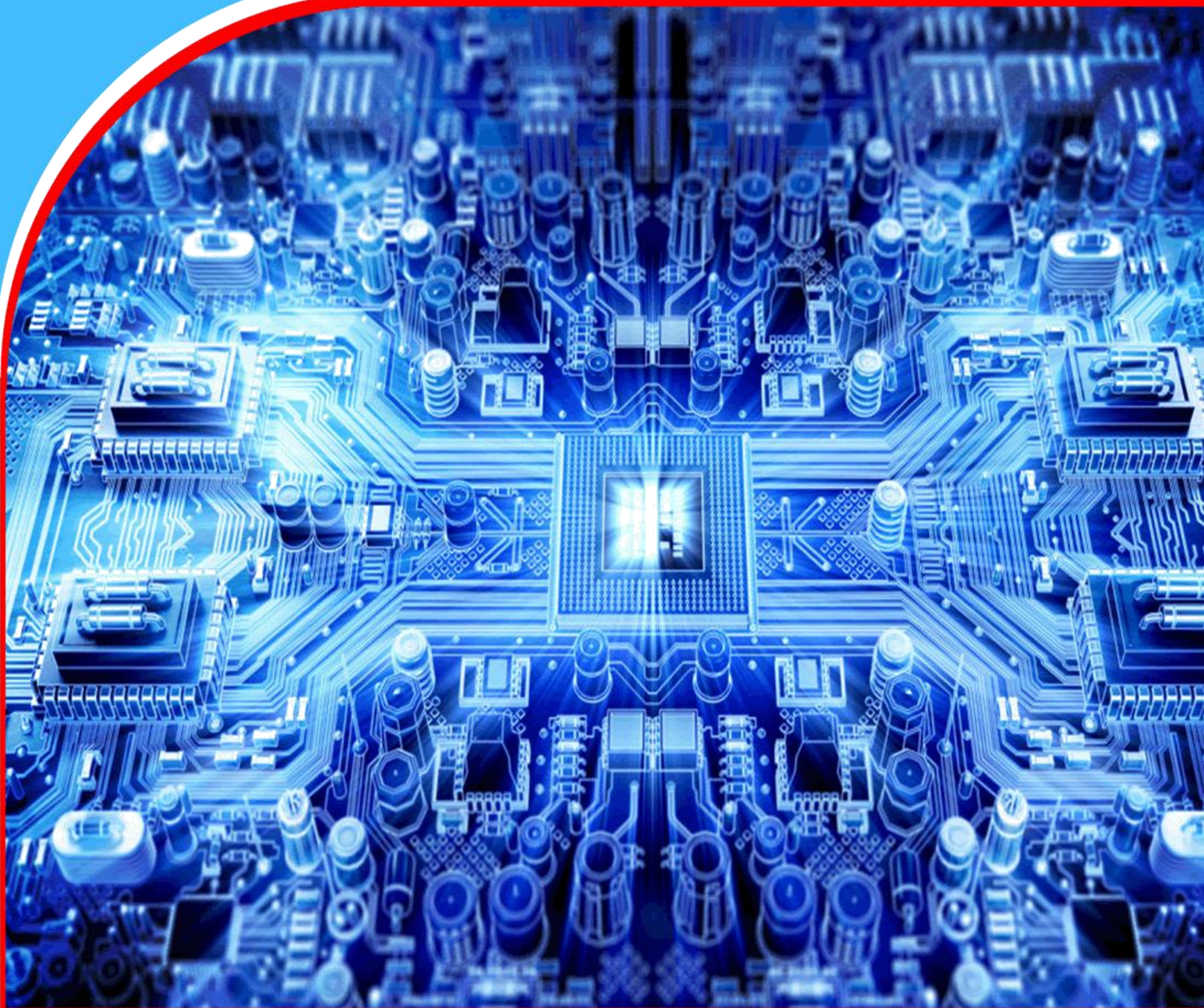
American Journal of
Computing and Engineering
(AJCE)



IoT and Fuzzy Logic Applied to Smart Public Hall for COVID-19 Monitoring System

Nyakuri Jean Pierre, Harerimana Felix, Karanguza Francois, Niyomufasha Ghadi, Mirembe Jean D'Amour, Uwimana Jean Lambert, Habiyaremye Theogene, Ndayisenga Jean Claude, and Bizimana Judith

AJP

American Journal of Computing and Engineering
ISSN 2790-5586 (Online)
Vol.6, Issue 1, pp 1 – 13, 2023
www.ajpojournals.org

IoT and Fuzzy Logic Applied to Smart Public Hall for COVID-19 Monitoring System

Nyakuri Jean Pierre[1*], Harerimana Felix[1], Karanguza Francois[1], Niyomufasha Ghadi[2], Mirembe Jean D'Amour[1], Uwimana Jean Lambert[1], Habiyaremye Theogene[2], Ndayisenga Jean Claude[2], and Bizimana Judith[3]

[1]Electrical and Electronics Department, Rwanda Polytechnic-Integrated Polytechnic Region College of Gishari (IPRC-Gishari)

[2]Mechanical Engineering Department, Rwanda Polytechnic-Integrated Polytechnic Region College of Gishari (IPRC-Gishari)

[3]ICT Department, Rwanda Polytechnic-Integrated Polytechnic Region College of Huye (IPRC-Huye)

[*]Corresponding Author's E-mail: njpindian@yahoo.fr

Article History

Received: 30th Jan 2023
Received in revised form: 21st Feb 2023
Accepted: 27th Feb 2023

Abstract

Purpose: Since the breakout of COVID-19 pandemic, various preventive measures have been put in place by WHO to prevent the spread of this disease. However, some people are unaware or less likely to follow rules regarding hygiene, physical distancing, properly wearing of face mask and body temperature measurement. One of the best solutions to this challenge is the introduction of the internet of things (IoT) technology to assist in implementation of the preventive measures. This paper presents an IoT-enabled solution that uses Fuzzy logic controller to assess the risks of being COVID-19 infected and monitor environment conditions in the public hall to limit the spread of the coronavirus.

Methodology: The proposed model employed sensors to measure in real-time the body temperature, hand sanitization, wearing of face mask, room ventilation and IP cameracontrolled by Fuzzy logic controller for decision making. In addition, it uses raspberry-pi for processing and data transmission to the cloud, liquid crystal display (LCD) for displaying data and web application was developed for user interface. The resulting sensor measurements were simulated using MATLAB software and the system made automatic decisions.

