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Fuzzy Logic Temperature Control on Blood Warmer Equipped with Patient Temperature and Blood Temperature

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ABSTRACT Body temperature in humans varies greatly depending on the location where the reading is taken. Normal core body temperature in humans is maintained by the hypothalamus and usually ranges from 36.5°C to 37.5°C. One of the causes of the failure of Too high or too low of a temperature during the blood transfusion procedure may cause blood to freeze or get damaged, both of which can be fatal to humans, therefore the purpose of this tool is to lower blood temperature admission to the patient can be achieved so that there is no temperature drop or temperature drop and so that the blood is not too hot because it can cause damage to red blood cells. This study uses the DS18B20 Sensor to control the heater with PID and Fuzzy controls, the MLX90614 Sensor to adjust the temperature according to the patient's body temperature and the Optocoupler Sensor as an indicator when fluids run out. Previous studies have not used the MLX90614 sensor to detect patient body temperature, have not used TFT Nextion and have not used Fuzzy controls. This Fuzzy control is used as a heater control which then the results are displayed on the Nextion TFT. The results of this study obtained the highest error value of 0.09 with an average error value of 0.04 and obtained the highest overshoot value of 0.8. From the results of the above study it can be concluded that by using the Fuzzy control the response time is slower with a larger overshoot. In the creation of this tool, the benefits that can be derived for the community are facilitating the monitoring of patient temperature and blood temperature during blood transfusions using the Blood Warmer device. The device is also equipped with sensors to detect patient and blood temperatures, and it comes with a Nextion TFT display. Therefore, this device is crucial in assisting the community in performing Blood Transfusions.

INDEX TERMS Body Temperature, Blood Transfusion, DS18B20 Sensor, MLX90614 Sensor, Optocoupler Sensor, Fuzzy Logic.

I. INTRODUCTION

Temperature measurement is one of the oldest known diagnostic methods and remains an important indicator in diagnosing disease, both in daily life and in medical care. To measure body temperature depends on the type of thermometer and body area used for measurement[1]. Normal temperatures in adults range from 36.5°C - 37.5°C. If the body temperature is below 36°C, it indicates hypothermia, whereas if the body temperature is more than 37.5°C it indicates hyperthermia[2]. A condition known as hypothermia occurs when the body's temperature control system struggles to adapt to the effects of cold weather. A body temperature below 35 degrees Celsius is also referred to as hypothermia. The thermoneutral zone, which is 36.5–37.5 °C, is where the human body can regulate temperature. Beyond that point, the body will actively balance heat generation and heat loss in order to regulate temperature[3]. Hypothermia can increase the risk of coagulopathy, blood transfusion, and death in adult trauma patients. In addition to hypothermia, cardiovascular disease can also increase the risk of death. Cardiovascular disease (CVD) is the single biggest contributor to global mortality Cardiovascular Disease encompasses multiple disorders, including atherosclerosis, hypertension, platelet hyperactivity, stroke, hyperlipidemia, and heart failure[4]. A fuzzy system has three steps in its procedure. Rule evaluation, fuzzing, and defuzzification. The input crisp values are converted into degrees of membership in the fuzzy sets throughout the fuzzification process. By entering the value into the membership function connected to the fuzzy set, one can ascertain the level of membership of each crisp value in each fuzzy set. Each fuzzy rule is given a strength value in the rule evaluation phase. The degrees of membership of the crisp input values in the fuzzy sets of the antecedent component of the fuzzy rule determine the strength. The stage of defuzzification converts the fuzzy outputs into precise values[5]. An effective control system must satisfy requirements for dependability, stability, low cost, and ease of use. The effectiveness of the control system may be enhanced by developing a mathematical model of the system. The values of the variables in certain systems are either unknown or are constantly changing, making it impossible to develop a mathematical model of the system. Fuzzy logic might be effective in certain situations for realising the control system. With the use of fuzzy logic theory, controllers can do calculations. Instead of using numeric expressions, symbolic ones are used. Fuzzy logic controllers rely on linguistic phrases and the connections between them as their underlying structure. When using fuzzy logic controllers, it is not necessary to create a model of the system being regulated[6]. Fuzzy systems can utilize expert systems, and can also transfer inaccurate data information into control strategies and reasoning systems and can use rules to solve many problems that cannot be modeled precisely[7]. Fuzzy logic describes a set as fuzzy if it lacks distinct boundaries and the change from membership to non-membership occurs gradually rather than abruptly. Additionally, fuzzy sets are defined using membership functions. To express linguistic concepts/values like cold, cold, or warm, several fuzzy sets are utilized[8].

