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COVID-19 Fuzzy Inference System

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***Abstract* — The Coronavirus COVID-19 has been considered a pandemic due to its rapid spread increasing the number of affected cases and causing severe health issues and deaths all over the world. Meanwhile no particular treatment or vaccination has been identified for this disease, and therefore, the initial and early identification is crucial to control and break down the chain of COVID-19. In this research, a smart fuzzy inference system is proposed for initial identification of COVID-19 based on the patient symptoms and travel and contact history. The symptoms include cold, cough, fever, flu, breathing difficulties, throat pain and headache. Based on a particular patient data, the proposed system predicts the severity level of the disease that he/she has.**

***Keywords*—COVID-19 identification, Fuzzy inference system.**

I. Introduction

During the month of December 2019, the World Health Organization's (WHO) [1] China office heard the first reports of a previously unknown virus behind several pneumonia cases in Wuhan. Coronaviruses are a large family of viruses that are known to cause illness ranging from the common cold to more severe diseases, and it can lead to death in multiple cases [2]. The common symptoms are cold, cough, fever, flu, breathing difficulties, throat sore and headache. According to the study of the Centers for Disease Control and Prevention [3] these symptoms usually appear between two days and two weeks of exposure to the virus. Journal of the American Medical Association [4] reports say that out of all COVID-19 patients 11 - 44% has fatigue, 76 - 82% has coughed and 98% have a fever [5]. In addition, due to the rapid increase in the number of cases, it announced as a pandemic disease [6].

Since there have been no specific treatment confirmed for COVID-19 yet, the early diagnosis and preventions will be crucial to control or to break down the chain of COVID-19 [7]. In this work we proposed a fuzzy inference system to diagnose the COVID-19 based on a number of the symptoms that appear on the patient and the patient travel and being in contact with infected person history.

II. Fuzzy Inference System

In this work, a smart fuzzy inference system is proposed for initial identification of COVID-19 based on few of symptoms and medi cal data. The symptoms include cold, cough, fever, flu, breathing difficulties, throat infection and headache [5, 6]. Based on a particular patient data, the proposed system will predict the severity level of the COVID-19 disease that he/she has.

The proposed COVID-19 fuzzy inference system is defined by identifying the input and output variables along with the fuzzy sets and membership functions of each variable. After that, a set of fuzzy rules that relates input variables with output variables are defined. The proposed inference system is capable to diagnose the COVID-19 based on the patient data.

The fuzzy inference system consists of four main components; fuzzification module, knowledge base, inference engine, and defuzzification module as shown in Fig.1.

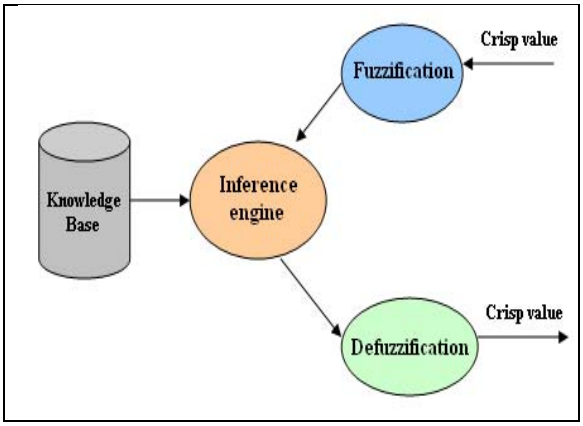

Fig.1: The fuzzy inference system

The fuzzification module transforms the crisp input value into a degree of membership of fuzzy sets by applying fuzzification membership functions. The Knowledge base contains the IF-THEN rules which are provided by field experts. The inference engine simulates the human reasoning process by making fuzzy inference on the inputs and IF-THEN rules. The defuzzification module transforms the fuzzy

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set obtained by the inference engine into a crisp output value [8]. The most commonly used fuzzy inference technique is Mamdani method. The Mamdani fuzzy inference process is performed in four steps; fuzzification, rule evaluation, aggregation of the rule outputs, and defuzzification. Our proposed COVID-19 fuzzy inference system is illustrated in Fig.2.

III. Input and Output Variables

We define 11 symptoms and patient history data as the input variables to the inference system. We group these variables into three categorize; most common symptoms, less common symptoms, and patient history. The most common symptoms category includes fever, tiredness, and dry cough. The less common symptoms category includes diarrhea, sore throat, pain and headache, conjunctivitis, loss of taste or smell, and breathing difficulties. The third category includes contact with an infected person and travel history within the last 14 days. The input variables are summarized in Table I. The output variable is risk of being COVID-19infected.

