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Mathematical Approach to Identify Coronavirus Disease (COVID-19) Using Fuzzy Logic Inference System

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Abstract. In this paper, we apply a fuzzy logic inference system based on Mamdani Fuzzy Inference System (MFIS) to determine the identification of the disease of COVID-19. For this purpose, we use the regarding centroid method of defuzzification with the aid of three parameters that must be taken as a symptom of identifying the disease COVID-19. By defining triangular fuzzy number with three inputs and one output, we have to calculate the consequence of COVID-19 in our expected fields. This have to be done by using the MATLAB toolbox of MFIS. It is noteworthy to observe that the obtained result might play important role in science, engineering and biomedical fields and also open a new horizon for the upcoming researchers to work smoothly in the related fields taking the other parameters as a symptom for identifying this disease using the MFIS.

Keywords: Coronavirus (COVID-19), Triangular fuzzy number, Linguistic variables, Mamdani Fuzzy Inference System, MATLAB toolbox.

AMS Mathematics Subject Classification (2010): 94D05

1. Introduction

In December 2019, Wuhan city of China became the center of an outbreak of pneumonia of unknown cause, latter named as Coronavirus disease (COVID-19), which raised intense attention not only within china but also internationally [1, 2]. The COVID-19 pandemic is the largest global crisis since the Second World War, affecting almost every nation on the Planet [3].

Coronaviruses are a family of viruses that can lead to respiratory diseases in humans. They get their name, **'**corona'**,** from the numerous crown-shaped spikes on the surface of the virus.

The coronavirus is the virus that can cause Middle East respiratory syndrome (MERS-CoV) and severe acute respiratory syndrome (SARS-CoV). Following the study, SARS-CoV was found to be passed from wild cats to humans. Chang et al. [4] demonstrate in his study that SARS-CoV is a new virus and recurrence. Few studies [5, 6] have described the new SARS-CoV virus as the source of Heaven's first pandemic. When the disease COVID-19 spread primarily as a pandemic all over the world, mainly the countries like; China, America, Italy, Spain etc. have been attacked severely. No

vaccine were probably effective when this disease originates. For this, millions of people have become death. After about one year from December 2019, with the executive effort of many scientists and researchers of different countries, the probable effective vaccines like as Oxford-AstraZeneca of COVID-19 have been recognized as vaccine primarily. Our main objective of this article is to identify the disease (COVID-19) using the MATLAB toolbox of MFIS.

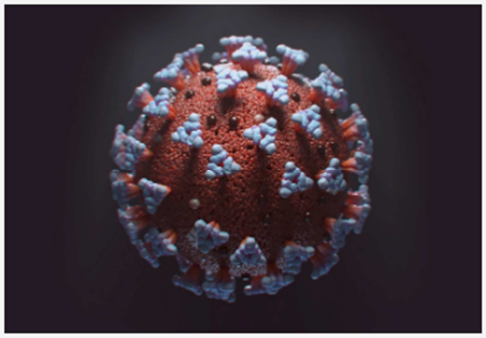

Figure 1: Coronavirus disease 2019 (COVID-19) is a virus (more specifically, a coronavirus) identified as the cause of an outbreak of respiratory illness first detected in Wuhan, China.

The article is prepared as follows: In Section 2, we discuss the basic concepts of triangular fuzzy number and fuzzy logic, in Section 3, we describe Fuzzy Inference System (FIS) and the method of MFIS, in Section 4, we discuss the consequence of our expected article with their graphical representations using MATLAB toolbox of MFIS and in Section 5 conclusions are given.

2. Basic concepts

Throughout this paper, we shall use the basic concepts as follows:

2.1. Triangular fuzzy number [7]

It is a fuzzy number represented with three points as follows: $A = (a, b, c)$
This representation is interpreted as membership function (Figure 2).

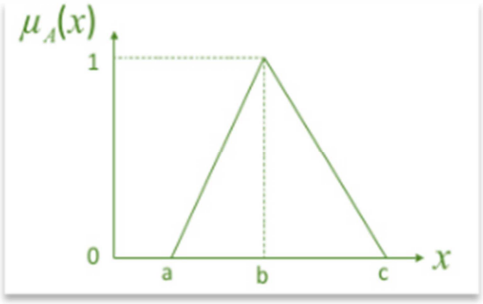

Figure 2: Graphical representation of triangular fuzzy number.