In earlier research, an automatic blood and infusion warmer with a PID control system was created. This system has the advantage of heating the heater on the device in accordance with the patient's body temperature in the range (36°C – 38°C), without manual settings from the operator, and there is a PID control system on the heater to optimize the temperature of the liquid that will enter through the vein. A DS18B20 sensor, an Arduino program manager, and a 4x16 Character LCD interface are used to display the measurement results. In order to ensure user comfort, it also has flaws, such as replacing the mechanics or temperature control system that can reduce the impact of ambient temperature on the output temperature results, adding a temperature monitoring data storage system so that it can track temperature changes in greater detail, creating smaller box designs, and more organized cable management. The following researcher developed a blood warmer called A Development Of Portable Fluid Warmer For Surigical Hypothermia Patients, which has the benefit of designing and producing an intravenous fluid warmer for surgical patients to prevent hypothermia and the risk of infection from cold. Heart effort is increased as a result. Heart failure and myocardial hypoxia may result from this. Warm liquids have been discovered to be effective at preventing hypothermia, however liquid warmers are expensive and large in design. Therefore, it is suggested that a portable fluid warmer be created for surgery patients. This study does have certain limitations, mainly that the proposed prototype has to heat up for 3 minutes longer than a commercial device, but that it costs much less and has smaller overall dimensions[9]. The following researcher used the to create a Blood Warmer Maximizing the effectiveness with which the heating element of the Blood Transfusion Warmer converts electrical energy into thermal energy will save time and money. The use of a closed-system strategy can be used to achieve this. In this study, the blood bag was heated in a 3 mm-thick acrylic chamber, which created a constrained environment perfect for optimization. A Peltier heating element was used in this experiment. The microcontroller utilizes the driver to control the heating element after receiving an input signal from the DS18B20 temperature sensor. It is inappropriate for use in the planning or execution of a blood transfusion due to its low precision and slow temperature heating response. This is essential for the efficient management of blood transfusion scenarios due to the risk of injury brought on by improper tools or a slow response to heating. A blood temperature that is either too high or too low, which can result in the blood becoming frozen or damaged, is one of the factors that may cause human death during the blood transfusion operation. Because blood transfusion warmers consume a substantial amount of electricity, some people have problems using them[10]. Using Temperature Control in Research There are various advantages of using fuzzy logic when designing a temperature control system. Control conventions are built on the techniques of control theory. Feedback from the controller ensures that the output will behave as planned. Fuzzy temperature controls are created and implemented using microcontrollers. The method to design provided in this study also helps keep the expenses associated with developing hardware and software to a minimum because the hardware in question is not a PC (personal computer) based system that makes decisions using on-board software tools. However, this study's methodology is flawed since it is more focused on what the system ought to do than on how it really performs its duties. As a result, this strategy places more emphasis on addressing problems than on quantitatively modeling the system[11]. The Fuzzy Logic for Temperature and Humidity Control in Data Centers: Implementation and Optimisation research project. The server room's humidity and temperature settings for the air conditioner may be adjusted precisely thanks to fuzzy logic implemented in microcontrollers and Wemos D1 used as an infrared remote control transmitter. We were able to effectively build and install a microcontroller-based fuzzy logic system to manage the temperature and humidity of the server room because simulated tests performed using Matlab produced values that matched the outcomes on the microcontroller. At the AC output, the average temperature deviation was 0.03500, and at the AC mode output, it was 0.01225. The technology is also intended to monitor environmental factors like