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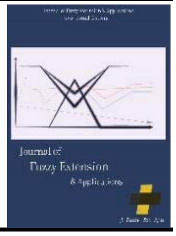

**Paper Type: Research Paper**

# A Decision-Making System for Corona Prognosis Using Fuzzy Inference System

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## Abstract

COVID-19, an epidemic disease, has challenged human lives all over the world. Governments and scientific communities are trying their level best to help the masses. This disease which is caused by corona virus majorly attacks the upper respiratory system rendering the human immunity incapacitated and, in some cases, proving fatal. Therefore, it is very much important to identify the infected people quickly and accurately, so that it can be prevented from spread. Early addressal of the symptoms can help to prevent the disease to become severe for all mankind. This calls for the development of a decision-making system to help the medical fraternity for the timely action. This proposed fuzzy based system predicts Covid-19 based on individuals' symptoms and parameters. It receives input parameters as fever, cough, breathing difficulty, muscle ache, sore throat, travel history, age, medical history in the form of different membership functions and generates one output that predicts the likelihood of a person being infected with COVID-19 using Mamdani fuzzy inference system. The timely prognosis of the disease at home isolation or at the security checks can help the patient to seek the medical treatment as early as possible. Patient case studies, real time observations, cluster cases were studied to create the rule base for FDMS. The results are validated by using real-time individuals test cases on the proposed system which yields 97.2% accuracy, 100% sensitivity and 96.2% specificity.

**Keywords:** Coronavirus disease, COVID-19, Fuzzy logic, Fuzzy inference system, Membership functions, Medical symptoms.

## 1 | Introduction



Coronaviruses are a group of viruses that can cause illness or infections in the human body. These viruses cause symptoms ranging from common cold and mild illness to Middle East Respiratory Syndrome (MERS), Sever Acute Respiratory Syndrome (SARS) and COVID-19. COVID-19 has come up as a big challenge to the medical as well as the investigation field since its inception. The first wave of this virus when it hit India in January 2020, affected the upper respiratory system of people to an extent that was not experienced before. The second wave, that hit India in March 2021 was even more life threatening. As at 2 July 2021, there have been 182,319,261 confirmed cases of COVID-19, including 3,954,324 deaths, reported to World Health Organization (WHO) globally [1]. Many countries are using various self-assessment tools and apps to self-analyze the infection at homes and raising measures to prevent the disease.

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Technology is playing an immense role to spread awareness and make people conscious about how to save themselves from this deadly disease. It is also proven to be successful in predicting the future outcomes and depict the outbreak consequences which can help in preventing the spread of such diseases [2].

Artificial Intelligence (AI) is used to allow individuals to fill questionnaires as self-assessment and medical chatbots are being updated and trained to screen people and spread advice on whether they need to be quarantined [3]. One of the popular systems of AI is fuzzy logic based expert system which has already been used in numerous applications such as air conditioners, washing machines, vacuum cleaners, transmission systems, medical diagnosis, aviation, weather prediction and many more since its inception in 1965 [4]–[6]. Fuzzy based methods are being applied across the computer systems, including both centralized and distributed systems to analyze the receiving performance data and then evaluate the CPU utilization [7]. Mamdani based fuzzy inference system which was first introduced in 1975 used human intelligence to develop a group of linguistic control rules [8]. Owing to its simple structure, it gives comparatively good results which makes it more popular. Fuzzy logic is one of the selected soft computing approaches for implementing the proposed COVID-19 prognosis system due to its robustness, simple reasoning, flexibility and ease of implementation to uncertain or approximate reasoning systems. However, finding a suitable membership function is dependent on expert knowledge. Storing the rule-base may require a significant amount of memory also.

Fuzzy logic has been utilized in the past for building a system that can diagnose various medical diseases like identification of severity of carpal tunnel syndrome, cystic fibrosis and other infectious diseases [9]–[13]. The main advantage of fuzzy based system is that it is based on human knowledge and experience [14]. Therefore, this pandemic outbreak motivated us to utilize this system to early diagnose such type of diseases which can help in taking preventive and corrective measures and help individuals to take measures for quick recovery and prevent spread. Keeping this in mind, this paper aims to develop a fuzzy decision-making system for corona prognosis which can alert a user for low, moderate, and high risk of being infected in terms of percentage. The proposed system can be used to predict the possiblilty of having corona based on various symptoms when provided to the system. Fuzzy means difficult to perceive; indistinct or vague. It is a type of set theory and logic in which variables may have degrees of applicability, rather than being just true or false in contrast to Boolean logic. This is similar to humans performing decision making that involves all intermediate range of values between 0 and 1. Fuzzy logic allows us to use imperfect (imprecision, vague and uncertain) information in a sensible way and imitates the way a person would make decisions. It can be implemented in hardware, software, or a combination of both.

