Remote Healthcare Monitoring using Expert System

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***Abstract*—With the introduction of the novel coronavirus and the ensuing epidemic, health care has become a primary priority for all governments. In this context, the best course of action is to implement an Internet of Things (IoT)-based remote health monitoring system. As a result, IoT systems have attracted significant attention in academia and industry, and this trend is likely to continue as wearable sensors and smartphones become more prevalent. Even if the doctor is a substantial distance away, IoT health monitoring enables the prevention of illness and the accurate diagnosis of one's current state of health through the use of a portable physiological monitoring framework that continually monitors the patient's systolic blood pressure, blood glucose, oxygen saturation, and diastolic blood pressure. The expert system generates a diagnosis of the patient's health status based on the sensor data. Once the patient's sensor data is transmitted to the cloud via a WiFi module, the expert system uses it to diagnose the patient's health status in order to facilitate any medical attention or critical care that may be required for his condition. The simulation is carried out in Matlab, and the results of the study are presented to demonstrate the suggested system's significance.**

***Keywords*—Internet of Things (IoT); remote health care monitoring; wearable sensors; fuzzy logic**

I. Introduction

Every time the human species makes technological advancements, health is always a major worry [1]. In recent years, both the academic community and the financial markets have placed a premium on the healthcare services sector. This industry has amassed substantial wealth as a result of its research potential [2]. Inadequate resources, skyrocketing healthcare expenditures, and ineffective hospital resource management are just a few of the problems plaguing the healthcare business [3]. Additional logistical challenges exist, such as the volume of medical treatment required by patients, the limited availability of beds and equipment, and the shortage of healthcare specialists. Patient monitoring is often passive, meaning that medical practitioners modify medications in response to changes in the patient's health situation [4]. The current Corona virus outbreak, which has wreaked havoc on the global economy, demonstrates how health care has become increasingly vital in today's world. In this case, it is always preferable to monitor patients in locations where the virus has spread using remote health monitoring devices. The Internet of Things' most major application is in healthcare management, where it is used to track health issues using the remote health monitoring technique. The Internet of Things (IoT) is a process that involves linking computers to the internet via sensors and networks [5]. These connected components can be included into health-monitoring devices. The data is then transmitted to remote computers, providing a simple, energy-efficient, significantly smarter, scalable, and interoperable method of tracking and optimizing care for any health concern. To aid people in living smarter lives, modern technologies now include a customisable interface, assistant gadgets, and tools for managing mental health [6]. Numerous attempts have been made to remotely send patient data without requiring an in-person hospital visit, utilizing recent advancements in IoT and wireless sensor networks. This enables doctors to decide on the most appropriate course of action or to summon specialized medical aid. In an emergency, the transmission of critical patient data can have a significant impact on the patient's life. The Internet of Things-based health monitoring systems have devised a novel method of tracking patients who live in remote locations.

Fig. 1. Proposed System.

Oman had 346K confirmed COVID-19 infections as of February 20, 2022, with 4K coronavirus fatalities [7]. A fever, shortness of breath, poor oxygen saturation, irregular blood pressure, and an elevated blood glucose level are all indications of risk. Patients who have elevated systolic and diastolic blood pressure are said to be in a hypertensive crisis, whereas those who have elevated blood glucose levels are said to be in a diabetic crisis. A patient who is hypertensive, diabetic, or hypoxemic has a decreased chance of survival and will require urgent care. Patients may be unaware of their condition. As a result, they perish due to a lack of therapy or meical attention. As a result, the current answer is a health monitoring system based on the Internet of Things (IoT) [8]. The response time is critical since the patient's health state may deteriorate in certain instances.Therefore, a continuous remote monitoring system via the Internet of Things presents significant opportunities in the field of e-health [9]. This technology has the ability to significantly improve healthcare and pave the way for numerous improvements using remote health care monitoring techniques. The Internet of Things serves as a catalyst for healthcare and is critical to healthcare services [9]. The body sensor network detects aberrant and unexpected situations by assessing physiological traits and symptoms and giving vital signals for medical investigation [10]. As a result, interim medications can be delivered immediately to avert potentially life-threatening conditions.