Also defined as

$$\mu_A(x) = \begin{cases} 0 & if\ x < a, \quad x > c \\ \dfrac{x-a}{b-a} & if\ a \le x \le b \\ \dfrac{c-x}{c-b} & if\ b \le x \le c \end{cases}$$

2.2. Fuzzy logic approach

Fuzzy logic is a kind of computational archetype which gave us a mathematical tool for human reasoning for handling the various type uncertainties. The ability for fuzzy logic allows us to express human knowledge in a linguistic manner.

Again, Fuzzy logic is an artificial intelligence (AI) system used to solve problems where the digital resolver is not sufficient to obtain precise results, which was developed by Zadeh et al. [8]. It uses a flexible computing system to handle extreme conditions. Fuzzy logic is a step-by-step computation system based on the "degree of truth," an alternative to Boolean logic. It considers numbers between 0 and 1 as a partial truth that can calculate for both numeric and linguistic parameters. Besides this, fuzzy logic can be applied in different fields of mathematics like as [9-11]. It improves known identity and converts into numeric and functional parameters in surface graphs [12, 13]. In this system, the relationship between input function (Fever, Oxyzen Saturation, and Tiredness) and output function (Consequence of COVID-19) constructs in the following way shown in table 1.

Parameters	Linguistic Variables	Range
1. Fever	No Fever (NF), Fever (F), Very Fever (VF)	96-106^{0}F
2. Oxyzen Saturation	Very Bad (VB), Good (G), Very Good (VG)	84-100%
3. Tiredness	No Tired (NT) , Tired (T), Very Tired (VT)	0-100%
4. Consequence of COVID-19	Corona $^-$Ve (CN), No Comment (NC), Corona $^+$Ve (CP)	0-100%

Table 1: Fuzzy linguistic variables and parameters

2.3. Fuzzy logic in medical diagnosis

The fuzzy logic framework used in different types of disease diagnosis [14, 15] where physicians and expert's knowledge are represented in the name of symptoms and diseases. As a result, we can frame the several types of membership function for the symptoms depending upon the tendency of the patient data and they have used to form a suitable fuzzy expert system. It is used for predicting and optimizing various dimensions of physical inputs as numerical factors to define the effect on the desired output. Fuzzy logic has found increasing applications within the biomedical field [16-19].

3. Fuzzy Inference System (FIS)

Fuzzy Inference System (FIS) is the principal unit of a fuzzy logic system. The initial work of this system is to make decision. For this, "If-then" rules are used. To imply this rules in FIS, we use the operations "or" or "and".

3.1. Functional blocks of FIS

To make the sense is clear, we will display the following functional blocks of FIS. It contains five parts.

1. **Rule Base** − It contains fuzzy If-then rules.
2. **Database** − It defines the membership functions of fuzzy sets used in fuzzy rules.
3. **Decision-making Unit** − It performs operation on rules.
4. **Fuzzification Interface Unit** − It converts the crisp quantities into fuzzy quantities.
5. **Defuzzification Interface Unit** − It converts the fuzzy quantities into crisp quantities.

Block diagram of FIS has been given in figure 3.

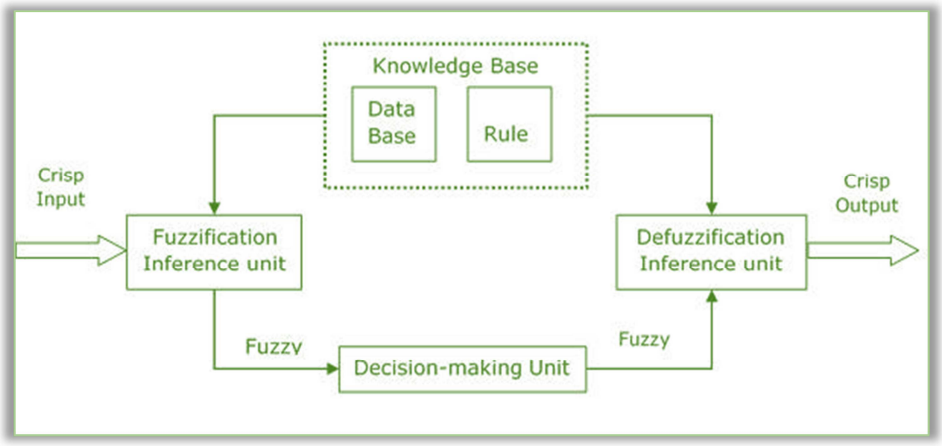

Figure 3: Block diagram of fuzzy inference system.