In this paper, a survey was carried out during the first wave of this pandemic during February 2020 – July 2020. The researchers found that the early symptoms among people who were infected with COVID-19 from 2 to 14 days after the disease is contracted, may have a mild to moderate, but self-limiting disease with symptoms similar to the seasonal flu. Other symptoms include: high temperature, tiredness, cough, difficulty in breathing, mucus, loss of appetite and body aches. Apart from this, the main concern is that it spreads quickly between people. Therefore, all people with coronavirus infection i.e., the symptotic ones and sometime asymptotic can infect others. COVID-19 had infected people of all ages. Old age people whose age is more than 45 and who are already suffering from diseases like diabetes, high blood pressure (BP) or heart problems have high risk of developing COVID-19 virus [15]–[17]. The German businessman who intended the business meeting in Wuhan was infected with corona. He reported symptoms of sore throat, chills and muscle ache followed by fever [18]. It was analyzed that those who have travel history with Wuhan are reported Corona positive. In another research study, author discusses the pediatric cases (age 15 and 9) of two families who had visited Wuhan and its neighboring province [19]. In India, first case of COVID-19 was found in Kerala where a female was infected with corona. She had visited Wuhan and reported the symptoms of dry cough and sore throat [20]. Another study reports the cluster case of the group of 23 Italian tourists who arrived in India on February 21, 2020. More than half of the group approximately 65% were found to be infected with COVID-19 on March 17, 2020. This paper discusses their onset symptoms, treatment and recovery graph till the time they were discharged from the hospital [21]. WHO and European Centre for Disease Prevention and Control (ECDC) suggested to avoid crowded

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places and direct communication with corona positive people. Precautionary actions such as wearing masks, washing hands, avoidance of public interaction, corona positive case detection and isolations can reduce its transmission [22]. The main objective of this paper is to predict the likelihood of a person being infected with COVID-19 disease so that timely dignose help in preventing and slow down transmission.

## 2 | Fuzzy Decision-Making System

The fuzzy based decision-making system is described with the help of *Fig. 1*. The fuzzification unit transforms the crisp input which is numerical input into fuzzy linguistic variables. Linguistic variables are variables which are words or sentences in a natural language. For example, the input like 'age' having numerical values from 0 – 100 is transformed to fuzzy variable as young age, middle age and old age with the help of membership functions. The Mamdani inference engine after receiving one or large number of input variables existing in a system, processes the linguistic information by using knowledge base according to fuzzy 'IF-THEN' rules. Finally averaging and weighting the results from all the individual rules into an aggregation output is made and the defuzzification unit converts this fuzzy output to the crisp output.

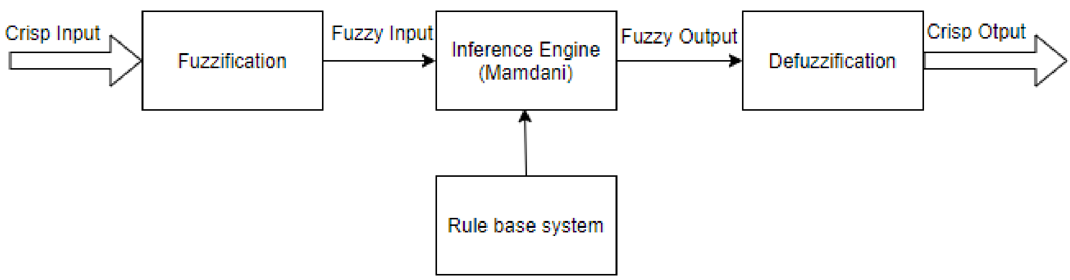



**Fig. 1. Fuzzy decision-making system [23].**

## 3 | Proposed Methodology

The proposed approach of our fuzzy decision-making system for the prediction of COVID-19 is based on the Fuzzy Inference System (FIS) implemented in MATLAB. FIS is the process of formulating input and output mappings with fuzzy logic and making decisions based on these mapping. The fuzzy logic Toolbox™ in MATLAB software provides us the tools for developing Mamdani inference system. All these tools are shown in *Fig. 2*. The fuzzy logic designer tool handles the number of input and output variables. Membership function editor is used to decide the shapes of all the membership functions related to each variable. Rule editor edits the rules that define the performance of system. Rule viewer is used to view the rules and how they are being activated. Surface viewer define view the dependency of one of the outputs on other inputs and thereby generates an output surface map for the system. The step-by-step procedure is given as follows.

### 3.1 | Designing Fuzzy Logic System

The first step is to decide the inputs and outputs which will build the system structure. Our system has eight inputs namely fever, cough, breathing difficulty, muscle ache, sore throat, travel history, age and medical history (Diabetic, High BP, Heart Disease, Thyroid etc.). The output is corona prognosis as shown in *Fig 3*. So, the fuzzy logic designer represents the total 8 inputs and 1 output.

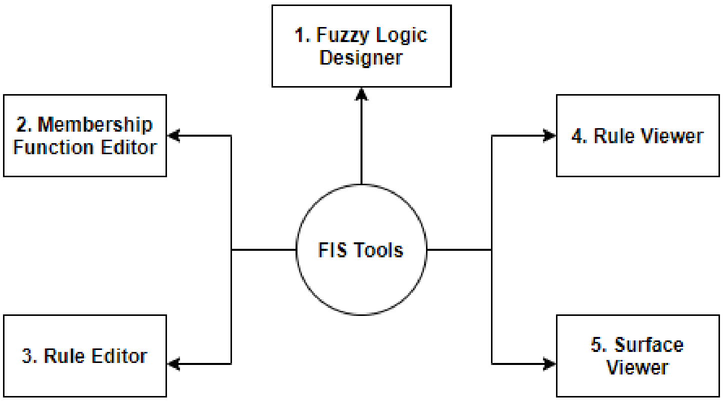



Fig. 2. Fuzzy inference system tools.