Findings: A prototype was implemented effectively and the results obtained from the system were fast, accurate, efficient and cost effective when compared to other commercially available systems.

Unique Contribution to Practice: The actual practice for implementing the preventive measures require the presence of the health care personnel (HCP) which is time consuming and risky for HCP. Therefore, this system works autonomously and effectively in monitoring and controlling the implementation of the COVID-19 preventive measures in the public hall.

Keywords: *Fuzzy logic, public hall, sensor, IoT, raspberry-pi, COVID-19*

INTRODUCTION

The breakout of COVID-19 pandemic has changed and exacerbated the human life style due to its strict preventive measures to limit the spread of this highly infectious disease[1]. In Rwanda, the total number of confirmed cases was 133 thousand with 1.6 thousand deaths and 665 million confirmed cases with 6.73 million deaths globally by January 2023 and it was still increasing[2]. The threatening to this speedy transmissible disease caused the closure of most of activities including education, business, tourism, transport and others and even prompted lockdown [3]. Since there is no pharmaceutical treatment and low vaccination rate, the effective way for combating COVID-19 transmission is the appropriate implementation of the non-pharmaceutical intervention (NPIs) such as face masks, hygiene measures, social distancing, well ventilated mass gatherings and even restricting movement [4].

The adoption of Artificial Intelligent (AI) in conjunction with ICT technologies has shown its effectiveness to contain the spread of COVID-19. AI and robotic technology solutions have been used in Rwanda as an efficient tool for control and management of COVID-19 pandemic[5]. AI and data science are now used in expediting diagnosis, containing, analyzing, and predicting COVID-19 in a quick, scalable, and effective manner[6]. Robotics utilization in healthcare management for COVID-19 has been implemented for patient care and treatment monitoring, and so far, it is supporting both healthcare professionals and epidemiologists [7].

AI and robots systems are also used to reduce interpersonal interaction, perform hospital cleaning and sterilization and help in patient monitoring with the overall objective of minimizing viral transmission to doctors and other medical professionals actively[8]. In Rwanda, robots are employed for taking the temperature measurements, providing foods and medications to patients in isolation rooms to minimize physical contact. Therefore, the ICT not only facilitate healthcare professionals and patients, but also improve overall healthcare facility efficiency by decreasing healthcare workload in managing the pandemic [9]

One of the growing popularity application of IoT technology in healthcare is the control and monitoring of infectious diseases[10]. In the context of COVID-19 pandemic, The IoT technology has proven significantly potential in the NPIs and healthcare monitoring systems [7]. The IoT platform provides capabilities of diagnosing, treating and monitoring COVID-19 patients more easily, due to its ubiquitous ability of sensing, actuation and seamless connectivity[11]. IoT-enabled wearable devices use Artificial Intelligence model for monitoring the entrance of mass gathering places to reduce the spread of the virus. The smart and autonomous devices with low human intervention enable a safe environment and enforce preventive measures for controlling the spread of infection diseases in the community[12].

In this paper, an AI system based on Fuzzy inference system and IoT technology for COVID-19 Monitoring is proposed for preventing, diagnosing and monitoring of the Coronavirus transmission in the enclosed space. The Raspberry pi 3 development board is used to gather data from the sensor unit, processes it and make decision according to the Fuzzy logic controller (FLC)[13][14]. The system also, consists of the sensing unit that uses contactless temperature sensor MLX 90614 to measure the body temperature, PIR sensor for hand sanitization and IP Camera to check the wearing of the face mask for monitoring the entrance door. It also uses the ambient temperature and relative humidity sensor HDT11 as well as air quality sensor MQ-2 for monitoring hall air ventilation. The resulting data is displayed on LCD and stored to the cloud platform where it can be accessed through the web application. Finally, MATLAB software is used to simulate the Fuzzy logic model.

LITERATURE REVIEW

The threatening to the entire world due to COVID-19 pandemic has drawn attention of many researchers to find solutions to tackle the spread of this highly transmissible disease. This section outlines the currently works done related to ICT, Artificial Intelligence and IoT solutions for COVID-19 containment.

ICT technologies have been used for raising the public awareness about COVID-19 pandemic[15]. Digital platforms (social media, mobile apps, SMS and others) play vital role for providing alternative digital solutions including early warning, remote diagnosis and monitoring as well as health care delivery[16][17]. Elliot et al. [18] and Florian V. et al. [19] described the integration of emerging technologies into COVID-19 contact tracing system for mitigating and breaking the transmission chains of coronavirus including contact tracing apps, 5G, GPS system, AI, IoT, blockchain, Geographical Information Systems (GIS), robotics and nanotechnologies. However, these technologies face challenges such as interoperability, standardization issues, widespread of the internet connectivity, low usage of smart phones and limited related infrastructure issues [20].

AI-powered tools for the diagnosis, screening and surveillance of COVID-19 have been developed. César Melo et al. [21] and Fan Yang et al. [22] developed and validated deep learning (DL) algorithms for detecting the wearing of face masks and body temperature on the human face area using RGB cameras and thermal camera. The combination on AI and Machine Learning (ML) algorithms has been used for predicting the risks of getting infected based on hygiene habits, age, travel history and current health status [23][24]. Q. V. Pham et al. [25] described AI algorithms for COVID-19 big data analytics to estimate and predict the pandemic level of severity, vaccines development and rapid patient development.

The adoption of IoT technology has played an important role for prevention, diagnosis and treating COVID-19 pandemic. B Varshini et al.[26] proposed an IoT-enabled smart door for opening and closing door by monitoring body temperature and face mask detection using machine learning techniques. This proposed system is limited to temperature monitoring and face mask detection. D. D. Putra et al. [27] developed a smart-Gate for COVID-19 Early Prevention at Public Area based on artificial intelligence to be integrated with the INCEPS website. This smart gate was limited at checking whether people are wearing face masks properly and activate a notification.

Abuzairi et al. [28] implemented non-contact infrared thermometer mounted on the wall which do not require operator for overcoming the challenges of hand held thermometer. Ashok G. et al. [29] developed a contactless hand sanitizer dispenser that has a built-in temperature monitoring system and an alarm system for users who display infection-related symptoms. These solutions also are limited to the body temperature screening and sanitization issues while several parameters need to be investigated to minimize the transmission of the pandemic.

After reviewing the related works and identifying current possible solutions and their gaps, a novel IoT solution to be applied in public hall was proposed to optimize the monitoring and containment of the pandemic in the enclosed room.