3.2. Mamdani fuzzy inference system (MFIS)

The MFIS was initially introduced as a method for creating a control system by synthesizing a set of linguistic control rules obtained from experienced human operators [20]. It was proposed in 1975 by Ebhasim Mamdani. In a Mamdani system, the output of each rule is a fuzzy set.

Since Mamdani systems have more intuitive and easier to understand rule bases, they are well suited to expert system applications where the rules are created from human expert knowledge, such as medical diagnostics.

The rules of inference system of MFIS will be described in the following four steps:

Step-1: Fuzzification
Step-2: Rules evaluation
Step-3: Aggregation of the rule outputs
Step-4: Defuzzificaion

Among these four steps of MFIS, we have been used all the steps for our article. From this, in step 4, we take only the centroid method of defuzzification.

3.3. Centroid method [21]

The most commonly used defuzzification method is the center of gravity method. On the basis of center of gravity of fuzzy set this method provides a crisp value. For discrete membership function, the defuzzified output x^* is given by

$$x^* = \frac{\sum_{i=1}^{n} x_i . \mu(x_i)}{\sum_{i=1}^{n} \mu(x_i)}$$

Here, x_i is considered as the sample element, $\mu(x_i)$ represents the membership function, and n is the number of elements in the sample.

4. Consequence and discussion with graphical representation

Considering the factors to identify COVID-19 disease defined as input parameters Fever, Oxyzen Saturation, and Tiredness. Also defined the output parameters as Consequence of COVID-19. The membership function for input variable Fever in three linguistic categories are; Fever (F), No Fever (NF), and Very Fever (VF). The membership function for input variable Oxyzen Saturation in three linguistic categories are; Very Bad (VB), Good (G), and Very Good (VG).The membership function for input variable Tiredness in three linguistic categories are; No Tired (NT), Tired (T), Very Tired (VT). Also, the membership function for output variable Consequence of COVID-19 in three linguistic categories are; Corona Negative (CN), No Comment (NC), and Corona Positive (CP).
By using triangular fuzzy number and MATLAB toolbox of MFIS, the followings are obtained:

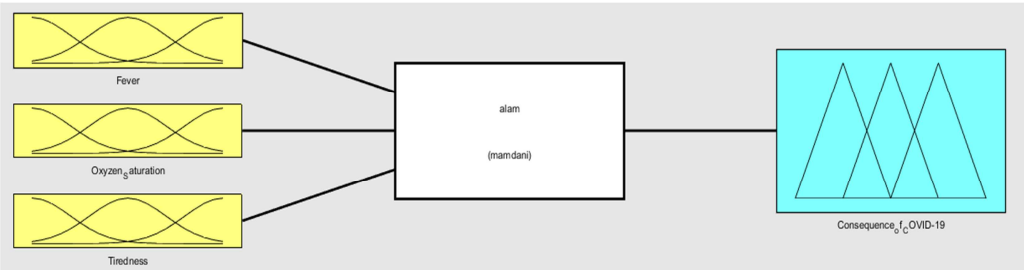

Figure 4: Variables in fuzzy logic

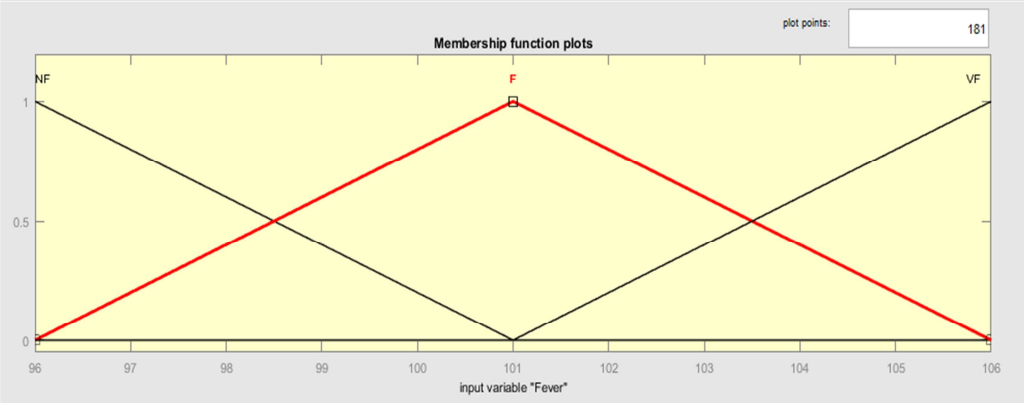

Figure 5: The membership function of input variable Fever in three linguistic categories; F, NF, and VF