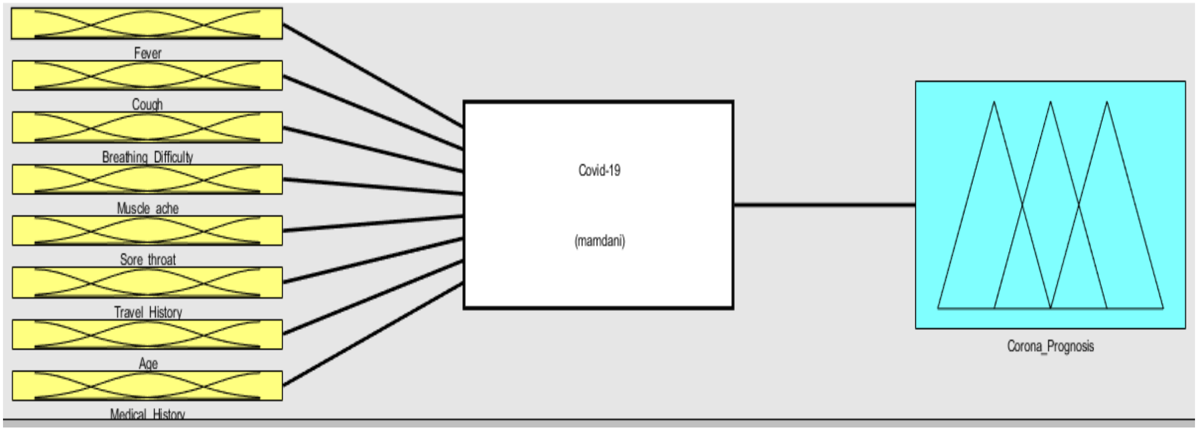



Fig. 3. Basic structure of FIS system.

## 3.2 | Define Membership Function

Once the basic structure of the system has been established, the next step is to determine the Membership Function (MF) for each input and output. A MF represents the degree of truth in fuzzy logic. An element in the input variable is associated to a degree of membership in the range [0, 1]. The associated membership function for fuzzified 8 inputs and 1 output are defined in *Tables 1* and *2*.

Table 1. Input variable and its membership functions.

| Input No. | Variable Name | Membership Function | Type of Membership Function |
|---|---|---|---|
| 1 | Fever [96,103] | Normal, High | Trapezoidal |
| 2 | Cough [0 100] | Mild, Moderate, Severe | Trapezoidal |
| 3 | Breathing Difficulty [0 100] | Mild, Moderate, Severe | Trapezoidal |
| 4 | Muscle Ache [0 100] | Mild, Moderate, Severe | Trapezoidal |
| 5 | Sore Throat [0 100] | Mild, Moderate, Severe | Trapezoidal |
| 6 | Travel History [0 100] | Almost No, Almost Yes | Trapezoidal |
| 7 | Age [0 100] | Young, Middle, Old | Trapezoidal |
| 8 | Medical History [0 100] | Almost No, Almost Yes | Trapezoidal |

**Table 2. Output variable and its membership function.**

| Output | Variable name | Membership Function | Type of Membership Function |
|---|---|---|---|
| 1 | Corona Prognosis [0 100] | Low, Moderate, High | Triangular |

We have decided to use trapezoidal membership function (Trapmf) for the inputs and triangular membership function (Trimf) for the output after experimentation. Changing the type of MF influences the results. Therefore, knowledge and experience play a major role in defining the MF. Graphical and mathematical representation of Trapmf and Trimf is given in *Table 3*.

**Table 3. Graphical and mathematical representation of MF.**

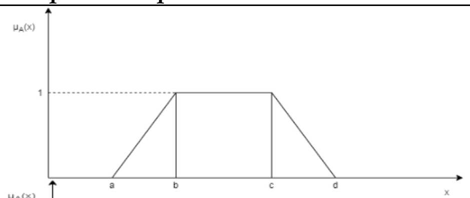
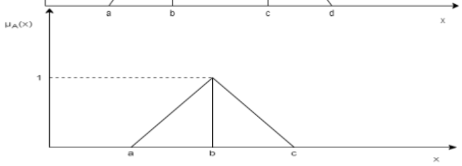
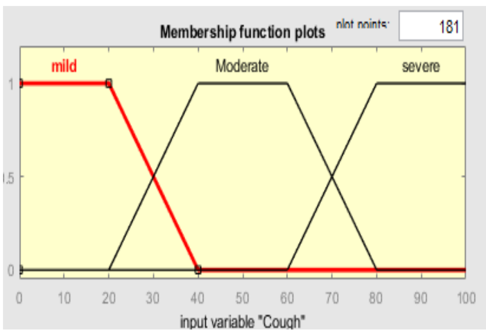
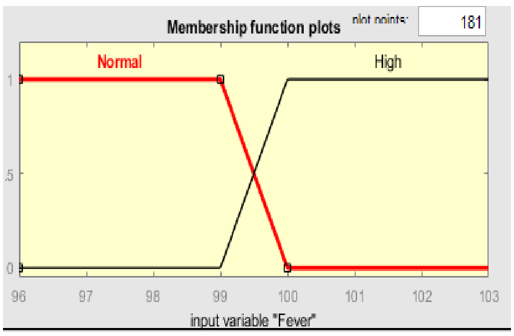
| MF | Graphical Representation | Mathematical Equation |
|---|---|---|
| Trapmf |  | $\mu_A(x) = \begin{cases} 0 & \text{if } x \leq a \\ (x-a)/(b-a) & \text{if } a \leq x \leq b \\ 1 & \text{if } b \leq x \leq c \\ (d-x)/(d-c) & \text{if } c \leq x \leq d \\ 0 & \text{if } d \leq x \end{cases}$ |
| Trimf |  | $\mu_A(x) = \begin{cases} 0 & \text{if } x \leq a \\ (x-a)/(b-a) & \text{if } a \leq x \leq b \\ (c-x)/(c-b) & \text{if } b \leq x \leq c \\ 0 & \text{if } c \leq x \end{cases}$ |

