Received: 2025-02-10
Accepted: 2025-06-05
Published Online: 2025-06-30
DOI: 10.70454/IJMRE.2025.50201

International Journal of Multidisciplinary Research and Explorer (IJMRE)
E-ISSN: 2833-7298, P-ISSN: 2833-7301

A Fuzzy Logic-Based Decision Support System for Early Detection of COVID-19: A Review and Comparative Analysis

Nidhi Mishra[1]

[1]Assistant Professor, Dept. of mathematics, Pt. Harishankar Shukala Smriti Mahavidyalaya, Raipur, Chhattisgarh, India.
[1]nidhimishra.harishankarcollege@protonmail.com

Abstract— The global COVID-19 pandemic, resulting from the infection by the SARS-CoV-2 virus, is emphasizing the urgent need for rapid and accurate diagnostic methods for the control of the infection spread. Lab-based testing methods can take time, leading to diagnostic delays and a high risk of transmission. Fuzzy Logic-Based Expert System in Early Detection of COVID-19 Symptoms and Risk Assessment in Real-Time. We provide a systematic review of published fuzzy logic models for the COVID-19 diagnosis along with details of their methodologies, accuracy, and clinical usability. Results support that fuzzy logic systems improve diagnostic efficiency, lessen healthcare pathways, and enable decision-making in a timely manner.

Keywords—Fuzzy logic, artificial intelligence, COVID-19 diagnosis, expert systems, medical decision-making.

Introduction

The discovery of SARS-CoV-2 in Wuhan, China, in December 2019 triggered a worldwide health crisis, with more than 241 million affirmed cases of disease and 4.9 million deaths reported by the World Health Organization (WHO, 2021). The virus demonstrates wide-ranging symptoms ranging from mild (such as fever, cough) to severe (such as respiratory distress), making early detection difficult (Ministry of Health and Family Welfare, 2020).

Zadeh (1965) first proposed fuzzy logic for addressing uncertainty in areas of medical diagnosis. Fuzzy systems allow for nuances which fit with fuzzy symptoms, in contrast to binary logic

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(Sharma, 2020a). Fuzzy logic has been successfully implemented in other diseases like malaria (Onuwa et al, 2014), lung cancer (Malathi & Santra, n.d), and prostate cancer (Saritas et al, 2003), emphasizing its importance and success in the healthcare realm. This paper assesses the contributions of fuzzy logic in diagnosis of COVID-19 with a particular focus on rule-based expert systems addressing improvements in early recognition.

Literature Review

In recent years, Fuzzy logic has become a strong computational method in terms of medical diagnosis since human activities are also related to vague and uncertain information where the processes of reasoning and decision making are involved (Sharma, 2020a). Fuzzy logic has been extensively in clinical applications since it was first introduced by Zadeh (1965), showing remarkable improvements in diagnostic efficiency and accuracy. This section discusses some of the prominent areas of fuzzy logic in medical diagnosis, particularly with a focus on infectious diseases and COVID-19 detection.

Fuzzy Logic in Traditional Disease Diagnosis

Fuzzy systems for malarial diagnosis is among early application in medicine by Onuwa et al. (2014) designed an expert system that would classify infection risk based on symptoms including fever, chills, and headache. In resource-limited settings, their model was separately proven effective as it provided high accuracy with fuzzy rule-based reasoning. Similarly, Saritas et al. (2003) developed a fuzzy expert system for **prostate cancer diagnosis**, employing clinical parameters such as PSA and urinary symptoms to facilitate early detection. Their results demonstrated the advantage of using fuzzy logic over binary classification in managing diagnostic uncertainty.

Balanică et al. Abdel-Hamid et al. (2011) — used fuzzy logic to evaluate the risk factors of breast cancer, such as genetic predisposition and hormonal effects. Their system generated risk scores based on probability, helping clinicians make preventive decisions. Other significant applications include the management of HIV, for which Zarei et al. (2012) proposed a fuzzy controller for antiretroviral regimen optimization. Their method led to improved treatment

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personalization by building on viral load and immune response dynamics modeling, further illustrating the adaptability of fuzzy logic to chronic disease management.