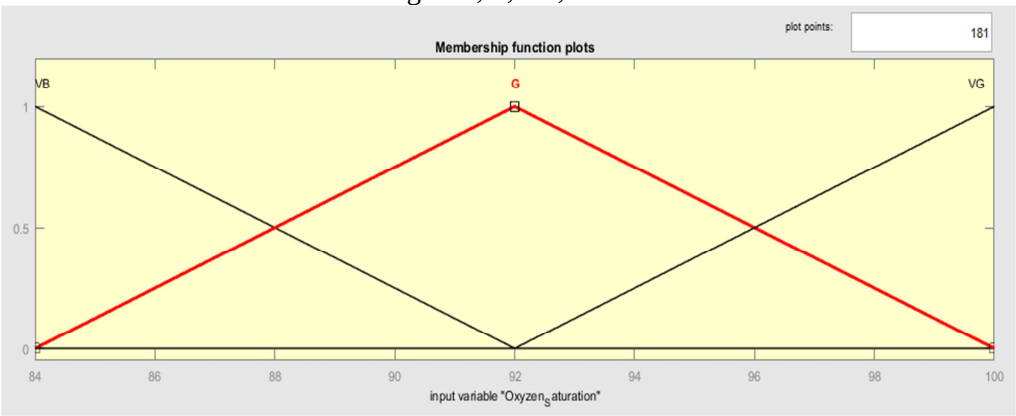

Figure 6: The membership function of input variable Oxyzen Saturation in three linguistic categories; VB, G, and VG.

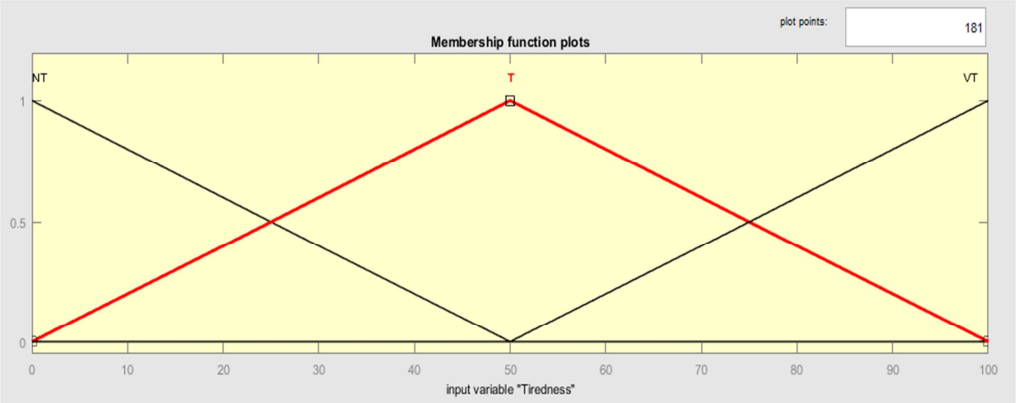

Figure 7: The membership function of input variable Tiredness in three linguistic categories; NT, T, and VT.

Applying fuzzification, the output variable provides the Consequence of COVID-19 that shows in figure 8.