SYSTEM DESIGN

The overall architecture design of the proposed system is presented in this section. The system consists of the sensing, processing, actuating and the data communication subsystems as illustrated in the figure1. The system flow chart is then described followed by the Fuzzy logic algorithm development for decision making.

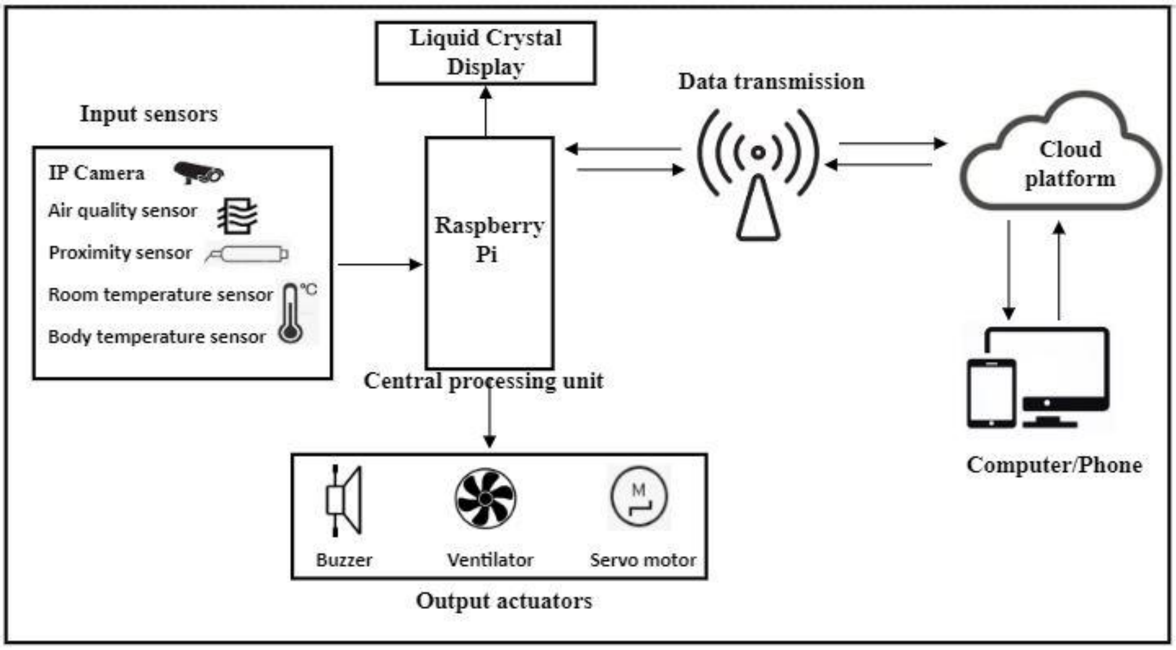


Figure 1: General system architecture of the proposed solution

Sensing Subsystem

The sensing subsystem is the crucial part of the system since it collects all necessary data for the proper function of the remaining parts. It consists of a Personal Infra-red sensor (PIR) and proximity sensor that detects the presence of a human body for activation of the system; a room ventilationsensor (SCD30) that detects the temperature and humidity to determine the relative room ventilation; a non-contact temperature sensor (MLX90614) that measures the exact body temperature of a person exposed to its field as well as the wearing of facemask detected by the IP camera both mounted on the entrance door of the hall. All data collected by each sensor is sent to the central processing unit (Raspberry-pi 3) for further processing and analysis and for decision making in the Fuzzy logic controller.

Processing Subsystem (Raspberry-pi 3)

The processing unit receives data from sensing unit processes it according to the program instructions stored in its memory and produces the result for actuation, data storage and data communication. The raspberry-pi3 development board with 40pins GPIO header (fully backwards compatible with previous boards which enable to collect and process many physiological) is used as a central unit to gather data from sensor modules processes them and activate different functions includes buzzer, door and room ventilator.

Actuation Subsystem

An electrical actuator is a device that converts electrical energy into mechanical force to move or control a mechanism or a system. In this system there are three actuators: An electrical ventilator, buzzer and a servo motor. The electric ventilator is used to monitor the normal room temperature, humidity and ventilation to reduce the risk of spread of the virus. The buzzer is used to warn that the presented person has high risk of being infected and hence preventive measures need to be taken. Finally, the servo motor monitors the opening and closing of the door for a single person if he fulfils the normal required conditions. All information is displayed on the Liquid Crystal Display (LCD) mounted on the main entrance to indicate the data measured and the decision taken for particular person with recommendation.

Data Communication Subsystem

Data is communicated between the system deployed in the public hall and the cloud platform for better remote monitoring through a router. Data collected from sensors is processed by the Raspberry-Pi 3 (The central unit) at the edge of the network and make the right decision based on Fuzzy inference system. The results and decisions made from the processing unit at the edge are communicated to the cloud platform for being easily accessed on the designed Web application via PC or Smart phone.