TABLE I: INPUT VARIABLES

Category 1	Fever
	Tiredness
	Dry cough
Category 2	Diarrhea
	Sore throat
	Pain and Headache
	Conjunctivitis
	Loss of taste or smell
	Breathing difficulties
Category 3	Travel history
	Contact with infected person

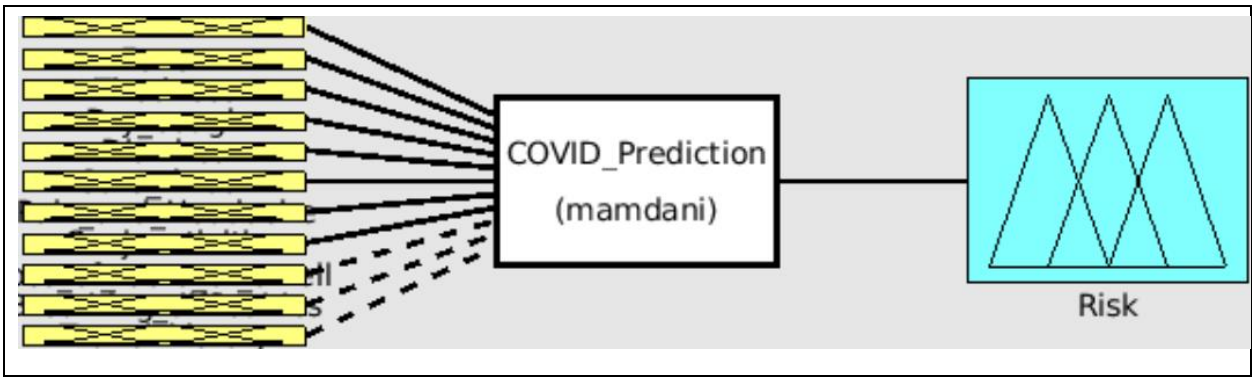

Fig.2: COVID-19 fuzzy inference system

IV. Membership Functions

Each input variable has two trapezoidal membership functions. The membership functions of the input variables are shown in Table II. The fever variable ranges between 35 and 40°C as presented in Fig. 3 while each of the remaining input variables has a level of the range from 0 to 10 as indicated in Fig. 4 [9] [10].

The output variable ranges from 0 to 100 and it has three trapezoidal membership functions; low, medium, and high risk as shown in Fig. 5.

V. Fuzzy Rules

The following fuzzy rules are defined:

If the 3 Category 1 symptoms are yes à Confirmed COVID

If 2 of Category 1 symptoms are yes AND 2 of Category 2 symptoms are yes à Confirmed COVID

If 1 Category 1 symptoms are yes AND 4 of Category 2 symptoms are yes à Confirmed COVID

If 2 of Category 1 symptoms are yes AND 1 of Category 2 symptoms are yes à Probable COVID

If 2 of Category 1 symptoms are yes à Probable COVID

If 1 of Category 1 symptoms are yes AND 3 of Category 2 symptoms are yes à Probable COVID

If 1 of Category 1 symptoms are yes AND 2 of Category 2 symptoms are yes à Probable COVID

If 2 of Category 1 symptoms are yes AND 1 of Category 2 symptoms are yes à Probable COVID

If 6 of Category 1 symptoms are yes à Probable COVID

If 1 of Category 1 symptoms are yes AND 1 of Category 2 symptoms are yes AND 1 of Category 3 symptoms are yes à Probable COVID

If 5 of Category 1 symptoms are yes AND 1 of Category 3 symptoms are yes à Probable COVID

If 4 of Category 1 symptoms are yes AND 1 of Category 3 symptoms are yes à Probable COVID

If 1 of Category 1 symptoms are yes AND 1 of Category 2 symptoms are yes à No COVID