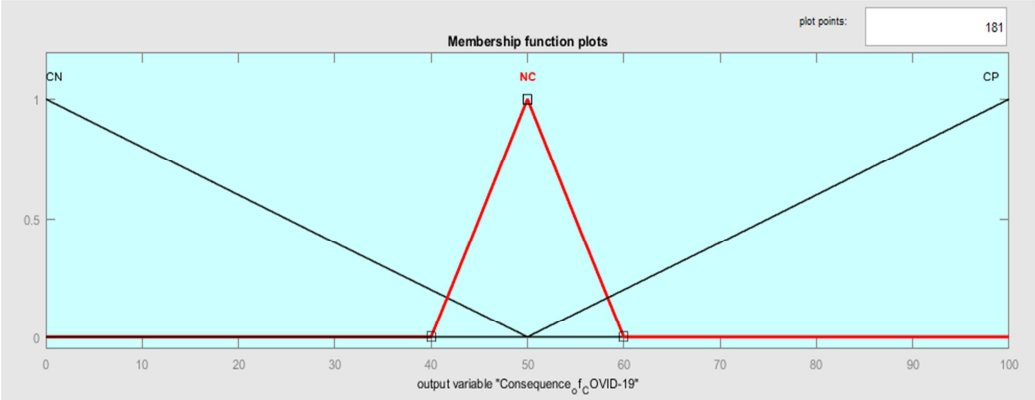

Figure 8: The membership function of output variable Consequence of COVID-19 in three linguistic categories; CN, NC, and CP.

Now, we need to apply step-2 in MFIS. The following rules are;

1. If (Fever is NF) and (Oxyzen Saturation is VB) and (Tiredness is NT) then (Consequence of COVID-19 is NC).
2. If (Fever is NF) and (Oxyzen Saturation is VB) and (Tiredness is T) then (Consequence of COVID-19 is CP).
3. If (Fever is NF) and (Oxyzen Saturation is VB) and (Tiredness is VT) then (Consequence of COVID-19 is CP).
4. If (Fever is NF) and (Oxyzen Saturation is G) and (Tiredness is NT) then (Consequence of COVID-19 is CN).
5. If (Fever is NF) and (Oxyzen Saturation is G) and (Tiredness is T) then (Consequence of COVID-19 is CP).
6. If (Fever is NF) and (Oxyzen Saturation is G) and (Tiredness is VT) then (Consequence of COVID-19 is CP).
7. If (Fever is NF) and (Oxyzen Saturation is VG) and (Tiredness is NT) then (Consequence of COVID-19 is NC).
8. If (Fever is NF) and (Oxyzen Saturation is VG) and (Tiredness is T) then (Consequence of COVID-19 is CN).
9. If (Fever is NF) and (Oxyzen Saturation is VG) and (Tiredness is VT) then (Consequence of COVID-19 is CN).
10. If (Fever is F) and (Oxyzen Saturation is VB) and (Tiredness is NT) then (Consequence of COVID-19 is CP).
11. If (Fever is F) and (Oxyzen Saturation is VB) and (Tiredness is T) then (Consequence of COVID-19 is CP).
12. If (Fever is F) and (Oxyzen Saturation is VB) and (Tiredness is VT) then (Consequence of COVID-19 is CP).
13. If (Fever is F) and (Oxyzen Saturation is G) and (Tiredness is NT) then (Consequence of COVID-19 is CN).
14. If (Fever is F) and (Oxyzen Saturation is G) and (Tiredness is T) then (Consequence of COVID-19 is CP).
15. If (Fever is F) and (Oxyzen Saturation is G) and (Tiredness is VT) then (Consequence of COVID-19 is CP).

16. If (Fever is F) and (Oxyzen Saturation is VG) and (Tiredness is NT) then (Consequence of COVID-19 is CN).
17. If (Fever is F) and (Oxyzen Saturation is VG) and (Tiredness is T) then (Consequence of COVID-19 is CP).
18. If (Fever is F) and (Oxyzen Saturation is VG) and (Tiredness is VT) then (Consequence of COVID-19 is CP).
19. If (Fever is VF) and (Oxyzen Saturation is VB) and (Tiredness is NT) then (Consequence of COVID-19 is NC).
20. If (Fever is VF) and (Oxyzen Saturation is VB) and (Tiredness is T) then (Consequence of COVID-19 is CP).
21. If (Fever is VF) and (Oxyzen Saturation is VB) and (Tiredness is VT) then (Consequence of COVID-19 is CP).
22. If (Fever is VF) and (Oxyzen Saturation is G) and (Tiredness is NT) then (Consequence of COVID-19 is CN).
23. If (Fever is VF) and (Oxyzen Saturation is G) and (Tiredness is T) then (Consequence of COVID-19 is CP).
24. If (Fever is VF) and (Oxyzen Saturation is G) and (Tiredness is VT) then (Consequence of COVID-19 is CP).
25. If (Fever is VF) and (Oxyzen Saturation is VG) and (Tiredness is NT) then (Consequence of COVID-19 is CN).
26. If (Fever is VF) and (Oxyzen Saturation is VG) and (Tiredness is T) then (Consequence of COVID-19 is CP).
27. If (Fever is VF) and (Oxyzen Saturation is VG) and (Tiredness is VT) then (Consequence of COVID-19 is CP).