In this study, we designed an expert system to enable remote patient monitoring to assess whether a patient is healthy or requires nutritional control, medical attention, or critical care. As depicted in Figure 1, the built expert system can be divided into two subsystems. The first subsystem is in charge of data collection. The patient is fitted with wearable sensors that monitor vital signs such as blood pressure, blood glucose, and oxygen saturation level. Bluetooth-enabled sensors connect to his smartphone. The smartphone is equipped with an app that records sensor readings and patient data and transmits them to the cloud via the internet.This subsystem is located at the patient end. The second subsystem is utilized to diagnose the patient's health status by utilizing cloud-based data. Expert systems that are based on fuzzy logic use this information to determine if the patient is healthy or need medical attention.The second subsystem is at the hospital end to diagnose the patient health state. The main contribution of this study can be summarized as follows:

1) The architecture of the remote health monitoring system was designed with the objective of monitoring patients' health status on a frequent basis.
2) Physicians and patients have access to the system's recommended system outcome at any time and from any location.
3) Using artificial intelligence logic, the proposed system runs health diagnostics to decide whether or not the patient is healthy or in need of medical assistance.
4) MATLAB simulations are utilized to illustrate the suggested system's study outcomes.

The paper is organized as follows: Section II highlights similar research on IoT-based health monitoring systems. Section III goes into the suggested expert system's system concept and architecture for diagnosing a patient's health condition based on body vital data collected from sensors and the fuzzy logic mechanism to suggest the patient's health state and appropriate recommendations. In Section IV, the experimental setup is detailed, in Section V, the simulation results are displayed, and in Section VI, the article is concluded.

II. Related Work

While significant effort has been made in the past to provide medical care outside of traditional hospital grounds, this has become much more critical in light of the present COVID-19 pandemic scenario [11], as seen by an increase in the number of publications. However, as several recent survey papers have highlighted, more work remains to be done in terms of providing medical diagnosis and care to patients at home[12]. For instance, as detailed in [13], a remote patient monitoring system tries to efficiently manage hospital resources by monitoring patients at home. It is an Internet of Things-based patient monitoring technology that automates the collection and transmission of patient data to remote databases. This data is accessible via the a web system, which features an intuitive user interface. The author in [14] describes a home monitoring and decision support system that is intended to assist clinicians in the diagnosis, remote monitoring, treatment, prescription, rehabilitation, and progression of individuals with Parkinson's disease. This is a data-collection expert system that supports clinicians in diagnosing and treating tremors. The author in [15] offers a Smart Architecture for In-Home Healthcare System, which is a healthcare solution that monitors patients and the elderly with special needs using photographs and facial expressions. The author in [16] did an extensive investigation of many Internet-of-Things-based technologies that could be employed for telemedicine and illness preventive services. A study was done to monitor children's health using a wireless system powered by the Internet of Things and capable of providing real-time notifications to parents and guardians [17]. The author in [18] delivers an IoT-based health monitoring solution for children with autism. A head-worn sensor is used to collect health information from autistic patients. The data acquired from these patients' brains is subsequently transmitted in real time to a monitoring server. If there are any discrepancies in the information read, an alarm is generated and an email is sent to the carer. Additionally, the physician is notified in the event of an emergency. Additionally, for scalability and security, personal information about patients can be stored in the cloud. Other researchers have developed a remote COVID-19 patient monitoring system that incorporates the examination of critical biological data such as PPG, ECG, and temperature to evaluate the patient's health status. Additionally, they discuss the challenges associated with security threats in IoT-based smart health systems [19]. Another Internet of Things system was developed to identify prospective COVID-19 patients by utilizing eight distinct learning algorithms that aid in the differentiation of cold symptoms from COVID-19 symptoms [20]. A study examines the use of IoT systems to monitor patients in smart cities in order to ensure that ambulances and other assistance can reach them swiftly [21]. The author in [22] developed a wearable Internet of Things health monitoring system with its own network, nicknamed the body area network, in which several sensors continuously monitor and record parameters. The author in [23] developed an Internet-of-Things-based health monitoring system capable of tracking a patient's basic symptoms such as heart rate, oxygen saturation percentage, body temperature, and eye movement. The capturing elements included heartbeat, SpO2, temperature, and eye blink sensors, while the processing device was an Arduino-UNO. Although the developed system has been implemented, no specified performance measures have been established for any of the patients. The author in [24] demonstrated an IoT-enabled healthcare monitoring kit. The developed system monitored fundamental health parameters such as heartbeat, electrocardiogram, body temperature, and respiration. The primary hardware components used in this project are the pulse sensor, temperature sensor, blood pressure sensor, ECG sensor, and Raspberry Pi. The author in [25] outlines an Internet of Things-based healthcare system in which ECGs and other healthcare data are recorded and securely transmitted to the cloud, where specialists can access them. Signal augmentation techniques, encryption, and other appropriate analysis are used to prevent identity theft or clinical error. The author in [26] discusses the health care monitoring system and IoT-based analyses. This research successfully built a new IoT-based framework for health applications. Three vital signs, including body temperature, heart rate, and blood pressure, may be precisely measured by the device. Physicians may view and monitor data in real time, even if patients complete their medical tests outside of the clinical setting.