System Flow Chart

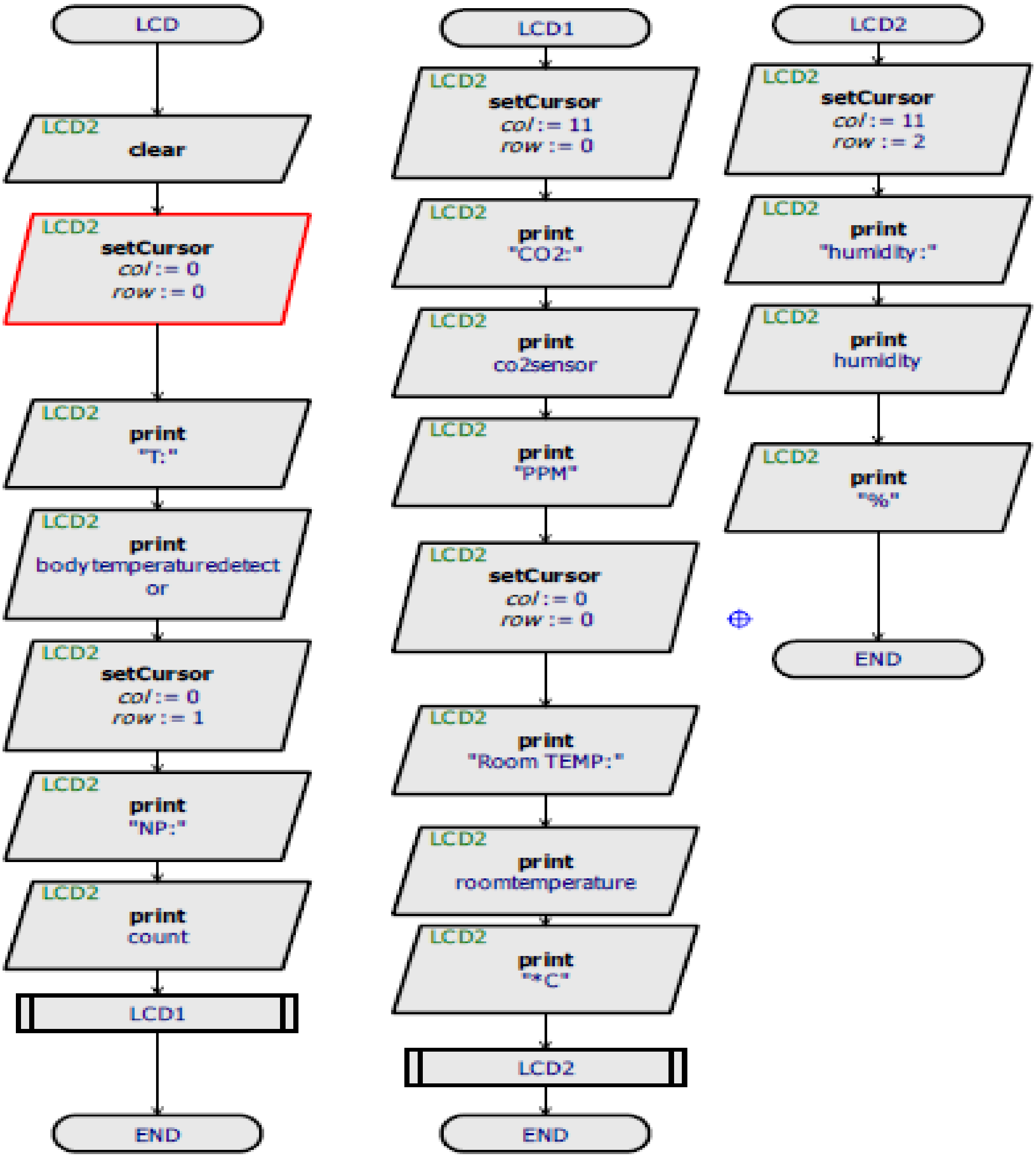


Figure 2: Flowchart of the smart public hall for COVID-19 monitoring system

Step1: Configure raspberry –pi to internet connection for sharing information with clouds.

Step2: Configure IP camera, body detector sensor, LCD display, room temperature, and humidity sensor, and servomotor to a raspberry pi.

Step3: Display prints number of entered person, and temperature from sensors that are fixed on the gate.

Step4: Display prints the temperature, humidity, and Co_2 in the hall by using sensors, which are fixed, in the hall.

Step5: Raspberry pi Stores the readings from all sensors to its memory and to the Cloud.

Step6: if motion sensor gets human being, the motion sensor inputs signal to raspberry Pi.

Step7: Body temperature sensor checks the temperature of entering human and IP camera checks if the entering human worn facemask.

Step8: If the entering human worn facemask and its body temperature is not greater than 35 and not less than 37.8.

Step9: Hand sanitizer sprays sanitizer to the human if his/hand is placed under hand sanitizer and thereafter the door opens for him/her.

Step10: Raspberry pi count the entered person and send to cloud.

Step11: Else , the entering human is not completing the information describe in Step8 , Step9, and Step 10,no sanitizer provided and doors will remain closed.

Step12: If room temperature becomes greater than 20 centigrade and less than 24 centigrade, the ventilator rotates at 50 percent of its full speed with help of PWM.

Step13: Else if room temperature becomes greater than or equal to 24, the ventilator rotates at its full speed.

Step14: Else, the ventilator will be off.

FUZZY LOGIC ALGORITHM AND MATLAB SIMULATION

Fuzzy logic approach is a machine learning technique for data analytics and intelligent decision making for uncertain problems based on the degree of truth. Fuzzy logic helps in right decision making as that can be made by human perception and reasoning based on the environment variation rather than convention true or false (1 or 0) logic.

Fuzzy Inference System for Decision Making

A Fuzzy logic algorithm consists of the pseudo-code for the working principle of the program controller from the beginning to the end. The system starts by defining the variable limits of experimental setup of the case. Next, the membership functions are determined according to the work controller in form of triangular or trapezoidal types for this study and this process is called Fuzzification. After, the Fuzzy rule based on IF-THEN sequence is set according to output command as per the needs. By applying the rules to the Fuzzy values the results are obtained and sent to defuzzifier. Finally, the Defuzzifier converts the results form Fuzzy inference into crisp output.

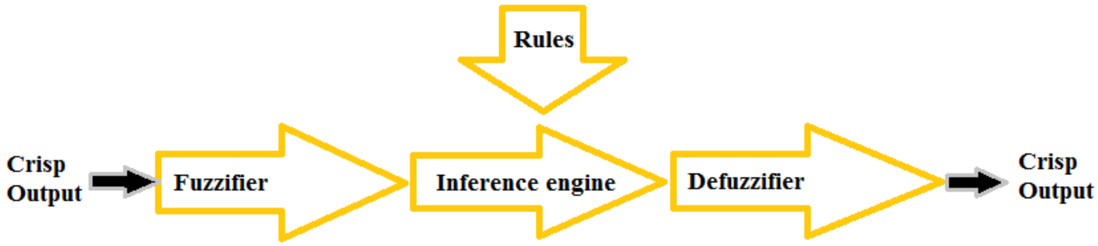


Figure 3: Fuzzy logic systems

Construction of membership functions

In this study, there are three input membership functions for monitoring the air ventilation in the public hall such as temperature, relative humidity and the air quality (CO2) and two input membership functions (such as body temperature and wearing of the face mask) for monitoring people entering in the public hall as illustrated in the Table 1.

Table 1: Input membership functions with their linguistic variables and corresponding ranges

Hall temperature in (^{0}C)		Hall relative humidity (%)		Hall air quality (CO2) (PPM)		Body Temperature(^{0}C)		Wearing of face mask (0 OR 1)	
Linguistic variable	**Range**	**Linguistic variable**	**Range**	**Linguistic variable**	**Range**	**Linguistic variable**	**Range**	**Linguistic variable**	**Range**
Low (L)	0-20	High (H)	60-100	Low(L)	0-400	Low(L)	0-35	NO	0-1
Normal (N)	21-24	Normal (N)	40-60	Normal (N)	400-1000	Normal(N)	35 - 37.8	YES	1-100
Dangerous (D)	25-50	Dangerous (D)	0-40	Dangerous	1000-2000	Dangerous	37.8 - 40		

The output membership functions of the fuzzy inference include the public hall Ventilator speed and opening/closing of the entrance door. The linguistic variables and their corresponding ranges are described in the Table 2.