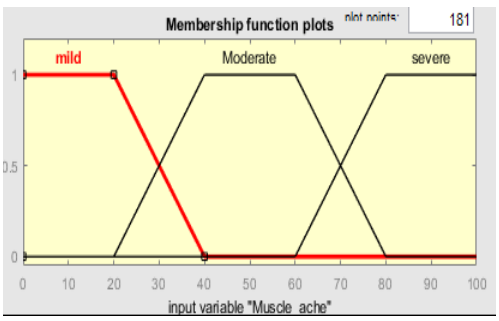
*Fig. 4 (a)–(b)* shows the software representation of defined input membership functions. *Fig. 5* shows the software representation of defined output membership function.



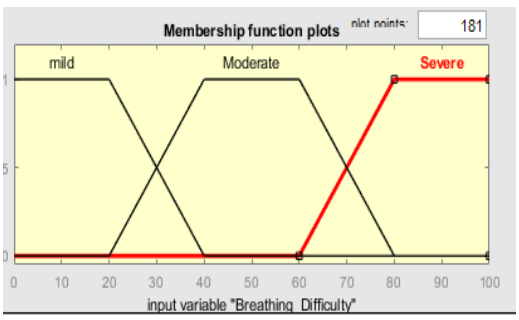

**(a)**




**(b)**




**(c)**




**(d)**

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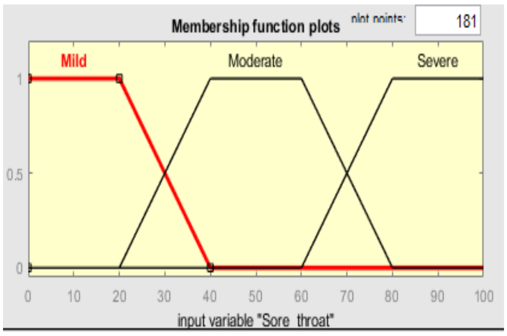
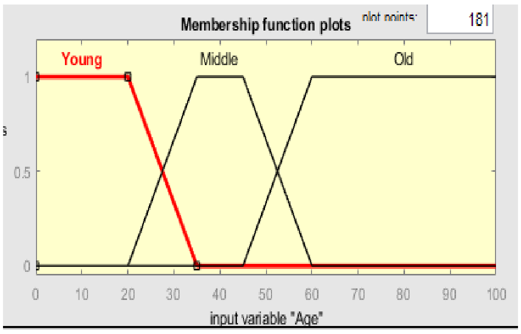
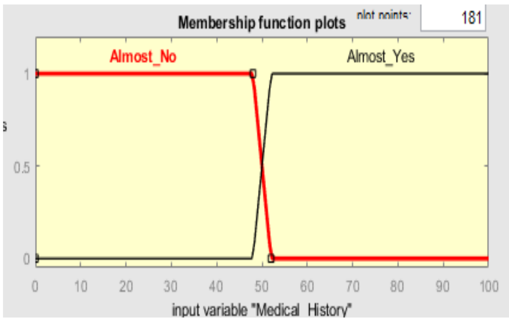
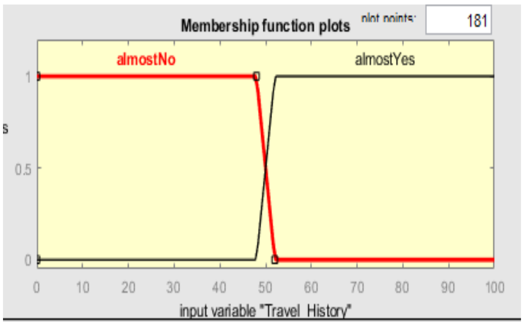



(e) (f)




(g) (h)

**Fig. 4. MF for input variables (a) fever (b) cough (c) breathing difficulty (d) muscle ache (e) sore throat (f) travel history (g) age (h) medical history.**