III. Proposed Expert System

A. System Architecture

The primary objective of this project is to develop a smart IoT-based health monitoring system capable of diagnosing a patient's health state based on sensor-read bodily vital statistics. The proposed system's initial section is implemented at the patient's end. A variety of body sensors are implanted in the patient, including a blood pressure sensor that detects both systolic and diastolic pressures, an oxygen saturation sensor, and a blood glucose sensor. These three vital signs of the body are frequently altered, especially when the patient is infected with COVID 19. These measurements must be reviewed frequently for such patients to avoid undesirable repercussions. However, it is difficult to visit the hospital on a frequent basis. As a result, this sensor data is transmitted to the cloud via a gateway and stored on a medical support service's data server.

The second section of the proposed system applies fuzzy logic to process on the sensor data received from the first subsystem and to diagnose the patient's health status The patient health status is summarised as healthy, requiring only dietary supervision, or requiring medical attention or critical care .

B. Fuzzy Based Health Diagnosis System

The suggested system utilizes wearable sensors on the patient to monitor systolic and diastolic blood pressure, oxygen saturation level, and blood glucose level. As illustrated in Fig. 2, these are the inputs to our diagnosis expert system at the medical care service center.

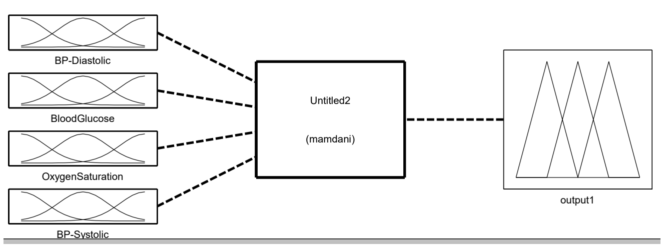

Fig. 2. Overview of Diagnostic System.

The inputs to the system has to be considered as membership function. The Blood pressure diastolic values are divided into four ranges: Normal, Stage 1 Hypertension, Stage 2 Hypertension, Hypertensive Crisis [27]. The Blood glucose input is divided as Low,Normal, Prediabetic, Diabetic. The oxygen saturation level is divided as Crisis,Hypoxemia, Normal.The Blood pressure Systolic values are divided as Normal, Elevated, Stage 1 Hypertension, Stage 2 Hypertension, Hypertensive Crisis.

The pressure in the arteries when the heart rests between beats is measured by the diastolic reading. This is when the heart receives oxygen and fills with blood.The input Blood Pressure Diastolic is measured in mmHg and the membership function is shown in Fig. 3. It is divided into four ranges : Normal(<80 mmHg), Stage 1 Hypertension (80mmHg - 89mmHg) , Stage 2 Hypertension (90mmHg - 120mmHg) , Hypertensive Crisis (>120mmHg).

The characteristic of Blood Pressure Diastolic is as follows:

$$Normal = \begin{cases} 1 & \text{if} \quad x \leq 79 \\ \frac{80-x}{80-79} & \text{if} \quad 79 < x < 80 \\ 0 & \text{if} \quad x \geq 90 \end{cases} \tag{1}$$

$$Stage1HT = \begin{cases} 1 & \text{if} \quad 80 \leq x \leq 89 \\ \frac{x-79}{80-79} & \text{if} \quad 79 < x < 80 \\ \frac{90-x}{90-89} & \text{if} \quad 89 < x < 90 \\ 0 & \text{if} \quad x \leq 79; x \geq 90 \end{cases} \tag{2}$$

$$Stage2HT = \begin{cases} 1 & \text{if} \quad 90 \leq x \leq 120 \\ \frac{x-89}{90-89} & \text{if} \quad 89 < x < 90 \\ \frac{121-x}{121-120} & \text{if} \quad 120 < x < 121 \\ 0 & \text{if} \quad x \leq 89; x \geq 121 \end{cases} \tag{3}$$

$$Crisis = \begin{cases} 1 & \text{if} \quad x \geq 121 \\ \frac{x-120}{121-120} & \text{if} \quad 120 < x < 121 \\ 0 & \text{if} \quad x \leq 120 \end{cases} \tag{4}$$

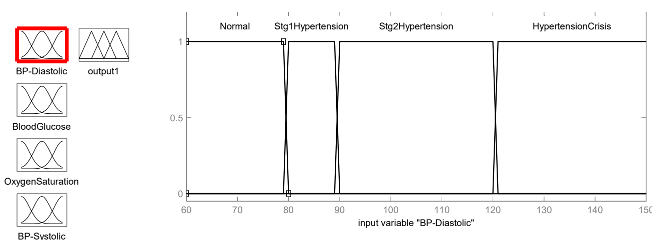

Fig. 3. Blood Pressure Diastolic Membership Function.