Table 2: Output membership with their linguistic variables and corresponding ranges

Ventilator speed		Door-Open/Close	
Linguistic variable	**Range**	**Linguistic variable**	**Range**
Low (L)	0-20	YES (Y)	0-1
Medium(M)	20-50	NO(N)	1-2
High (H)	50-100		

Fuzzy Inference System Editor

The Fuzzy logic tool box in MATLAB is used to demonstrate the Fuzzy inference system editor plots for input room temperature, relative humidity, air quality, body temperature and wearing of face mask membership functions. It also indicates the output air ventilator speed and door Open/Close membership functions of the system as illustrated in Figure 4.

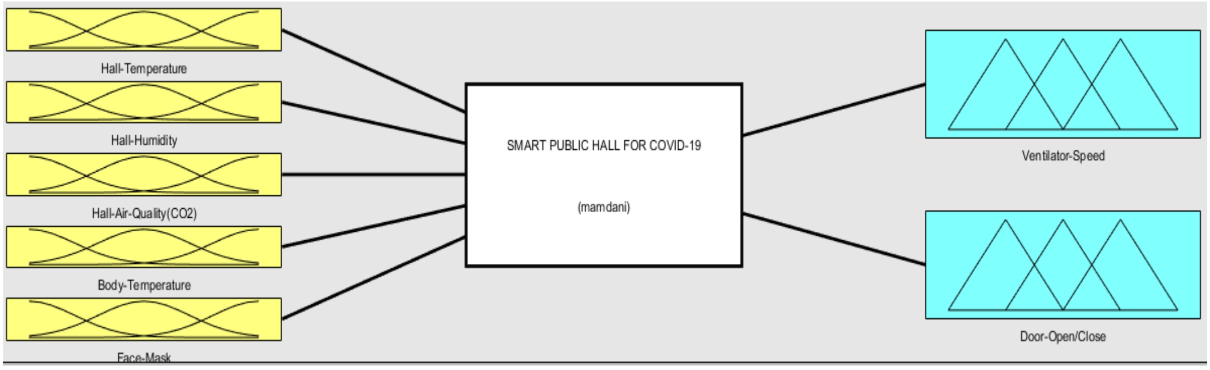


Figure 4 : Fuzzy inference system editor

Fuzzy IF-THEN Rules

The Fuzzy rule system is a set of the IF-THEN rules based on the knowledge of expert in the field of application to address complex real-world problems. The Fuzzy rule system in initiated by measuring the body temperature between 35 and 37.8 degree celsius, IF the condition is met THEN the sanitization system starts and the wearing of the face mask is checked up and IF all conditions are met THEN open the public hall door, otherwise keep the door closed. The Fuzzy rules ends at controlling the speed of the hall ventilator. IF the air quality (CO2) ranges between 400-1000 PPM, hall temperature and relative humidity ranges between 20-24 degree celsius and 40-60 % respectfully, THEN the ventilator speed is at 50% of its maximum speed. Otherwise speed up or slow down the ventilator conditionally as illustrated in the IF-THEN rule figure 5.