Now, using aggregation of the rules output and Centroid method of defuzzification the following figure 9 gives the required output of this article as example. The result may differ for taking the other values as input.

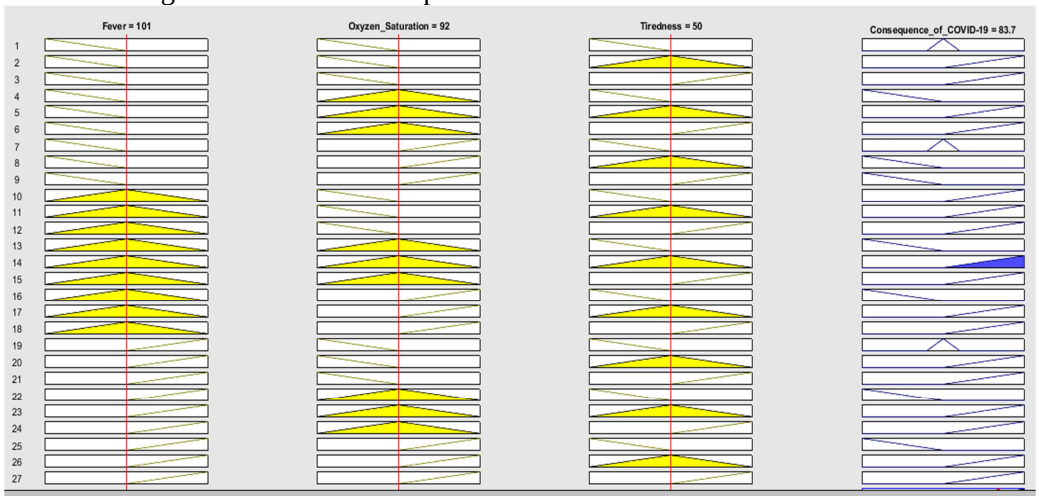

Figure 9: Final representation of result level for making comment.

In this process, the relationship between the input function (Fever, Oxyzen Saturation, and Tiredness) and output function (Consequence of COVID-19) have been represented graphically as surface in figure 10, 11, and 12 respectively.

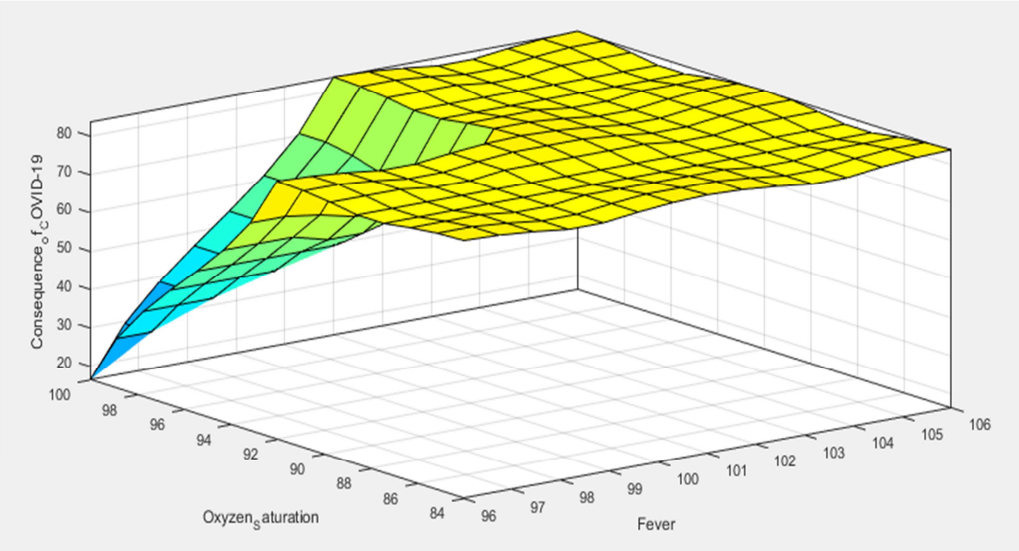

Figure 10: Relationship between Fever, Oxyzen Saturation, and Consequence of COVID-19.