If 1 of Category 1 symptoms are yes à No COVID

If 6 of Category 1 symptoms are yes à No COVID

If 5 of Category 2 symptoms are yes à No COVID

If 4 of Category 2 symptoms are yes à No COVID

If 3 of Category 2 symptoms are yes à No COVID

If 2 of Category 2 symptoms are yes à No COVID

If 1 of Category 2 symptoms are yes à No COVID

TABLE II: MEMBERSHIP FUNCTIONS OF THE INPUT VARIABLES

Number	Name	Range	Membership Function 1	Membership Function 2
1	Fever	35-40°C	'No':'trapmf',[35 35 36 37]	'Yes':'trapmf',[36.5 38 40 40]
2	Tiredness	0-10	'No':'trapmf',[0 0 3 6]	'Yes':'trapmf',[4 7 10 10]
3	Dry cough	0-10	'No':'trapmf',[0 0 3 6]	'Yes':'trapmf',[4 7 10 10]
4	Diarrhea	0-10	'No':'trapmf',[0 0 3 6]	'Yes':'trapmf',[4 7 10 10]
5	Sore throat	0-10	'No':'trapmf',[0 0 3 6]	'Yes':'trapmf',[4 7 10 10]
6	Pain and Headache	0-10	'No':'trapmf',[0 0 3 6]	'Yes':'trapmf',[4 7 10 10]
7	Conjunctivitis	0-10	'No':'trapmf',[0 0 3 6]	'Yes':'trapmf',[4 7 10 10]
8	Loss of taste or smell	0-10	'No':'trapmf',[0 0 3 6]	'Yes':'trapmf',[4 7 10 10]
9	Breathing difficulties	0-10	'No':'trapmf',[0 0 3 6]	'Yes':'trapmf',[4 7 10 10]
10	Travel history	0-10	'No':'trapmf',[0 0 3 6]	'Yes':'trapmf',[4 7 10 10]
11	Contact with infected person	0-10	'No':'trapmf',[0 0 3 6]	'Yes':'trapmf',[4 7 10 10]

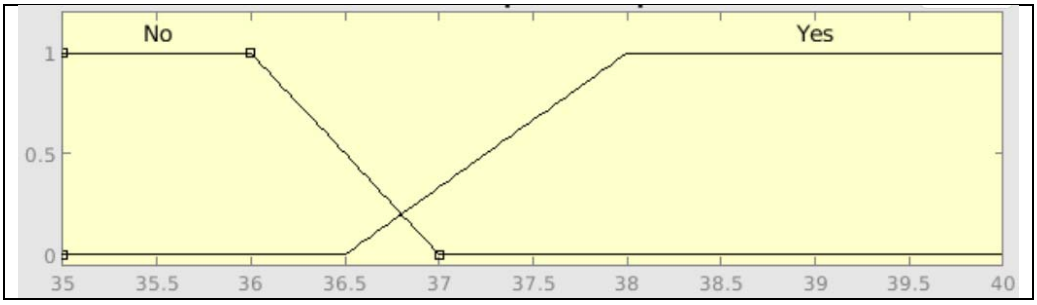

Fig. 3: The fever membership functions

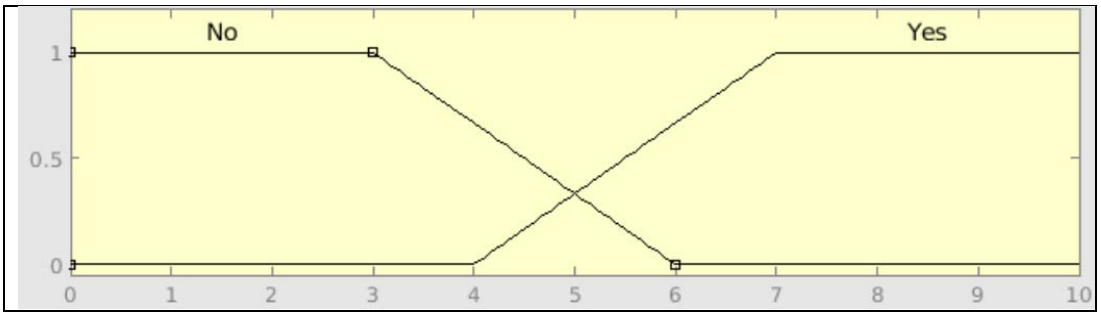

Fig. 4: The tiredness membership functions

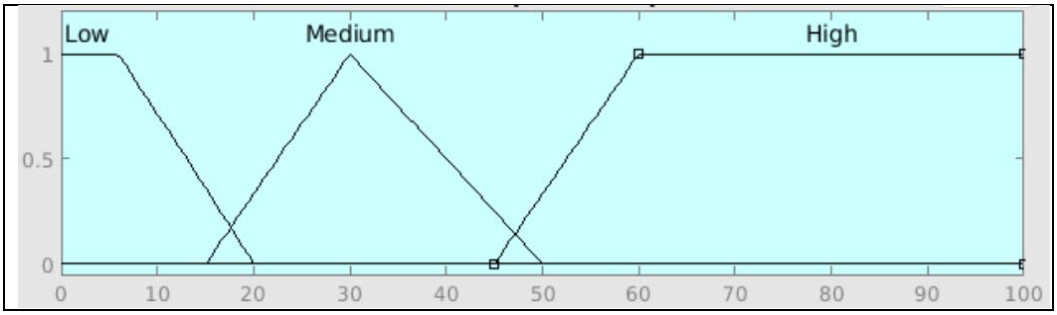

Fig. 5: The risk of COVID-19 membership functions

VI. Conclusion

We proposed a smart fuzzy inference system for the initial identification of COVID-19 based on the symptoms that appears on the patient. The symptoms include cold, cough, fever, flu, breathing difficulties, throat infection and headache. The medical data can include body temperature, breathing air peak flow rate, blood pressure, and having a chronic disease. The proposed inference system can help doctors to detect COVID-19 based on the patient data.

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