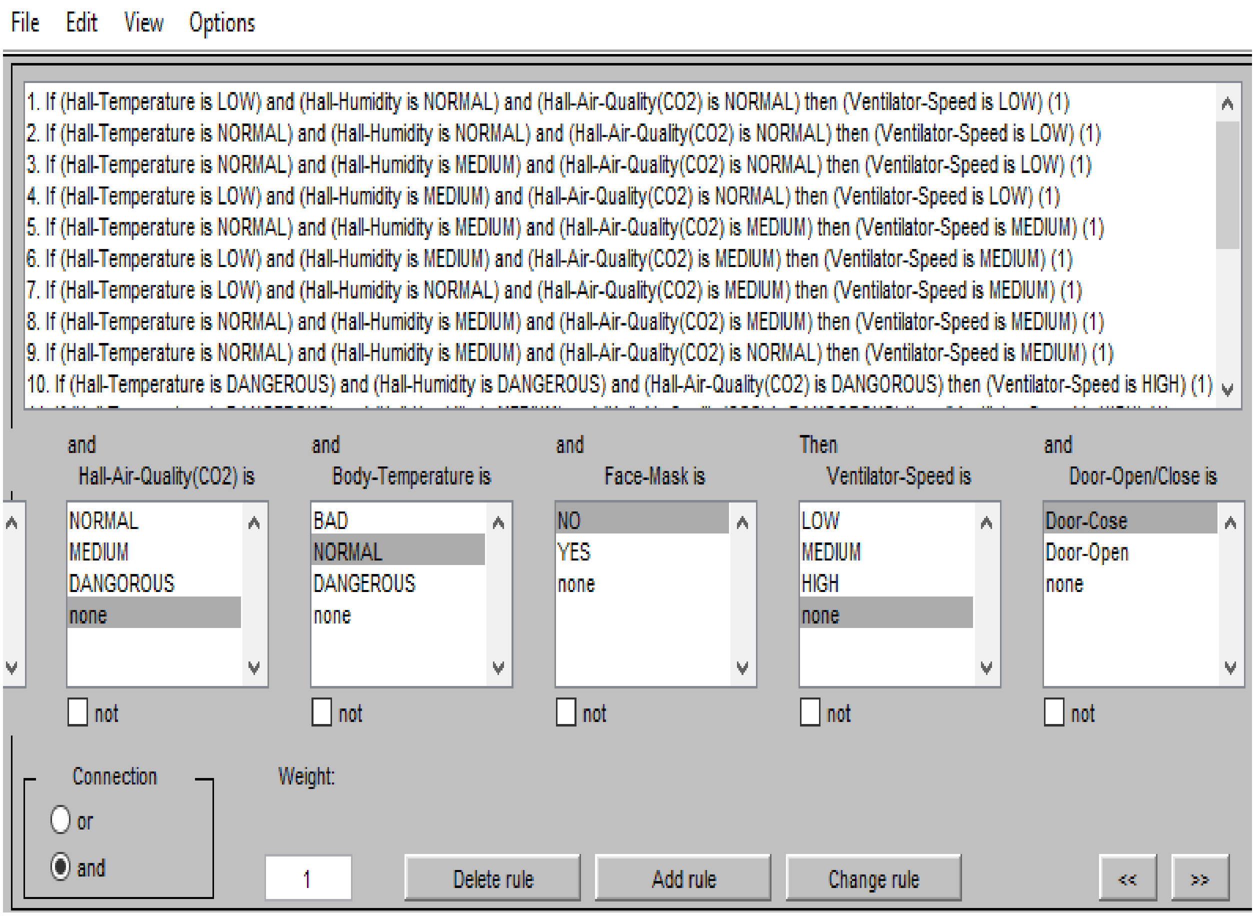


Figure 5: Fuzzy IF-THEN Rules editor

MATLAB Fuzzy logic toolbox results simulation

The general interpretation of the entire Fuzzy inference process is viewed in the Rule viewer. By adjusting the input values of the hall temperature, relative humidity, air quality, body temperature and the wearing of the face mask, you can view the corresponding output of each Fuzzy rule, the aggregated output Fuzzy set and the defuzzified output values as illustrated in the figure Figure 6.

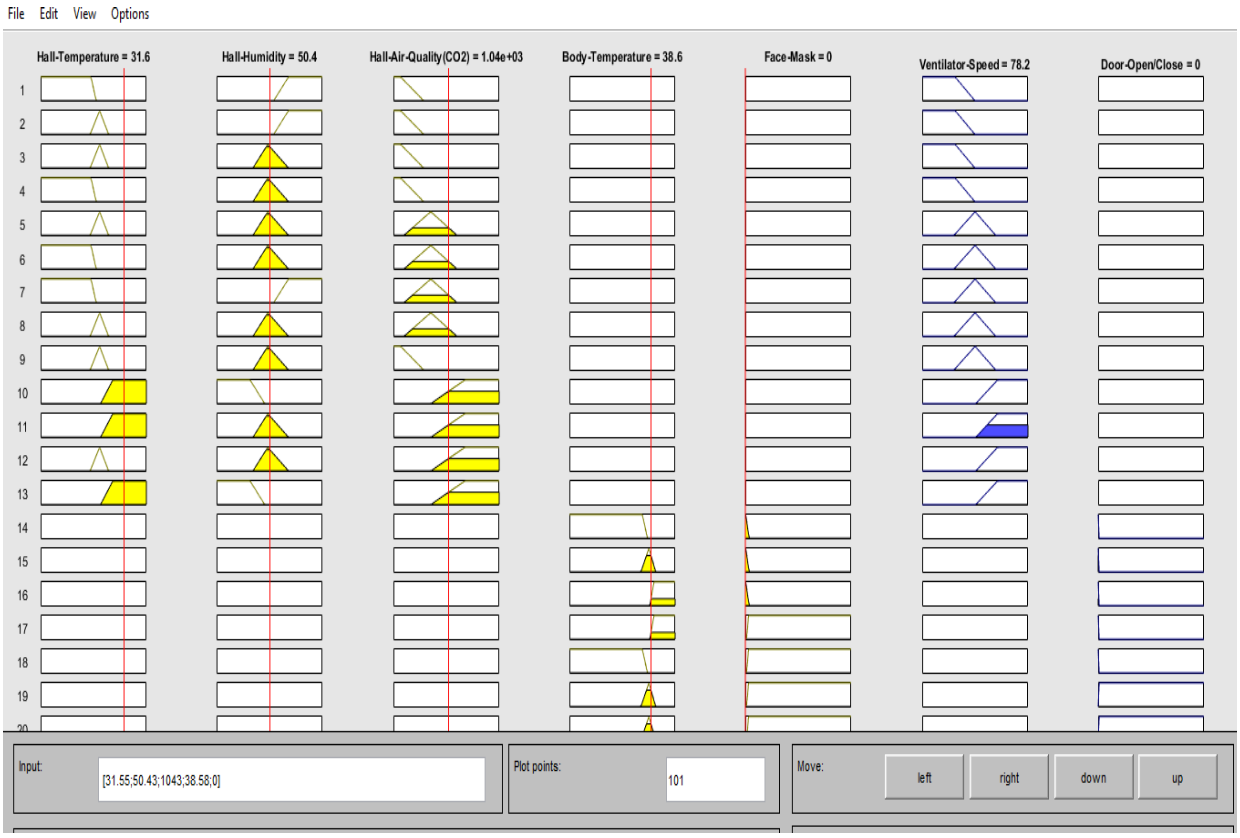


Figure 6: Fuzzy rule viewer

The 3D Surface view of the proposed system allows viewing and interpreting the output surfaceof the Fuzzy system. In this paper, figure 7a, 7b, and 7c describes the ventilator output speedcorresponding to the variation of the Hall temperature, relative humidity and air quality Fuzzyinput variables. Furthermore, in Fig7.d the opening and closing output surface view corresponding to the input values of the body temperature and wearing of the face mask is illustrated.

American Journal of Computing and Engineering
ISSN 2790-5586 (Online)
Vol.6, Issue 1, pp 1 – 13, 2023
www.ajpojournals.org