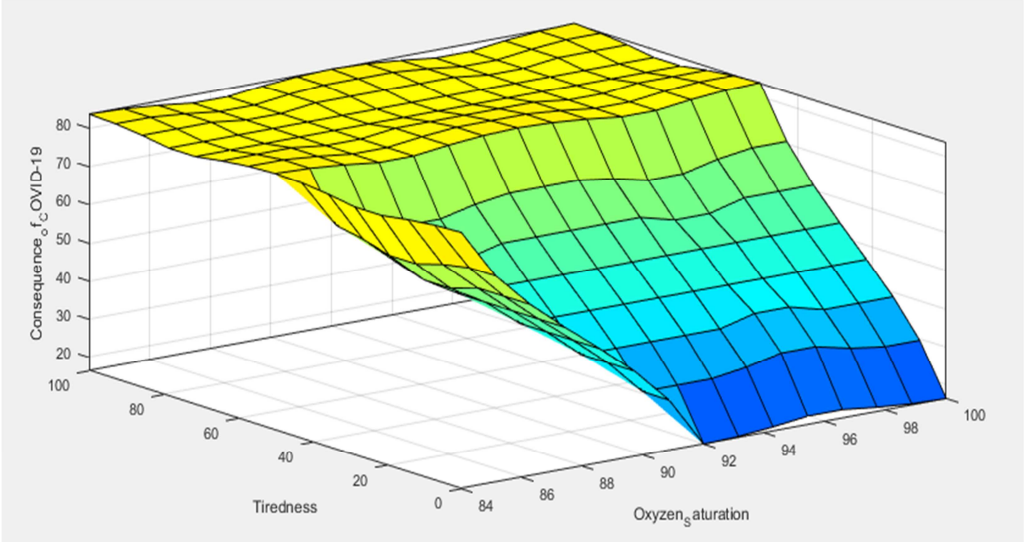

Figure 11: Relationship between Oxyzen Saturation, Tiredness, and Consequence of COVID-19.

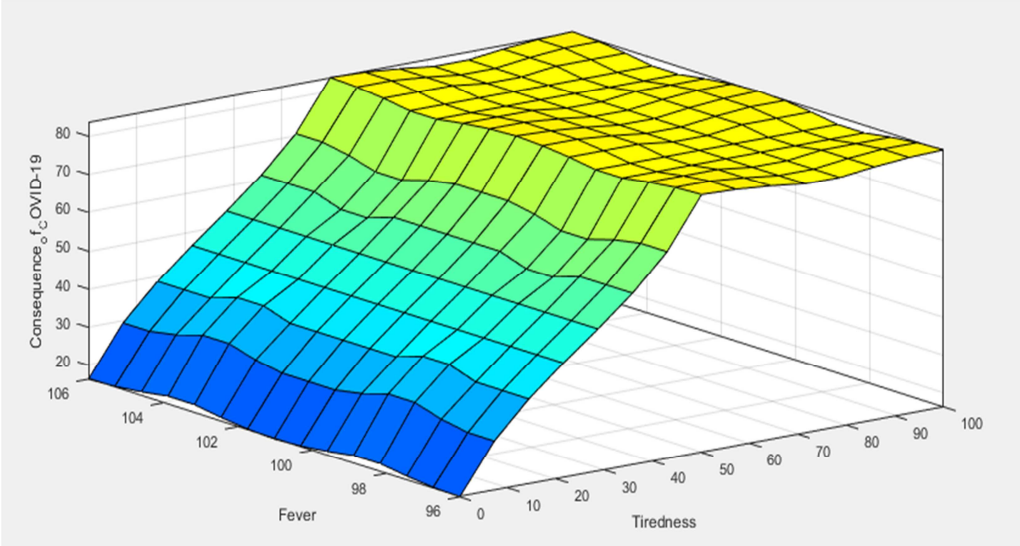

Figure 12: Relationship between Tiredness, Fever, and Consequence of COVID-19.

5. Conclusions

This article collaborates us to diagnosis COVID-19 disease mathematically involving three parameters taking as a symptom of this disease. By applying the MFIS method using the MATLAB toolbox, we have stood a final model with their graphical representation that ensures us to make a comment mathematically about the present condition of this disease. The consequence of this model may also differ on the basis of changing the values of input parameters in each case. We are strongly optimistic that the future researchers will be developed more to this model following the idea about our proposed model that must create a remarkable influence on science, engineering and biomedical fields.

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