Diabetes is defined as a blood glucose level that is higher than normal. And if a diabetic patient's blood glucose level isn't controlled, it can lead to death [28]. As a result, there's a big need to keep track of blood glucose levels and make sure you're getting the right amount of insulin.Blood glucose is another input considered , which is measured in mmol / L and the membership function is shown in Fig. 3. It is divided into four ranges :Low(0 mmol / L - 3.9 mmol / L), Normal(4.0 mmol/L - 5.4 mmol/L), Prediabetic(5.5 mmol/L - 6.9 mmol/L) and Diabetic(>7.0 mmol/L) as shown in Fig. 4.

The characteristic of Blood Glucose is as follows:

$$Low = \begin{cases} 1 & \text{if} \quad x \leq 3.9 \\ \frac{4-x}{4-3.9} & \text{if} \quad 3.9 < x < 4 \\ 0 & \text{if} \quad x \geq 4 \end{cases} \tag{5}$$

$$Normal = \begin{cases} 1 & \text{if} \quad 4 \leq x \leq 5.4 \\ \frac{x-3.9}{4-3.9} & \text{if} \quad 3.9 < x < 4 \\ \frac{5.5-x}{5.5-5.4} & \text{if} \quad 5.4 < x < 5.5 \\ 0 & \text{if} \quad x \leq 3.9; x \geq 5.5 \end{cases} \tag{6}$$

$$Prediabetic = \begin{cases} 1 & \text{if} \quad 5.5 \leq x \leq 6.9 \\ \frac{x-5.4}{5.5-5.4} & \text{if} \quad 5.4 < x < 5.5 \\ \frac{7-x}{7-6.9} & \text{if} \quad 6.9 < x < 7 \\ 0 & \text{if} \quad x \leq 5.4; x \geq 7 \end{cases} \tag{7}$$

$$Diabetic = \begin{cases} 1 & \text{if} \quad x \geq 7 \\ \frac{x-6.9}{7-6.9} & \text{if} \quad 6.9 < x < 7 \\ 0 & \text{if} \quad x \leq 6.9 \end{cases} \tag{8}$$

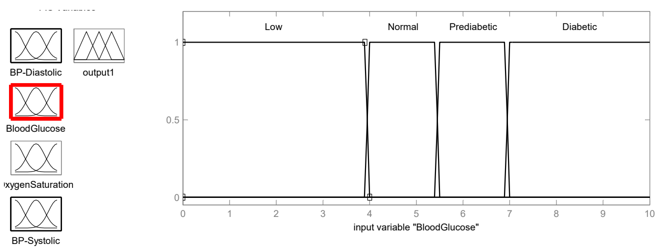

Fig. 4. Blood Glucose Membership Function.

The percentage of oxygen in a person's blood is known as oxygen saturation. A pulse oximeter is a gadget that medical practitioners frequently use for fast tests or continuous monitoring [29]. The oxygen saturation level in a healthy person ranges from 95% to 100%. If a person's levels go below this range, they may feel symptoms including difficulty breathing and confusion, which are signs of a shortage of oxygen. The input Oxygen Saturation is divided into three ranges: Critical Crisis (<90%), Hypoxemia (90% - 94%) and Normal (95% - 100%) as shown in Fig. 5.

The characteristic of Oxygen Saturation is as follows:

$$Crisis = \begin{cases} 1 & \text{if} \quad x \leq 89 \\ \frac{90-x}{90-89} & \text{if} \quad 89 < x < 90 \\ 0 & \text{if} \quad x \geq 90 \end{cases} \tag{9}$$

$$Hypoxemia = \begin{cases} 1 & \text{if} \quad 90 \leq x \leq 92 \\ \frac{x-89}{90-89} & \text{if} \quad 89 < x < 90 \\ \frac{94-x}{94-92} & \text{if} \quad 92 < x < 94 \\ 0 & \text{if} \quad x \leq 89; x \geq 94 \end{cases} \tag{10}$$

$$Normal = \begin{cases} 1 & \text{if} \quad x \geq 95 \\ \frac{x-94}{95-94} & \text{if} \quad 94 < x < 95 \\ 0 & \text{if} \quad x \leq 6.94 \end{cases} \tag{11}$$

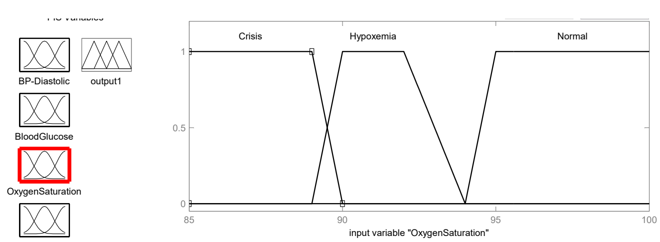

Fig. 5. Oxygen Saturation Membership Function.