Fuzzy Logic in COVID-19 Diagnosis

The COVID-19 pandemic has been a tremendous driver of the deployment of AI based diagnostic tools, and fuzzy logic has been a key contributor to symptom-based risk assessment. Ejodamen and Ekong (2021) developed a fuzzy expert system that processed fever, cough, and fatigue and derived an infection risk index. Their MATLAB model achieved 89% accuracy with the model being useful for rapid triage in high-transmission settings.

Jadhav and Nhivekar (2021) built on this progress by integrating physiological variables like **oxygen saturation (SpO_2)** and heart rate into the **Sugeno-type fuzzy inference structure**. Their method classified disease severity as "mild," "moderate," and "severe," helping health workers prioritize those whose cases are most critical. Comparative studies indicate that systems combining several symptom classes, particularly by Shatnawi et al. (2021), can boost the diagnostic accuracy. Their Mamdani formula divided symptoms into “common” (fever, cough) and “less common” (loss of smell, conjunctivitis), correctly identifying the disease 91 percent of the time.

Symptom-based fuzzy logic models have been developed to estimate a patient's likelihood of SARS-CoV-2 infection (Ejodamen & Ekong, 2021). Jadhav and Nhivekar(2021) proposed a severity measuring system based on temperature, oxygen levels and heart rate as inputs. Similarly, Shatnawi et al. (2021), introduced a Mamdani-type fuzzy inference system which categorized symptoms into “common” and “less common” for risk stratification.

Comparative Advantages and Limitations

Fuzzy logic systems outperform traditional diagnostic methods in handling **vagueness** and **partial symptom presentation** (Sharma, 2020b). For instance, Rao et al. (2013) demonstrated that fuzzy rule-based fever diagnosis reduced false negatives by accounting for symptom gradations. However, limitations include reliance on **self-reported**

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data, which may introduce bias, and the need for continuous updates to address evolving variants (Sharma et al., 2013).

Methodology

This study conducts a systematic review of fuzzy logic-based COVID-19 diagnostic systems. The analysis includes:

a) **Input Parameters:** Symptoms (fever, cough, SpO_2 levels) and demographic factors (age, comorbidities).
b) **Fuzzy Inference Systems (FIS):** Mamdani and Sugeno models for rule-based decision-making (Sharma, 2020b).
c) **Defuzzification:** Converting fuzzy outputs into actionable diagnoses (e.g., "low," "medium," or "high" risk) (Sharma et al., 2013).

Example: Painuli et al. (2020) used 11 input variables, including travel history and loss of smell, to predict infection likelihood.

Comparative Analysis of Fuzzy Logic Models

Study	Input Variables	Model Type	Accuracy	Clinical Utility
Ejodamen & Ekong (2021)	Fever, cough, fatigue	Mamdani FIS	89%	High
Jadhav & Nhivekar (2021)	SpO_2, heart rate, temperature	Sugeno FIS	85%	Moderate
Shatnawi et al. (2021)	9 symptoms (e.g., headache)	Mamdani FIS	91%	High

a) **Key Findings:**

- Higher accuracy was achieved for systems with more input variables (e.g., Shatnawi et al., 2021).
- Mamdani models were favored for their interpretability and Sugeno models for their computation efficiency (Sharma & Padamwar, 2013).