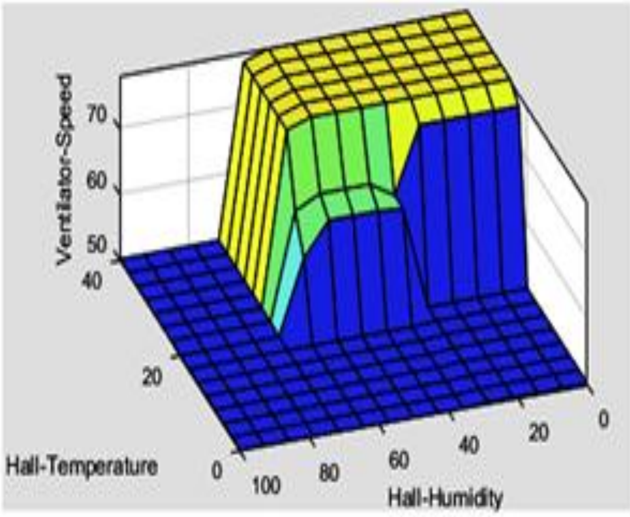


Fig: 7a

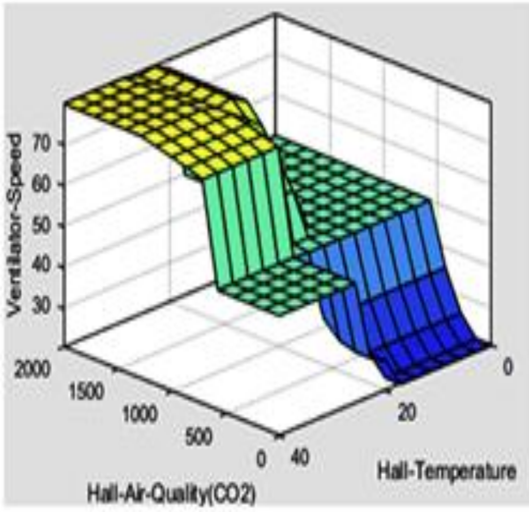


Fig: 7b

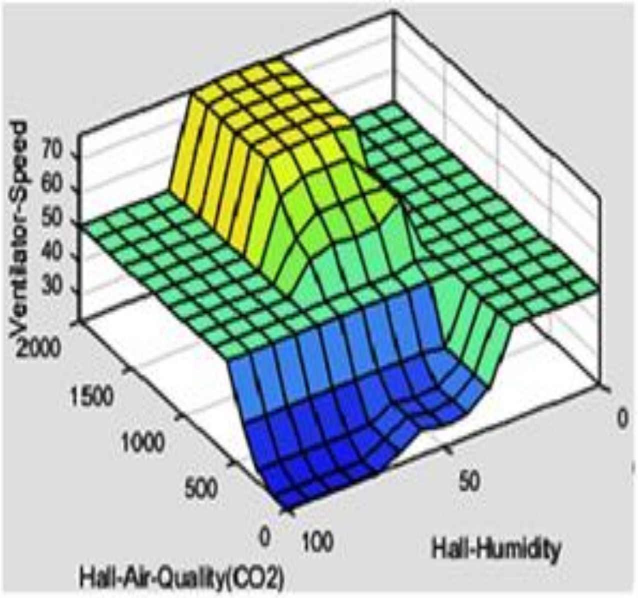


Fig: 7c

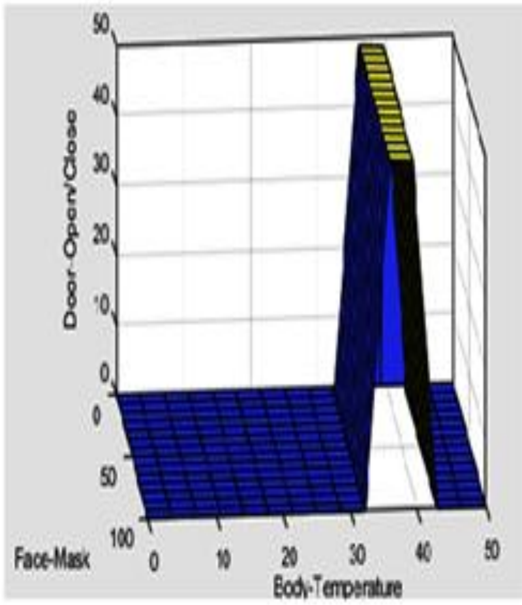


Fig: 7d

Figure 7: Three dimensional surface viewer

DISCUSSION

The system has been designed and simulated in Fuzzy logic ToolBox in MATLAB software as shown in Fig6 and Fig7a, Fig7b, Fig7c and Fig7d rules and surface views. The output results obtained from the simulation correspond to the input to the system as expected from the design objectives. The system prototype composed of sensors, raspberry-PI 3 and actuators has been implemented in workshop and works exactly as predicted and the results obtained correspond to the results obtained in simulation during the system design process. The system prototype deployed at GISHARI Integrated Polytechnic College Staff Room that accommodates 75 permanent staff, has proven high accuracy in room ventilation monitoring and door entrance control for COVID-19 risk management.

CONCLUSION

In this research paper, the SPHCMS was developed for COVID 19 transmission monitoring in the enclosed area. The system consists of different type of sensors to detect properly the body temperature, wearing face mask, relative humidity, room temperature and air ventilation for indoor COVID 19 transmission monitoring. The protype was implemented, tested and the results showed that the system is accurate with low cost compared to existing.

RECOMMENDATION

We recommend the implementation of this solution since it will provide effective COVID-19 pandemic management in the contained area and so provide the data-driven capabilities for additional researches. In addition, we advise future studies to incorporate machine learning techniques for making predictions.

REFERENCES

[1] T. Leppäaho and P. Ritala, “Surviving the coronavirus pandemic and beyond: Unlocking family firms’ innovation potential across crises,” *J. Fam. Bus. Strateg.*, vol. 13, no. 1, 2022, doi: 10.1016/j.jfbs.2021.100440.

[2] WHO COVID-19 Dashboard. Geneva, “COVID-19 Global situation,” *World Health Organization*, 2023.

[3] J. M. Guaita Martínez, P. Carracedo, D. Gorgues Comas, and C. H. Siemens, “An analysis of the blockchain and COVID-19 research landscape using a bibliometric study,” *Sustain. Technol. Entrep.*, vol. 1, no. 1, p. 100006, 2022, doi: 10.1016/j.stae.2022.100006.

[4] D. Bisanzio *et al.*, “Estimating the effect of non-pharmaceutical interventions to mitigate COVID-19 spread in Saudi Arabia,” *BMC Med.*, vol. 20, no. 1, pp. 1–14, 2022, doi: 10.1186/s12916-022-02232-4.

[5] M. Clarisse *et al.*, “Use of Technologies in COVID-19 Containment in Rwanda,” *Rw. Public Heal. Bul*, vol. 2, no. 2, pp. 7–12, 2020, [Online]. Available: www.rwandapublichealthbulletin.org

[6] T. A. Soomro, L. Zheng, A. J. Afifi, A. Ali, M. Yin, and J. Gao, *Artificial intelligence (AI) for medical imaging to combat coronavirus disease (COVID-19): a detailed review with direction for future research*, vol. 55, no. 2. Springer Netherlands, 2022. doi: 10.1007/s10462-021-09985-z.

[7] C. Yang, W. Wang, F. Li, and D. Yang, “An IoT-Based COVID-19 Prevention and Control System for Enclosed Spaces,” *Futur. Internet*, vol. 14, no. 2, 2022, doi: 10.3390/fi14020040.

[8] L. Unruh *et al.*, “A comparison of 2020 health policy responses to the COVID-19 pandemic in Canada, Ireland, the United Kingdom and the United States of America,” *Health Policy (New. York).*, vol. 126, no. 5, pp. 427–437, 2022, doi: 10.1016/j.healthpol.2021.06.012.