When your heart beats, it squeezes and pushes blood to the rest of your body through your arteries. Your systolic blood pressure is the result of this force exerting pressure on those blood vessels[27].The input systolic blood pressure is divided into five ranges: Normal (<121 mmHg), Elevated (121mmHg - 129mmHg), Stage1 Hypertension (130mmHg - 139mmHg), Stage2 Hypertension (140mmHg- 80mmHg) and Hypertensive Crisis (>180) as shown in Fig. 6.

The characteristic of Blood Pressure Systolic is as follows:

$$Normal = \begin{cases} 1 & \text{if} \quad x \leq 120 \\ \frac{121-x}{121-120} & \text{if} \quad 120 < x < 121 \\ 0 & \text{if} \quad x \geq 121 \end{cases} \tag{12}$$

$$Elevated = \begin{cases} 1 & \text{if} \quad 121 \leq x \leq 129 \\ \frac{x-120}{121-120} & \text{if} \quad 120 < x < 121 \\ \frac{130-x}{130-129} & \text{if} \quad 129 < x < 130 \\ 0 & \text{if} \quad x \leq 120; x \geq 130 \end{cases} \tag{13}$$

$$Stage1HT = \begin{cases} 1 & \text{if} \quad 130 \leq x \leq 139 \\ \frac{x-129}{130-129} & \text{if} \quad 129 < x < 130 \\ \frac{140-x}{140-139} & \text{if} \quad 139 < x < 140 \\ 0 & \text{if} \quad x \leq 129; x \geq 140 \end{cases} \tag{14}$$

$$Stage2HT = \begin{cases} 1 & \text{if} \quad 140 \leq x \leq 179 \\ \frac{x-139}{140-139} & \text{if} \quad 139 < x < 140 \\ \frac{180-x}{180-179} & \text{if} \quad 179 < x < 180 \\ 0 & \text{if} \quad x \leq 139; x \geq 180 \end{cases} \tag{15}$$

$$Crisis = \begin{cases} 1 & \text{if} \quad x \geq 180 \\ \frac{x-179}{180-179} & \text{if} \quad 179 < x < 180 \\ 0 & \text{if} \quad x \leq 179 \end{cases} \tag{16}$$

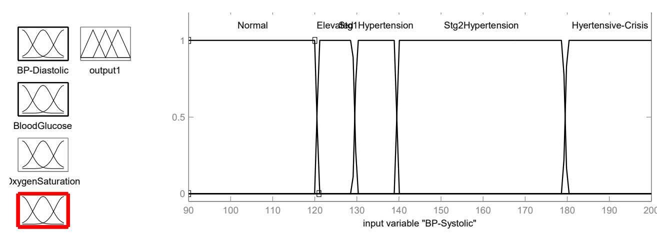

Fig. 6. Blood Pressure Systolic Membership Function.

The output of the expert system is the diagnosis of health state of the based on the data obtained from the sensors. In the pandemic situation, it is recommended to get hospitalised if the condition of the patient is critical and needs medical care. So here the output membership function is divided into four ranges: Healthy (<40), Diet Control (40 - 59), Medical Attention (60-79), Critical Care (80-99) as shown in Fig. 7.

The characteristic of Output health state is as follows:

$$Healthy = \begin{cases} 1 & \text{if} \quad x \leq 39 \\ \frac{40-x}{40-39} & \text{if} \quad 39 < x < 4 \\ 0 & \text{if} \quad x \geq 40 \end{cases} \tag{17}$$

$$DietControl = \begin{cases} 1 & \text{if} \quad 40 \leq x \leq 59 \\ \frac{x-39}{40-39} & \text{if} \quad 39 < x < 40 \\ \frac{60-x}{60-59} & \text{if} \quad 59 < x < 60 \\ 0 & \text{if} \quad x \leq 39; x \geq 60 \end{cases} \tag{18}$$

$$MedicalAttention = \begin{cases} 1 & \text{if} \quad 60 \le x \le 79 \\ \frac{x-59}{60-59} & \text{if} \quad 59 < x < 60 \\ \frac{80-x}{80-79} & \text{if} \quad 79 < x < 80 \\ 0 & \text{if} \quad x \le 59; x \ge 80 \end{cases} \tag{19}$$

$$CriticalCare = \begin{cases} 1 & \text{if} \quad 80 \le x \le 99 \\ \frac{x-79}{80-79} & \text{if} \quad 79 < x < 80 \\ \frac{100-x}{100-99} & \text{if} \quad 99 < x < 100 \\ 0 & \text{if} \quad x \le 79; x \ge 100 \end{cases} \tag{20}$$

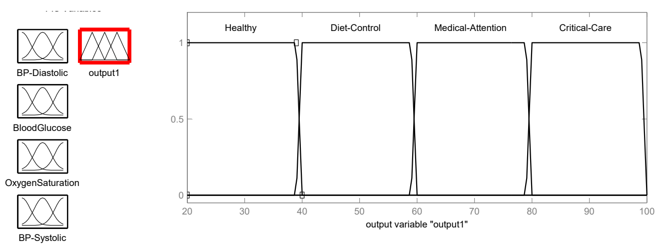

Fig. 7. Output Health State Membership Function.