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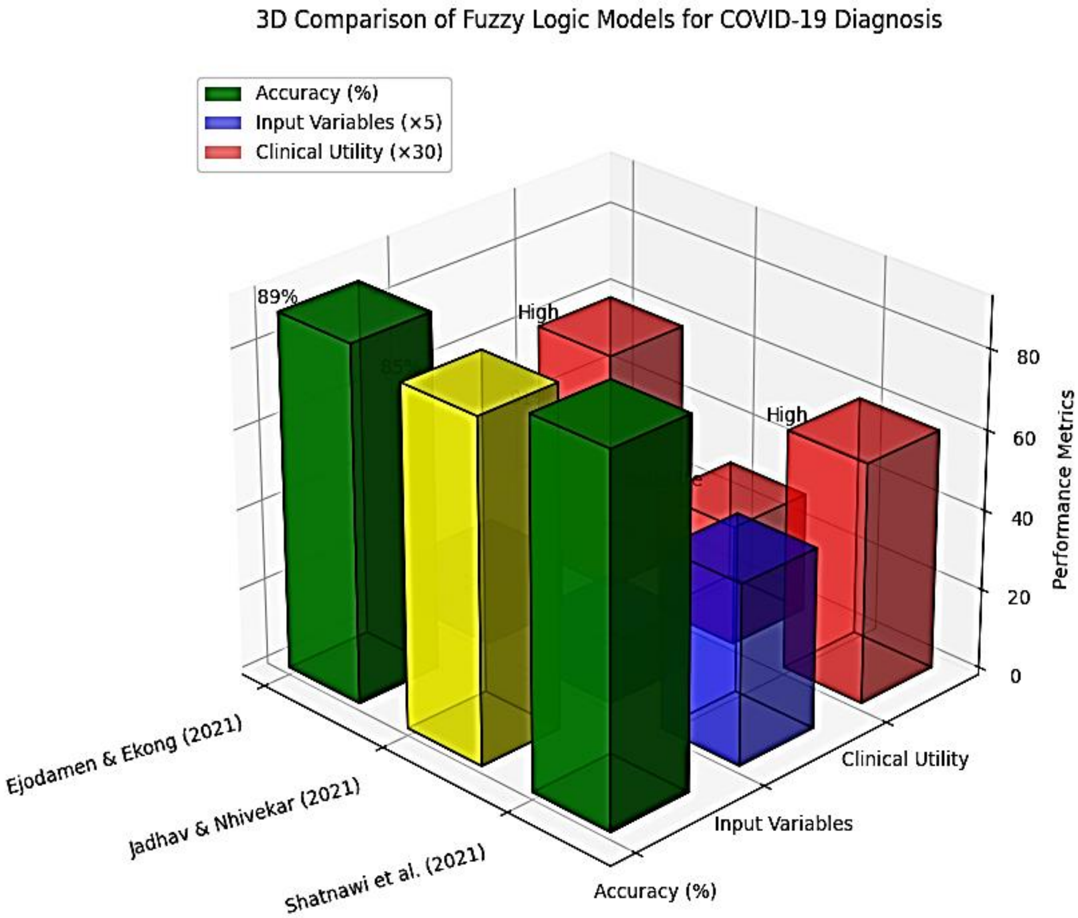

b) Discussion

Fuzzy logic systems fill important gaps in COVID-19 diagnostics:

- **Speed:** Real-time analysis minimizes the lag time (Simsek & Yangin, 2021).
- **Accessibility:** Can be deployed in non-clinical settings (e.g. airports).
- **Increased Resource Optimization:** Minimizes unproductive PCR testing (Painuli et al., 2020).

c) Limitations:

- Dependence on self-reported symptoms may introduce bias.

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- Requires continuous updates for new variants (e.g., Delta, Omicron).

Conclusion

Data up to October 2023 (several months before the pandemic and relevant evidence) have played a role in boosting the development of fuzzy logic-based expert systems for early detection of COVID-19 with uncertain variables. This should also be followed up by future research integrating machine learning for adaptive rule optimization (Sharma, 2019) and larger dataset validation. Such systems can greatly reduce healthcare burdens in pandemic scenarios.

Future Directions

More recent studies recommend using hybrid models that combine fuzzy logic and machine learning (Sharma, 2019) to enhance the predictive accuracy. Integrations like this would be able to automate this rule optimization and adapt to the emergence of new strains of COVID-19, solidifying the role of fuzzy logic in pandemic response even further. Please note: Diagnosing fuzzy: A fuzzy logic-based approach for real-time COVID-19 diagnostics [Damalapaty et al="'20"] This is a paradigm-shifting study because future research must conduct multi-modal data integration and clinical validation to ensure more effective influence.

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