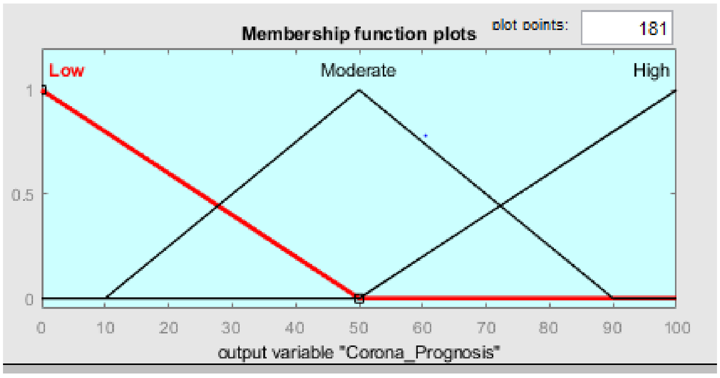



**Fig. 5. MF for output variable corona prognosis.**

## 3.3 | Defining Rules

After defining the membership functions, next step is to define the rules in rule editor using IF-THEN rules. The canonical form of the fuzzy rules is IF (a set of condition is satisfied) THEN (a conclusion can be inferred). After analyzing the different case studies of COVID-19 symptoms, the rules for fuzzy decision-making system are defined. The IF part of the rule takes eight inputs and the THEN part has the output as corona prognosis in terms of LOW (having very low chances of being affected by corona virus), MODERATE (can have more chances of being affected by corona virus) and HIGH (surely be affected by corona virus). Rules are created based on literature (explained in related work) and taking real use cases. Data is collected from the COVID infected patients. After analyzing those use cases, a total of 77 (IF-THEN) rules are created and accordingly their output is specified. Some of these rules are tabulated in *Table 4*. For aggregation, “max” method is used. Aggregation is the method in which the fuzzy sets represent the output by combining the fired rules into a fuzzified output.

Table 4. Some of the defined rules of FDMS.

| Rule No. | Fever | Cough | Breathing Difficulty | Muscle Ache | Sore Throat | Travel History | Age | Medical History | Corona Prognosis |
|---|---|---|---|---|---|---|---|---|---|
| 2 | Normal | Mild | Mild | Mild | Mild | No | Middle | No | Low |
| 7 | Normal | Mild | Mild | Mild | Mild | No | Middle | Yes | Low |
| 8 | Normal | Mild | Mild | Moderate | None | No | Middle | No | Low |
| 13 | Normal | Mild | Mild | Mild | Mild | yes | Middle | No | Low |
| 17 | Normal | Mild | Mild | Moderate | Moderate | No | Middle | No | Low |
| 23 | High | Mild | Mild | Moderate | Moderate | No | Old | Yes | Moderate |
| 28 | High | Mild | Moderate | Moderate | Moderate | Yes | Young | No | Moderate |
| 33 | Normal | Mild | Mild | Moderate | Moderate | Yes | Old | Yes | Moderate |
| 37 | High | Moderate | Moderate | Moderate | Mild | Yes | Old | No | Moderate |
| 38 | High | Moderate | Moderate | Mild | Mild | Yes | None | No | Moderate |
| 41 | High | Severe | Severe | Severe | Severe | Yes | Old | Yes | High |
| 46 | High | Severe | Severe | Severe | Moderate | Yes | Young | Yes | High |
| 52 | High | Moderate | Moderate | Moderate | Moderate | Yes | Young | Yes | High |
| 62 | High | Moderate | Moderate | Moderate | Severe | Yes | Old | Yes | High |
| 69 | Normal | Severe | Severe | Severe | Severe | Yes | Old | None | High |
| 77 | High | Moderate | Severe | Severe | Severe | Yes | Young | No | High |

## 3.4 | Defuzzification of the Output

To convert the fuzzified output into crisp output, defuzzification is needed. After defuzzification, using the aggregated fuzzy output, a specific decision or real value is calculated. Various methods of defuzzification are there like centroid, bisector, middle of maximum, smallest of maximum, largest of maximum, center of gravity etc. but here after experimentation, "Centroid" method of defuzzification is used which uses center of area under the curve of aggregated output. This way the Low, Moderate and High fuzzy outputs have been converted to crisp output ranging from 16.3% – 83.7%.

# 4 | Results and Discussions

## 4.1 | Rule Viewer

To view and analyze the result of output parameter based on different input parameters used, rule viewer is used, which is represented in *Fig. 6*. In *Table 5*, some of the predicted output values corresponding to different input values are summarized. Depending on the value of input parameters, type of membership function used, the method of aggregation and defuzzification selected and the rules designed, our output ranges from 16.3% – 83.7% representing the corona prognosis chances from LOW to HIGH. The yellow color represents the fired rules for a particulare set of inputs and blue color represent the aggregated output in *Fig. 6*. We took different values of all input parameters according to the literature and data we collected and tested our system. Some of the results are shown in *Table 5*.

It is evident from *Table 5* that as the values of some of the input parameters like fever or breathing difficulty increases, then the value of corona prognosis increases. This gives an interpretation that if fever is 98, cough is 15, breathing difficulty is 78, muscle ace is 15, sore throat is 15, travel history is 0 and age is 38 then corona prognosis is predicted to be 23.5%. After analyzing the different case studies of COVID 19 (literature study and real use cases), it has been found that the persons showing the symptoms of fever, cough, breathing difficulty, sore throat and having travel and medical history (Diabetic, High BP, Heart Disease, Thyroid etc.) have more chances of corona prognosis.