The expert system's fuzzy rules are defined as a set of all conceivable input combinations. When the normal range of the input Systolic Blood Pressure is considered first, it can be combined with the other input ranges of oxygen saturation (3 ranges: crisis, hypoxemia, normal), blood glucose (4 ranges: low, normal, prediabetic, and diabetic), and diastolic blood pressure (4 ranges: normal, stage 1 hypertension, stage 2 hypertension, and hypertensive crisis) to create a total of 48 rule sets. As a result of the input Systolic Blood Pressure having five ranges (Normal, Elevated, Stage 1 Hypertension, Stage 2 Hypertension, and Hypertensive Crisis), the total number of rule sets for the fuzzy system will be 48*5=240, as illustrated in Fig. 8. The combination of the four input sensors specified ranges results in a total of 240 rules. These rules produce a person's health state, which may be healthy, diet-controlled, medically attended, or severely cared for. If all sensor input values are within the usual range, the patient is termed healthy. If any of these inputs—Systolic Blood Pressure, Diastolic Blood Pressure, or Blood Glucose level—is found to be slightly elevated above the usual range, the patient is advised as to have Diet Control. If more than one or two input values are outside the normal range or within critical ranges, the patient is referred to a critical care unit or advised for official medical attention. To facilitate comprehension, few rules are further described as follows:

RULE: IF Systolic Blood Pressure == Normal AND Oxygen Saturation == Normal AND Blood sugar == Normal AND Diastolic Blood Pressure == Normal then output health state = Healthy

RULE: IF Systolic Blood Pressure == Elevated AND Oxygen Saturation == Normal AND Blood sugar == Prediabetic AND Diastolic Blood Pressure == Normal then output health state = Diet Control

RULE: IF Systolic Blood Pressure == Normal AND Oxygen Saturation == Hypoxemia AND Blood sugar == Normal AND Diastolic Blood Pressure == Normal then output health state = Medical Assistance

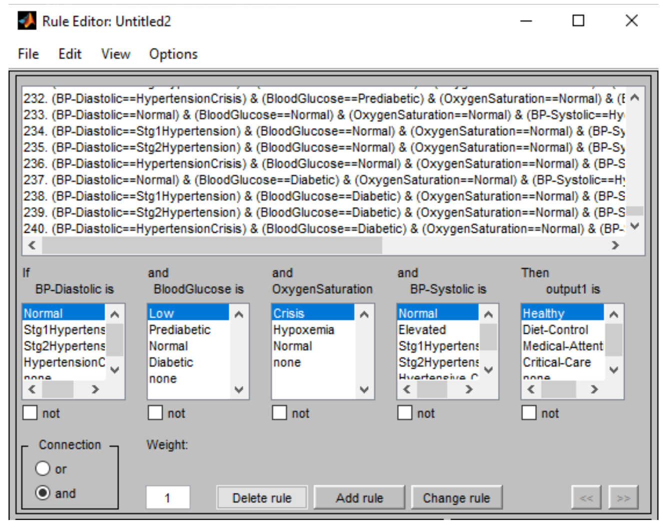

Fig. 8. Rules for Fuzzification.

RULE: IF Systolic Blood Pressure == Stage 2 Hypertension AND Oxygen Saturation == crisis AND Blood sugar == Normal AND Diastolic Blood Pressure == Stage 1 Hypertension then output health state = Critical Care

IV. Experimental Setup

Matlab is used to simulate the suggested expert system. The implementation makes use of the fuzzy logic tool. A four-input, single-output fuzzy logic system was developed for diagnosing a patient's health status. The blood glucose level, the diastolic blood pressure value, the oxygen saturation level, and the systolic blood pressure value are all inputs. As discussed previously, four inputs have distinct ranges: oxygen saturation (3 ranges: crisis, hypoxemia, and normal); blood glucose (4 ranges: low, normal, prediabetic, and diabetic); diastolic blood pressure (4 ranges: normal, stage 1 hypertension, stage 2 hypertension, and hypertensive crisis); and systolic blood pressure (5 ranges: normal, elevated, stage 1 hypertension, stage 2 hypertension, and hypertensive crisis). The output of the fuzzy logic system is the patient's state of health, which is classified into four categories: healthy, diet control, medical attention, and critical care. As illustrated in Fig. 9, the fuzzy logic rules are programmed. The output health status of any set of input values is calculated by the use of fuzzy logic, which adheres to fuzzy principles.

