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Enhancing COVID-19 Diagnosis through Fuzzy Logic Framework-A Comprehensive Approach

Nidhi Mishra

[1]**Department of Mathematics, Pt. Harishankar Shukala Smriti Mahavidyalaya, Raipur, Chhattisgarh, India**

Email address:nidhimishra1908@gmail.com

ABSTRACT: COVID-19 is caused by a dangerous novel coronavirus known as severe acute respiratory syndrome corona-virus 2, first identified in the City of Wuhan in China. Since then, it has been declared a global pandemic by the World Health Organization. The late diagnosis of COVID-19 patients caused the fast spreading of the virus worldwide. This paper discusses how fuzzy logic and a rule-based expert system can help diagnose or detect COVID–19 in the early stages and get the result immediately without any delay.

Keywords: Fuzzy Logic, Artificial intelligence, Expert system, Medical diagnosis, COVID-19

1. INTRODUCTION

COVID-19 is caused by a new coronavirus called Severe Acute Respiratory Syndrome Corona Virus 2 (SARS-CoV-2). The primary case was eminent in Wuhan, China, in December 2019 and has been spread worldwide. The syndrome was declared a global epidemic by the World Health Organization (WHO) on March 11, 2020, due to profound anxiety, both with alarming levels of spread and severity [1]. At this instant, approximately 241 million confirmed cases, including 4.9 million deaths, were reported to WHO [2]. According to WHO, the most common symptoms of COVID-19 detected in confirmed cases are Fever, Dry cough, and Fatigue; severe symptoms of COVID-19 are difficulty in breathing or shortness of breath, pressure in the chest, and chest pain and other symptoms of COVID-19 are loss of taste and smell, nasal blockage,headache, sore throat joint or muscle pain, conjunctivitis, nausea or vomiting, different types of skin rash, diarrhea and dizziness, [3]. It was determined that the severity and symptoms of the disease differ according to age, chronic disease, genetic factors, or immune system. We saw the various situations of COVID-19 from the systematic, comprehensive reviews and analysis articles [4,5,6,7,8]. At that time, several

new variants of COVID-19 were identified in the United Kingdom (UK), South Africa, Brazil, and India. Preface findings have suggested that these mutations increase the virus's transmissibility. The Delta variant, first funded in India, is currently affected in most countries worldwide [12].

The severity of COVID-19 symptoms can range from very mild to severe. Some people may have only a few symptoms, and some may have no symptoms, which is called asymptomatic. Some people may experience worsened symptoms, such as pneumonia and shortness of breath. On the other hand, older people are at higher risk of severe illness from COVID-19, and the risk increases with age. People with existing medical conditions may have a higher risk of serious illness. The decision on whether to test for COVID-19 can be made based on the individual patient's verbal appearance, whether they have virus symptoms, and how severe they are. Therefore, an inference system bringing out proper human logic capabilities can be developed to support the decision of whether to test or not, to clarify the virus symptoms of the person, to make numerical data to get relative results and to make quickly decisions [11].

Therefore, this paper discusses the study with a primary objective uses of the expert system based on fuzzy logic for experts and physicians to help early detection of COVID-19 infection risk and precise method and to obtain a numerical output on symptoms of the virus from every person.Medical diagnosis is a complex process in the medical field since the related symptoms can be complicated and unclear. Today, medical diagnosis procedures are carried out with the help of computer-related technologies based on human reasoning, which is increasing daily. These systems are primarily based on the principles of artificial intelligence. They are designed not only to make a diagnosis based on symptoms but also to prescribe treatments based on Fuzzy's medical diagnostic decision. On the other hand, the outputs of this approach help both to gain awareness and to be able to take apart information by synthesizing and choosing the suitable options. Thus, alternative studies on intelligent systems that provide rapid results regarding COVID-19 symptoms are critical to help detect whether a person has been infected with the virus.

2. Review of Literature

In recent years, there has been a growing interest in the application of fuzzy logic in various domains, particularly in the development of expert systems for medical diagnosis and decision-making processes. This review synthesizes the findings from a selection of studies

that have explored the use of fuzzy logic in different applications, ranging from medical diagnosis to decision support systems.