[9] B. Katarina, F. J. Abraham, C. Mutimukwe, and R. Mugisha, “A Web-Based Program About Sustainable Development Goals Focusing on Digital Learning , Digital Health Literacy , and Nutrition for Professional Development in Ethiopia and Rwanda : Development of a Pedagogical Method Corresponding Author :,” vol. 6, no. 12, doi: 10.2196/36585.

[10] M. Dionisio, S. J. de Souza Junior, F. Paula, and P. C. Pellanda, "The role of digital social innovations to address SDGs: A systematic review," *J. High Technol. Manag. Res.*, vol. 34, no. 1, 2023, doi: 10.1016/j.hitech.2022.100442.

[11] Y. Dong and Y. D. Yao, "IoT platform for covid-19 prevention and control: A survey," *IEEE Access*, vol. 9, pp. 49929–49941, 2021, doi: 10.1109/ACCESS.2021.3068276.

[12] D. Gupta, S. Bhatt, M. Gupta, and A. S. Tosun, "Future Smart Connected Communities to Fight COVID-19 Outbreak," *Internet of Things (Netherlands)*, vol. 13, p. 100342, 2021, doi: 10.1016/j.iot.2020.100342.

[13] J. P. Nyakuri *et al.*, "IoT and AI Based Smart Soil Quality Assessment for Data-Driven Irrigation and Fertilization," *Am. J. Comput. Eng.*, vol. 5, no. 2, pp. 1–14, 2022, doi: 10.47672/ajce.1232.

[14] T. J. Claude, N. Gaudence, M. Didacienne, and N. J. Pierre, "Fuzzy logic applied to smart baby's health and feeding sequence monitoring system," *Proc. - 2020 21st Int. Arab Conf. Inf. Technol. ACIT 2020*, 2020, doi: 10.1109/ACIT50332.2020.9300087.

[15] S. Kumar, C. Xu, N. Ghildayal, C. Chandra, and M. Yang, "Social media effectiveness as a humanitarian response to mitigate influenza epidemic and COVID-19 pandemic," *Ann. Oper. Res.*, vol. 319, no. 1, pp. 823–851, 2021, doi: 10.1007/s10479-021-03955-y.

[16] B. Lin *et al.*, "Revealing the linguistic and geographical disparities of public awareness to Covid-19 outbreak through social media," *Int. J. Digit. Earth*, vol. 15, no. 1, pp. 868–889, 2022, doi: 10.1080/17538947.2022.2070677.

[17] Y. Siriwardhana, C. De Alwis, G. Gur, M. Ylianttila, and M. Liyanage, "The Fight against the COVID-19 Pandemic with 5G Technologies," *IEEE Eng. Manag. Rev.*, vol. 48, no. 3, pp. 72–84, 2020, doi: 10.1109/EMR.2020.3017451.

[18] A. Asadzadeh, Z. Mohammadzadeh, Z. Fathifar, S. Jahangiri-Mirshekarlou, and P. Rezaei-Hachesu, "A framework for information technology-based management against COVID-19 in Iran," *BMC Public Health*, vol. 22, no. 1, pp. 1–15, 2022, doi: 10.1186/s12889-022-12781-1.

[19] F. Vogt, B. Haire, L. Selvey, A. L. Katelaris, and J. Kaldor, "Effectiveness evaluation of digital contact tracing for COVID-19 in New South Wales, Australia," *Lancet Public Heal.*, vol. 7, no. 3, pp. e250–e258, 2022, doi: 10.1016/S2468-2667(22)00010-X.

[20] M. J. M. Chowdhury, M. S. Ferdous, K. Biswas, N. Chowdhury, and V. Muthukkumarasamy, "COVID-19 Contact Tracing: Challenges and Future Directions," *IEEE Access*, vol. 8, pp. 225703–225729, 2020, doi: 10.1109/ACCESS.2020.3036718.

[21] C. Melo, S. Dixe, J. C. Fonseca, A. H. J. Moreira, and J. Borges, "Ai based monitoring of different risk levels in covid19 context," *Sensors*, vol. 22, no. 1, pp. 1–18, 2022, doi: 10.3390/s22010298.[22] H. Monitoring, "Contactless Measurement of Vital Signs Using Thermal and," 2022.

23] D. De Caprio *et al.*, "Building a covid-19 vulnerability index," *J. Med. Artif. Intell.*, vol. 3, no. December, pp. 1–12, 2020, doi: 10.21037/jmai-20-47.

[24] "COMBATTING COVID-19 : ARTIFICIAL INTELLIGENCE TECHNOLOGIES & CHALLENGES," no. July, 2022, doi: 10.14293/S2199-1006.1.SOR-.PPVK63O.v1.

[25] Q. V. Pham, D. C. Nguyen, T. Huynh-The, W. J. Hwang, and P. N. Pathirana, “Artificial Intelligence (AI) and Big Data for Coronavirus (COVID-19) Pandemic: A Survey on the State-of-the-Arts,” *IEEE Access*, vol. 8, no. Cdc, pp. 130820–130839, 2020, doi: 10.1109/ACCESS.2020.3009328.

[26] B. Varshini, H. Yogesh, S. D. Pasha, M. Suhail, V. Madhumitha, and A. Sasi, “IoT-Enabled smart doors for monitoring body temperature and face mask detection,” *Glob. Transitions Proc.*, vol. 2, no. 2, pp. 246–254, 2021, doi: 10.1016/j.gltp.2021.08.071.

[27] D. D. Putra, M. Febriyanto, M. M. Nadra, W. Shalannanda, E. R. Firzal, and A. Munir, “Design of smart-gate based on artificial intelligence possibly for COVID-19 early prevention at public area,” *Proceeding 14th Int. Conf. Telecommun. Syst. Serv. Appl. TSSA 2020*, pp. 2021–2024, 2020, doi: 10.1109/TSSA51342.2020.9310878.

[28] T. Abuzairi, N. Imaniati Sumantri, A. Irfan, and R. Maulana Mohamad, “Infrared thermometer on the wall (iThermowall): An open source and 3-D print infrared thermometer for fever screening,” *HardwareX*, vol. 9, p. e00168, 2021, doi: 10.1016/j.ohx.2020.e00168.

[29] A. G. John, P. J. Thusnavis, M. Bella, I. S. Vasantha, and P. Sneha, “Internet of Things (IoT) based automated sanitizer dispenser and COVID ‑ 19 statistics reporter in a post ‑ pandemic world,” *Health Technol. (Berl).*, 2023, doi: 10.1007/s12553-023-00728-4.