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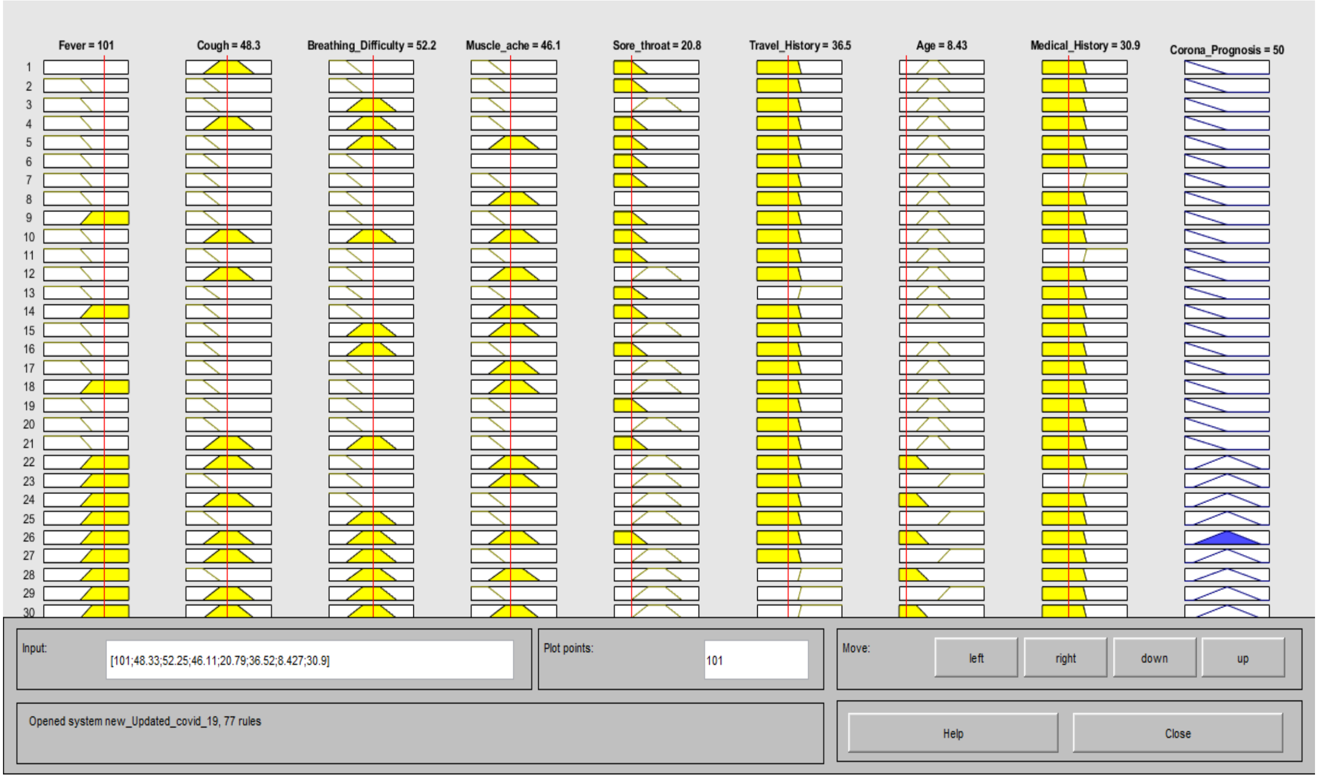


**Fig. 6. Rule viewer.**

## 4.2 | Surface Viewer

Surface Viewer is also used to analyze the behavior of the output with respect to the inputs. Input values are taken based on literature and data collected from COVID infected patients. According to data inputs, *Fig. 7* shows different output surface maps of the system output by taking the different combination of two inputs. We took all the combinations of two inputs to check output on surface view. For example, *Fig. 7(a)* shows the behaviour of the output with respect to the two inputs namely travel history and breathing difficulty. The blue colored area denotes the LOW chances of corona prognosis, green as MODERATE and yellow as HIGH. According to the defined membership functions, this surface takes the shape. It shows that as the value of breathing difficulty increases and travel history is almost yes, then, the chances of Corona prognosis keep on moving towards HIGH. Similarly, *Fig. 7(b)* shows the effect of fever and cough, *Fig. 7(c)* shows the effect of fever and breathing difficulty, *Fig. 7(d)* shows the effect of travel history and fever. *Fig. 7(e)* shows the effect of muscle ache and fever and *Fig. 7(f)* shows the effect of age and travel history on corona prognosis.

## 4.3 | Performance Evaluation

For the purpose of validating the performance of the proposed decision-making system, we have conducted a survey using a questionnaire and recorded the symptoms of the randomly chosen 72 individuals from all walks of life. Out of these, 19 individuals were found to be corona positive and the remaining 53 were corona negative. The survey asked questions related to all the 8 parameters which are primary symptoms namely fever, cough, breathing difficulty, sore throat and other factors namely age, travel history and underlying medical history (Diabetic, High BP, Heart Disease, Thyroid etc.). After simulating each individual's data on the proposed system, results were compared with their actual output. The chances of corona prognosis in % are converted to output YES and NO by defining a threshold of 50%. A value less than or equal 50% is taken as corona prognosis being negative (not infected by COVID) and above 50% as prognosis being positive (infected by COVID). The confusion matrix of 72 individuals is shown in *Table 6*.