Saritas et al. (2003) presented a fuzzy expert system designed for the diagnosis of prostate cancer [23]. Their work highlighted the potential of fuzzy logic in handling uncertain and imprecise data in medical diagnosis, particularly in the context of cancer detection.Balanică et al. (2011) evaluated breast cancer risk using fuzzy logic [24]. Their study demonstrated the effectiveness of fuzzy logic in assessing complex medical conditions like cancer risk, where traditional binary classification may not capture the nuances of the disease.Zarei et al. (2012) employed fuzzy modeling and control techniques in the context of HIV infection [25]. Their research showcased the utility of fuzzy logic in modeling dynamic systems and optimizing control strategies, particularly in healthcare applications.Rao et al. (2013) developed a rule-based expert system for fever diagnosis using fuzzy logic [26]. Their work illustrated how fuzzy logic can be applied to interpret symptoms and make diagnostic decisions in medical contexts where uncertainty and vagueness are prevalent.Sharma (2020a) provided a comprehensive overview of fuzzy logic theory, laying the groundwork for understanding its applications across various domains [27]. The author discussed the principles and concepts of fuzzy set theory, elucidating its relevance in dealing with imprecise information.Building upon the theoretical foundations, Sharma (2020b) explored the applicability of fuzzy set theory concepts in practical scenarios [28]. The study discussed how fuzzy logic can be effectively utilized in decision-making processes to accommodate ambiguity and uncertainty.In a different domain, Sharma et al. (2013) investigated trends in fuzzy graphs, highlighting the versatility of fuzzy logic in representing and analyzing complex networks and relational structures.

Furthermore, Sharma (2012) and Sharma (2013) discussed the application of fuzzy logic in decision-making systems and intelligence cycles, respectively [30,31]. These studies emphasized the role of fuzzy logic in handling uncertain information and generating alternatives in decision-making processes.Finally, Sharma (2019) provided an overview of various applications of fuzzy generated systems, ranging from industrial control to pattern recognition [32].

The study underscored the diverse range of domains where fuzzy logic techniques can be effectively applied. So, the reviewed literature demonstrates the wide-ranging applications of fuzzy logic across various domains, including medical diagnosis, decision support systems, graph theory, and intelligence cycles. These studies collectively highlight the flexibility and

adaptability of fuzzy logic in handling uncertain and imprecise information, making it a valuable tool in diverse problem-solving contexts.

3. Leveraging Fuzzy Logic Frameworks for Enhanced Diagnostic Systems

Fuzzy set theory, along with fuzzy logic, is a very suitable and applicable basis for constructing knowledge-based systems in medicine for various tasks such as the interpretation of sets of medical findings, syndrome differentiation, diagnosis of diseases, mixed diagnosis of integrated medicine, the optimal selection of medical treatments integrating medicine, and for real-time monitoring of patient data. [5], [6]. The application of fuzzy logic in the medical field started in the early70's. After that, the paper was published by Zadeh (1965). One of the most essential fields developed by Zadeh is the Fuzzy Rule rule-based system [10]. Many researchers have used fuzzy expert systems for medical diagnosis of Asthma[18], Heart Disease[19], Malaria[20], Cancer[21,22,23], HIV[24], and Fever[25].

4. Discussion and Analysis

The prediction and diagnosis of COVID-19 disease is significant for everyone, especially for medical professionals. The uses of fuzzy-based logic in the medical field are increasing rapidly. This research paper discusses the fuzzy systems designed for early deduction of COVID-19. For example- in the fuzzy expert system model for determining coronavirus risk, Pius UagbaeEjodamen and Victor EshietEkong developed this model, simulated it with MATLAB, and tested sample data. The outcome shows that the model was a handy decision support tool for early evaluating people's COVID-19 health status [12]. B.T. Jadhav and G.S. Nhivekar designed a modal for the Severity Measurement of COVID-19; the system has input parameters, including temperature, oxygen level, and heart rate, defined with three fuzzy linguistic values. The output variable severity diagnosis has average, medium, and high undefined linguistic values by the unclear membership value. The model is designed to view the resultant output of the FIS while provided with the input data. The resulting production is used for input clinical parameter random number generator [13].