Fig. 9 illustrates the outcome of the centroid method defuzzification. The output health state of a patient can be determined using any combination value of inputs of diastolic blood pressure,blood glucose level,oxygen saturation level and systolic blood pressure values. As indicated, the diastolic blood pressure is 74.3, which is within the normal range of the input. Blood glucose level is 5, which is likewise within the usual range. The oxygen saturation level is 90.6, which is within the range of hypoxemia, and the systolic blood pressure is 108, which is within the normal range. The output health state value derived using the centroid approach is 69.4, indicating that the patient requires medical intervention.

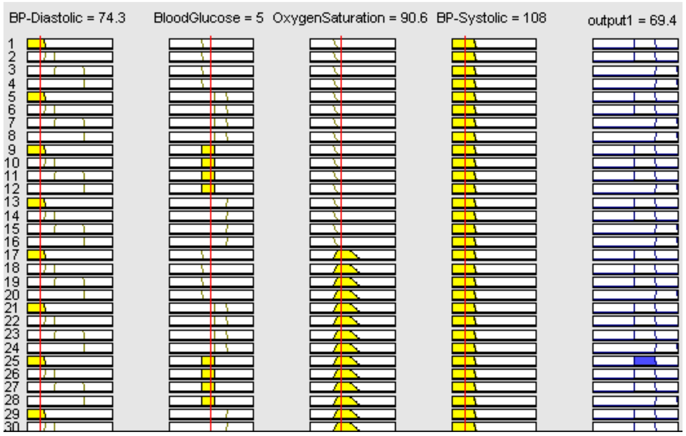

Fig. 9. Simulation Result.

V. SIMULATION RESULTS

Matlab's fuzzy logic toolbox provides a platform for solving any system defined by an input and output set and guided by particular rules. As a result, we chose Matlab's fuzzy toolbox for this project's simulation platform. The simulation result shown in Fig. 10 depicts the patient's output health condition for all possible combinations of the two inputs Blood glucose and Diastolic Blood Pressure. For example it can be easily understood that when the Diastolic Blood Pressure is in Hypertensive Crisis range (>120mmHg) and Blood Glucose is in Diabetic Range (>7.0 mmol/L), then the output health state is in Critical Care (80-99).If the Diastolic Blood Pressure is Normal(<80 mmHg) and the Blood Glucose is Normal(4.0 mmol/L - 5.4 mmol/L), then the output state is in the healthy range Healthy (<40).

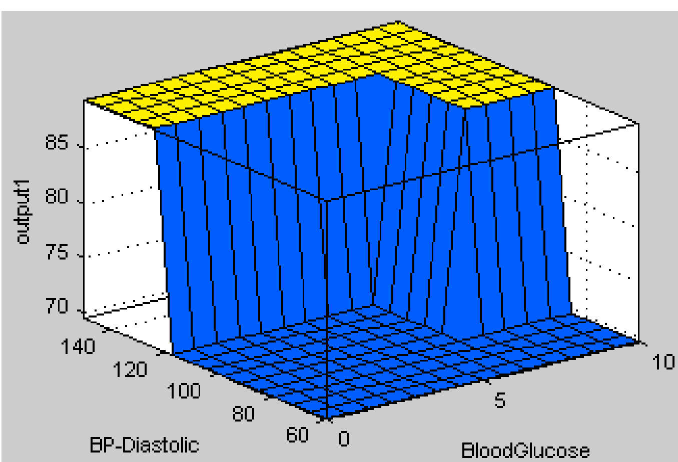

Fig. 10. Diastolic BP and Blood Glucose Surface View.

Fig. 11 shows the surface view output for the input combination of all ranges of Blood glucose and Systolic Blood Pressure.For example it is also observed that if the Blood glucose is in the normal range (4.0 mmol/L - 5.4 mmol/L) and Systolic Blood Pressure is also normal (<121 mmHg) then the output health state is in the range Healthy (<40).