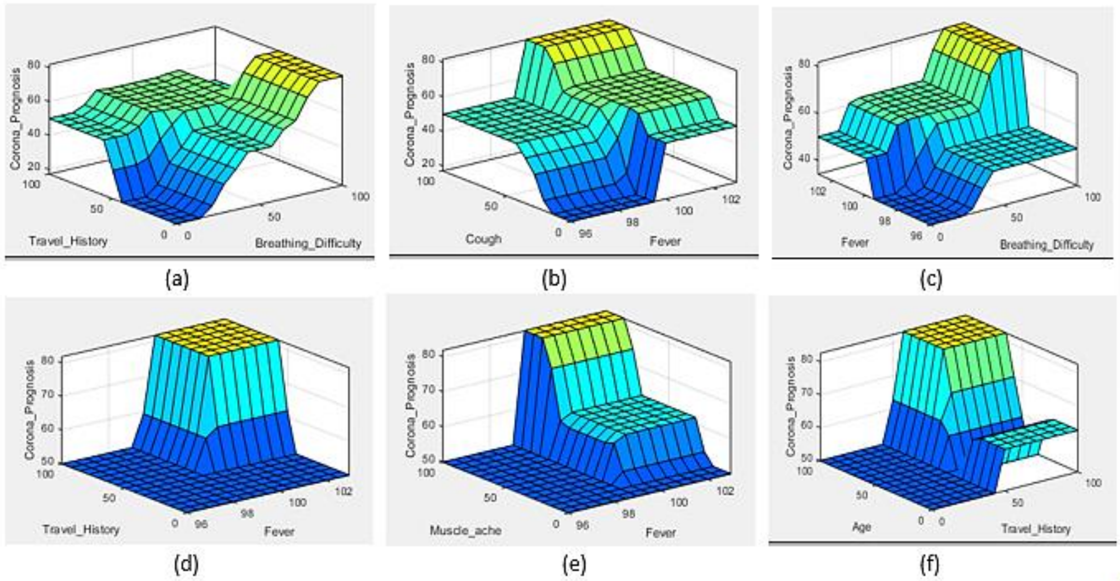


**Fig. 7. Surface view with different inputs.**

**Table 5. A few predicted corona prognosis.**

| S.No. | Fever | Cough | Breathing Difficulty | Muscle Ache | Sore Throat | Travel History | Age | Medical History | Corona Prognosis | Predicted output | Actual Output |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 97 | 15 | 15 | 15 | 15 | 0 | 38 | 0 | 16.3% | No | No |
| 2 | 98 | 15 | 78 | 15 | 15 | 0 | 38 | 0 | 23.5% | No | No |
| 3 | 99 | 25 | 66 | 30 | 32 | 10 | 29 | 10 | 35.1% | No | No |
| 4 | 99 | 48 | 78 | 48 | 15 | 20 | 38 | 20 | 48.6% | No | No |
| 5 | 99.5 | 48 | 78 | 48 | 50 | 80 | 55 | 20 | 56.2% | Yes | No |
| 6 | 100 | 50 | 73 | 50 | 50 | 80 | 15 | 30 | 64.6% | Yes | Yes |
| 7 | 102 | 50 | 78 | 48 | 50 | 80 | 55 | 80 | 76.5% | Yes | Yes |
| 8 | 103 | 85 | 90 | 80 | 80 | 100 | 70 | 100 | 83.7% | Yes | Yes |

**Table 6. Confusion matrix.**

| N=72 | Predicted No (False) | Predicted Yes (True) |
|---|---|---|
| Actual No (False) | 51 (TN) | 2 (FP) |
| Actual Yes (True) | 0 (FN) | 19 (TP) |

From this confusion matrix, the following metrics are evaluated to test the performance of the proposed system.

Sensitivity $= \frac{TP}{TP+FN} = \frac{19}{19+0} = 100\%$ .

Specificity $= \frac{TN}{TN+FP} = \frac{51}{51+2} = 96.2\%$.

Precision$= \frac{TP}{TP+FP} = \frac{19}{19+2} = 90.4\%$ .

Accuracy$= \frac{TP+TN}{TP+FP+TN+FN} = \frac{19+51}{19+2+51+0} = 97.2\%$ .

Here TP is true positive, TN is true negative, FP is false positive and FN is false negative.

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It is found that the accuracy of the system is 97.2% with the sensitivity of 100% which implies that all the infected cases have been correctly predicted by the system.

## 5 | Conclusions

In the wake of novel coronavirus pandemic, we have proposed a fuzzy decision-making system to predict the probability of a person being infected with the virus. The framework of this system is built using Mamdani inference system which comprises eight inputs and a single output variable. Eight linguistic variables have been taken as input as they are the primary symptoms of infection. Output variable depicts the risk level of being corona positive. Rule base consist of all the rules that have been formed on the basis of data driven approach. Our proposed FDMS gives 100% sensitivity and 97.2% accuracy when tested on 72 individuals. The accuracy of the system can be increased by increasing the rules, but that increases the complexity of the system as well. The intended system can be set up both online and offline where quick prognosis is required. Also, along with artificial intelligence mechanisms, this FDMS can be integrated to develop a more sophisticated tool to the mankind.

## Conflicts of Interest

All co-authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

## References

[1] WHO. (2020). *Coronavirus disease (COVID-2019) situation reports*. Retrieved April 30, 2021 from https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports/

[2] Agrebi, S., & Larbi, A. (2020). Use of artificial intelligence in infectious diseases. In *Artificial intelligence in precision health* (pp. 415-438). Academic Press.

[3] Ahaskar, A. (2020). *How WhatsApp chatbots are helping in the fight against Covid-19*. Retrieved March 27, 2021 from https://www.livemint.com/technology/tech-news/how-whatsapp-chatbots-are-helping-in-the-fight-against-covid-19-11585310168911.html

[4] Zadeh, L. A. (1973). Outline of a new approach to the analysis of complex systems and decision processes. *IEEE transactions on systems, man, and cybernetics*, (1), 28-44. DOI: 10.1109/TSMC.1973.5408575

[5] Singh, H., Gupta, M. M., Meitzler, T., Hou, Z. G., Garg, K. K., Solo, A. M., & Zadeh, L. A. (2013). Real-life applications of fuzzy logic. *Adv. Fuzzy Syst*. https://doi.org/10.1155/2013/581879

[6] Ali, D., Yohanna, M., Ijasini, P. M., & Garkida, M. B. (2018). Application of fuzzy–Neuro to model weather parameter variability impacts on electrical load based on long-term forecasting. *Alexandria engineering journal*, *57*(1), 223-233.

