Yes) then (Severity is Less Severe) |
| 6. | If (AT is Medium) and (BT is Medium) and (Ethanol is Medium) and (Cold is Yes) and (BS is Yes) then (Severity is Normal) |
| 7. | If (AT is Low) and (BT is Medium) and (Ethanol is Low) and (Cold is Yes) and (BS is No) then (Severity is Normal) |
| 8. | If (AT is Medium) and (BT is Low) and (Ethanol is Medium) and (Cold is No) and (BS is Yes) then (Severity is Normal) |
| 9. | If (AT is Low) and (BT is High) and (Ethanol is Low) and (Cold is No) and (BS is Yes) then (Severity is Less Severe) |
| 10. | If (AT is Medium) and (BT is Medium) and (Ethanol is Medium) and (Cold is Yes) and (BS is No) then (Severity is Less Severe) |
| 11. | If (AT is Low) and (BT is Medium) and (Ethanol is Medium) and (Cold is No) and (BS is No) then (Severity is Less Severe) |

C. Membership functions for the factors

We will construct membership functions for the input variables by using gaussian membership function as shown in fig.2,3 &4.

i. Atmospheric Temperature (AT)

```matlab
x = 0:0.1:60;
y = gaussmf (x, [8.493 -2.22e-16]);
y1 = gaussmf (x, [3.61 26.5]);
y2 = gaussmf (x, [4.247 40]);
plot (x, y, x, y1, x, y2)
xlabel ('Input variable "AT"');
ylabel ('Membership grade');
title ('Membership functions plots for AT');
ylim ([0 1]);
legend ('Low', 'Medium', 'High');
```

Figure 2: Gaussian membership function for Atmospheric Temperature in three linguistic categories; Low, Medium and High

ii. Body Temperature

```matlab
x = 95:0.1:105;
y = gaussmf (x, [0.4247 97]);
y1 = gaussmf (x, [0.4247 98]);
y2 = gaussmf (x, [1.274 101]);
plot (x, y, x, y1, x, y2)
xlabel ('Input variable "BT"');
ylabel ('Membership grade');
title ('Membership functions plots for BT');
ylim ([0.05 1.05]);
legend ('Low', 'Medium', 'High');
```

Figure 3: Membership functions plots for BT

iii. Ethanol

```matlab
x = 0.00:0.1:1.00;
y = gaussmf (x, [0.124 -1.89e-16]);
y1 = gaussmf (x, [0.024 3.9]);
y2 = gaussmf (x, [0.124 1.9]);
plot (x, y, x, y1, x, y2)
xlabel ('Input variable "Ethanol"');
ylabel ('Membership grade');
title ('Membership functions plots for Ethanol');
ylim ([0 1]);
legend ('Low', 'Medium', 'High');
```

Figure 4: Membership functions plots for Ethanol
iii. **Ethanol**

```matlab
x = 0:0.1:190;
y = gaussmf (x, [19.11 2.5]);
y1 = gaussmf (x, [12.74 75]);
y2 = gaussmf (x, [16.99 140]);
plot (x, y, x, y1, x, y2)
xlabel ('Input variable "Ethanol"');
ylabel ('Membership grade');
title ('Membership functions plots for Ethanol');
ylim ([0.05, 1.05]);
legend ('Low', 'Medium', 'High');
```

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E. **Output**

**Table 4: Normal Severity level of the infected patient**

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**Table 5: Less Severe level of infected patient**
Table 6: Severe level of the infected patient

V. CONCLUSION
Coronaviruses abbreviated as CoV contains large family of viruses which causes basic symptoms like: cold, cough and fever. Out of these viruses COVID-19 is newly strained that introduced in 2019 which has not been identified before. The inference which we have developed in the research article, we may conclude the following observations;
1) From tab. 4 we may observe that if the atmospheric temperature is medium, more intake of ethanol and slightly higher body temperature then we will get Normal severity level of infected patient.
2) From tab. 5 if the atmospheric temperature is low, body temperature is medium, the intake ethanol quantity and patient suffering from cough then we may observe the severity level in the patient.
3) From tab. 6 we may observe that when the patient faces the difficulty in breathing difficulty, has sneezing problem with low intake of ethanol quantity then severity level will slightly higher be as compare to other cases.
So, our proposed inference system may be useful to the proper diagnostic of COVID-19 infected patients.

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AUTHORS PROFILE
Nitesh Dhiman received the M.Sc. Degree in Mathematics from GKV, Hardwar in 2013, UGC-CSIR-JRF in Mathematics (June-2016 &June-2017) and pursuing Ph.D. in Mathematics from C.C.S. Uni., Meerut, India. His research interest includes Fuzzy Logic in Medical Sciences.
M. K. Sharma received a Ph.D. Degree in Fuzzy Reliability Theory from C.C.S. Uni., Meerut India in 2007. He is currently an Associate Professor in the Department of Mathematics, C.C.S. Uni., Meerut India. He has contributed more than 60 research articles to professional Journals. He has participated and presented more than 40 research articles in National and International conferences. His research interest includes Reliability Theory, Fuzzy logic, Intuitionistic fuzzy logic, vague logic and their applications in Engineering and Healthcare.