The output surface view of Oxygen Saturation level and Blood Glucose is shown in Fig. 12. The output health state

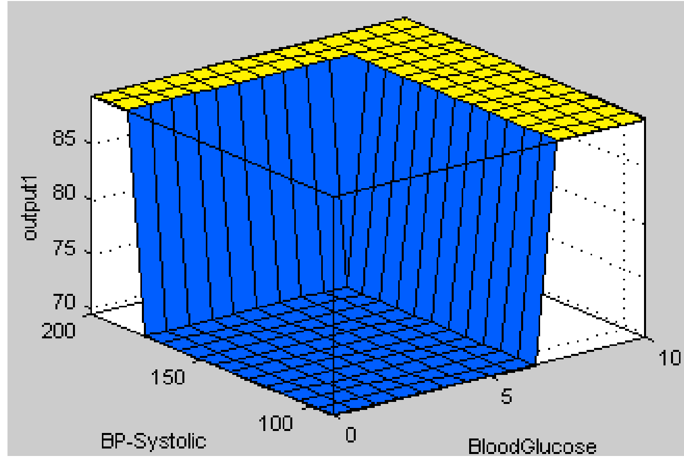

Fig. 11. Systolic BP and Blood Glucose Surface View.

for all input combination of the inputs Oxygen Saturation level and Blood Glucose can be easily calculated. For example if the Oxygen level is in Hypoxemia range (90% - 94%) and Blood glucose is in Normal range (4.0 mmol/L - 5.4 mmol/L), then the output Health state is in Medical Attention range (60-79). If the oxygen saturation level is in Critical Crisis (<90%) and the Blood Sugar Diabetic(>7.0 mmol/L) then the output health state is in critical care (80-99).

Fig. 13 shows the output health state for all the input range combination of systolic and diastolic blood pressure. For example it is also observed that if Systolic Blood Pressure is in Hypertensive Crisis range (>180) and the Diastolic Blood Pressure is in Hypertensive Crisis range (>120mmHg) then the output health state is in the critical care range.

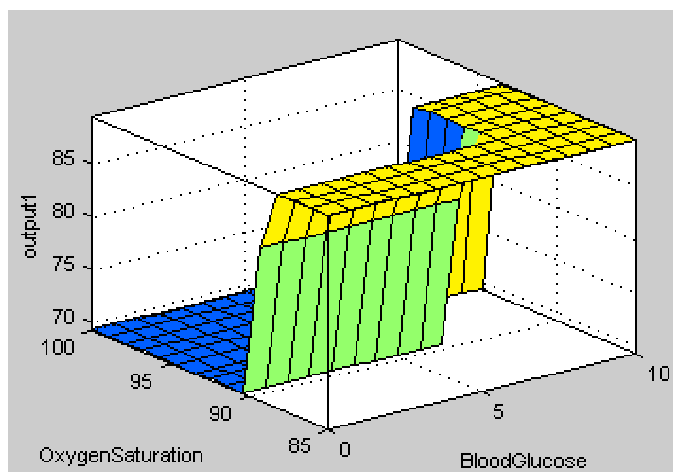

Fig. 12. Oxygen Saturation and Blood Glucose Surface View.

VI. CONCLUSION

The suggested smart health monitoring system enables healthcare practitioners to quickly identify particular patients' health vital information and give the appropriate service based on their health status. This monitoring system will become more adaptive and updatable in the future as a result of

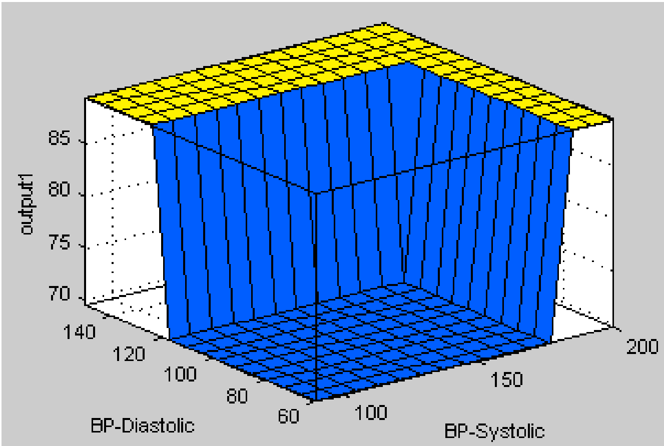

Fig. 13. Systolic and Diastolic Blood Pressure Surface View.

IoT technology. By monitoring diastolic blood pressure, blood glucose level, oxygen level, and systolic blood pressure level, we have made diagnosis and treatment easier with this proposed expert system. Contactless tracking and treatment of patients, particularly COVID-19 patients, is now possible with the use of a specifically developed IOT smart health monitoring device. The output health state is diagnosed using the fuzzy approach based on the sensor data obtained. The proposed system generates the following outputs for the four input sensor data received: healthy, diet control, medical attention, and critical care. When the patient's sensor data falls within the ranges wherein the output is judged to be necessary for medical attention or critical care, the patient can be hospitalized immediately. The Matlab simulation results demonstrate the significance of the expert system in enabling the remote health monitoring process. The proposed approach will enhance the current healthcare system, potentially saving a large number of lives during this pandemic situation.

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