[7] Buriboev, A., Kang, H. K., Ko, M. C., Oh, R., Abduvaitov, A., & Jeon, H. S. (2019). Application of fuzzy logic for problems of evaluating states of a computing system. *Applied sciences*, *9*(15), 3021. https://doi.org/10.3390/app9153021

[8] Mamdani, E. H., & Assilian, S. (1975). An experiment in linguistic synthesis with a fuzzy logic controller. *International journal of man-machine studies*, *7*(1), 1-13.

[9] Kunhimangalam, R., Ovallath, S., & Joseph, P. K. (2013). A novel fuzzy expert system for the identification of severity of carpal tunnel syndrome. *BioMed research international*. https://doi.org/10.1155/2013/846780

[10] Hassanzad, M., Orooji, A., Valinejadi, A., & Velayati, A. (2017). A fuzzy rule-based expert system for diagnosing cystic fibrosis. *Electronic physician*, *9*(12), 5974. DOI: 10.19082/5974

[11] Arji, G., Ahmadi, H., Nilashi, M., Rashid, T. A., Ahmed, O. H., Aljojo, N., & Zainol, A. (2019). Fuzzy logic approach for infectious disease diagnosis: A methodical evaluation, literature and classification. *Biocybernetics and biomedical engineering*, *39*(4), 937-955.

[12] Ahamad, M. K., & Bharti, A. K. (2021, March). Prevention from COVID-19 in India: Fuzzy Logic Approach. *International conference on advance computing and innovative technologies in engineering (ICACITE)* (pp. 421-426). IEEE.

[13] Shaban, W. M., Rabie, A. H., Saleh, A. I., & Abo-Elsoud, M. A. (2021). Detecting COVID-19 patients based on fuzzy inference engine and Deep Neural Network. *Applied soft computing*, *99*, 106906. https://doi.org/10.1016/j.asoc.2020.106906

[14] Sivanandam, S. N., Sumathi, S., & Deepa, S. N. (2007). *Introduction to fuzzy logic using MATLAB* (Vol. 1). Berlin: Springer.

[15] [15] Joint Mission. (2020). *Report of the WHO-China Joint Mission on Coronavirus Disease 2019 (COVID-19)* 2020. Retrieved from https://www.who.int/docs/default-source/coronaviruse/who-china-joint-mission-on-covid-19-final-report.pdf

[16] Jin, Y. H., Cai, L., Cheng, Z. S., Cheng, H., Deng, T., Fan, Y. P., ... & Wang, X. H. (2020). A rapid advice guideline for the diagnosis and treatment of 2019 novel coronavirus (2019-nCoV) infected pneumonia (standard version). *Military medical research*, *7*(1), 1-23.

[17] Singhal, T. (2020). A review of coronavirus disease-2019 (COVID-19). *The Indian journal of pediatrics*, *87*(4), 281-286.

[18] Rothe, C., Schunk, M., Sothmann, P., Bretzel, G., Froeschl, G., Wallrauch, C., ... & Hoelscher, M. (2020). Transmission of 2019-nCoV infection from an asymptomatic contact in Germany. *New England journal of medicine*, *382*(10), 970-971.

[19] Ji, L. N., Chao, S., Wang, Y. J., Li, X. J., Mu, X. D., Lin, M. G., & Jiang, R. M. (2020). Clinical features of pediatric patients with COVID-19: a report of two family cluster cases. *World journal of pediatrics*, 1. DOI: 10.1007/s12519-020-00356-2

[20] Andrews, M. A., Areekal, B., Rajesh, K. R., Krishnan, J., Suryakala, R., Krishnan, B., ... & Santhosh, P. V. (2020). First confirmed case of COVID-19 infection in India: A case report. *The Indian journal of medical research*, *151*(5), 490. DOI: 10.4103/ijmr.IJMR_2131_20

[21] [21] Thangaraj, J. W. V., Murhekar, M., Mehta, Y., Kataria, S., Brijwal, M., Gupta, N., ... & Bhargava, B. (2020). A cluster of SARS-CoV-2 infection among Italian tourists visiting India, March 2020. *The Indian journal of medical research*, *151*(5), 438. DOI: 10.4103/ijmr.IJMR_1722_20

[22] Adhikari, S. P., Meng, S., Wu, Y. J., Mao, Y. P., Ye, R. X., Wang, Q. Z., ... & Zhou, H. (2020). Epidemiology, causes, clinical manifestation and diagnosis, prevention and control of coronavirus disease (COVID-19) during the early outbreak period: a scoping review. *Infectious diseases of poverty*, *9*(1), 1-12.

[23] Rizvi, S., Mitchell, J., Razaque, A., Rizvi, M. R., & Williams, I. (2020). A fuzzy inference system (FIS) to evaluate the security readiness of cloud service providers. *Journal of cloud computing*, *9*(1), 1-17.

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