An innovative fuzzy inference system was designed by MaadShatnawi et al. In this work, an intelligent fuzzy inference system was proposed for the early diagnosis of COVID-19 based on the patient's symptoms, including fever, cold, cough, flu, throat infection, breathing difficulties, and headache. The COVID-19 fuzzy inference system was designed by identifying the input and output variables and each variable's fuzzy sets and membership functions. Then, fuzzy rules relating to input and output variables are set. This inference system diagnoses COVID-19 based on the patient data. The designed system applied the

Mamdani Fuzzy model to build the COVID-19 inference system. They define nine symptoms as the input variables to the inference system and categorize these variables into two categories: most common symptoms and less common symptoms. The most common symptoms category includes tiredness, fever, and dry cough.

In contrast, the less common symptoms include loss of taste or smell, headache, diarrhea, sore throat, conjunctivitis, and breathing difficulties. The output variable is the risk of being COVID-19 infected or not [14]. Sathyapriyas et al. analyze COVID-19 using fuzzy logic, and the valuable educative tool MATLAB is used to materialize the analysis on decision-making. They used the symptoms of COVID-19 as inputs and analyzed the positive results of COVID-19 patients [15].Deepak Painuli et al. developed a fuzzy rule-based system for predicting Covid-19. This system uses 11 symptoms like age, sex, fever, dry cough, breathing problem, flu and cold, medical history, travel history, and two recently identified symptoms by some infected patients: loss of hearing ability and sense of smell. This system predicts whether the patient is suffering from the Coronavirus by comparing his symptoms with those of COVID-19 as declared by the World Health Organization. The main aim of this model is to avoid exertion and to make people check their symptoms and find the probability of being infected by COVID-19. Novel Coronavirus remains on the human body for 14 days, so it might be possible that for the duration of early stages of infectivity, there are no symptoms. Still, if the patient has any medical history or might travel to the infected country or might come in contact with an infected person, then they have to do this estimation daily for up to 14 days. This model can only help those who can identify their symptoms, but if someone is unaware of the virus and has been exposed to other persons, it is highly believed that those persons might be infected by that person [16].

HakanSimsek et al. constructed a more practical and valuable Mamdani-type fuzzy inference intelligence technique for experts and doctors to identify COVID-19 infection risk and to get a numerical output on symptoms of the COVID-19 virus from every person coming testing for COVID-19. They designed three FISs based on different symptoms and then obtained the personal risk index of an individual by combining the outputs of these subsystems in a final FIS. Numerical output can also be helpful in terms of self-control to help individuals make decisions about seeking appropriate medical care such as Centers for Disease Control and Prevention [17].

5. CONCLUSION

Based on the above discussion, there are many ways to diagnose COVID–19 patients with symptoms at an early stage. The system is also able to make decisions even in a difficult situation. As discussed earlier, the fuzzy expert system applies the fuzzification procedure where the membership functions are defined on the input variable; this helps to evaluate the degree of truth for every rule. Each rule represents a symptom; every disease has specific symptoms at an early stage. Then, the fuzzy rule-based system finds the result regarding membership value. Finally, the defuzzification procedure is used to find output as a crisp value, defined as a mild, moderate, or severe condition. The assessment on whether to test for COVID-19 can be made based on the individual applicant's verbal expression of whether they have symptoms of the virus and how severe the symptoms are. Therefore, an expert system bringing out suitable human reasoning capabilities can be developed to maintain the decision of whether to test or not, to make further clear the virus symptoms of the person, to make them numerical data and to get comparative results, and to handle growing demand better and make fast decisions. In this paper, we discussed different fuzzy expert systems related to fuzzy logic, fuzzy inference systems, expert knowledge, related literature, and information from WHO for describing an early diagnosis of the personal risk index of the COVID-19 pandemic.

No doubt, the above fuzzy expert systems are presented to support medical diagnoses, reduce health costs, and take advantage of health resources based on accurate data preferred by medical groups. Both health centers and patients will benefit as the doctors can save time diagnosing patients and focus more on treating COVID–19 patients. Patients can diagnose themselves and get the proper treatment as soon as possible. Every patient can use the system independently, saving time and money. Only when the system states that the patient is suffering from COVID-19 can the patient seek medical attention from the nearest hospital. This expert system can be located anywhere, including airports, bus stations, grocery shops, train stations, and even on individual devices.

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