temperature and humidity as well as electricity voltage online via a website and to send out alerts using the social media platform Twitter. Fuzzy logic for humidity management, which has been successfully applied by controlling the air conditioner's mode, specifically by switching to dry when the humidity is excessive, is missing from the research, though. Since the system uses the same mode even when the humidity is too low, more research is required to determine the various air conditioner modes that may increase humidity[12]. The research has advantages. One of the functions of fuzzy logic-based controllers used in smart buildings is the design and development of sophisticated controllers for interior lighting and HVAC systems. Numerous interior thermal comfort variables, including temperature, humidity, air quality, air velocity, thermal comfort, and energy control, may be precisely regulated using a fuzzy-logic model. An optional fuzzy logic controller that may include freshly controlled real-world events like ambient temperature, humidity, and daily use is one of the journals' downsides; as a result, it is utilized outdoors for good fuzzy logic control[13][14]. that was done The advantage of fuzzy logic-based temperature and humidity measurement for pharmacy warehouses is that it keeps the environmental values necessary to retain the drug structure in those facilities at the required level and to give them a longer lifespan. These values are chosen in accordance with the guidelines for using a fuzzy logic system of fuzzy experts to track the temperature and humidity in the pharmaceutical warehouse in order to maintain the humidity and temperature values of the medicine cabinet at predetermined intended values. However, this research has a flaw in that, in an effort to keep the cabinet protected at normal levels, the cooling and humidifying continually changing because of the loss of temperature and humidity. changes as a result of the escaping interior air[15]. The following researcher developed an instrument for warming blood using an infrared temperature sensor, the MLX90614ESF (Research on Infrared Body Temperature Measurement). The widely used MLX90614 infrared temperature sensor, proximity sensor ultrasonics, and RGB LEDs are utilized by Preventing the Spread of Viruses to provide immediate response during fever screening. Additionally, it contains flaws, such as the fact that the outcomes are still ambiguous or borderline[16]. Commercial infrared (IR) thermopile MLX90614 This tiny, non-contact thermometer is made up of an IR thermopile detector that has been factory calibrated and a signal processing device that comprises digital signal processing and 17-bit analogue-to-digital conversion. With an accuracy of 0.2 °C between 36 and 38 °C, it is suited for medical purposes[17]. The following researcher will employ an authorized improved optocoupler sensor. Using an optocoupler sensor, The Drip Dose Infusion Accuracy Based on Optocoupler and Microcontroller Sensor may be able to identify the infusion droplets. This precisely calibrated sensor is required for the accurate monitoring of infusion rates and droplet volumes. This increased accuracy is advantageous for both macro (20 drops/cc) and micro (60 drops/cc) drips. For macro drip, the accuracy of the volume readings ranges from 95% to 99%, while for micro drip, it ranges from 94.5 to 97%. For velocity, the appropriate accuracy range is 92.37-98.46%. The optocoupler test showed that 4.31V was needed for the microcontroller to be able to detect liquid drips. It is possible to supply high, or 1 on the microcontroller, using this voltage. The optocoupler sensor readings may be processed by the Arduino microcontroller, shown on the OLED screen, and accompanied by a buzzer when the speed measurement abruptly changes. This is one of the study's drawbacks. while reading swiftly, accuracy ranged from 92.37 to 98.46%. The accuracy of the measurement is significantly influenced by the position of the sensor within the chamber. Depending on the manufacturer of the infusion set, the infusion chamber could alternatively be bigger or smaller. We need to develop an optocoupler sensor that can be put trustably in all brands in order to be ready for the future[18]. The following scientist created a Blood Warmer device using the DS18B20 temperature sensor and This project seeks to build a completely automated hot water dispenser that can be managed by a blind person without endangering themselves or others using an Arduino Mega and a DS18B20 temperature sensor. just placing a DS18B20 sensor in the water and adjusting the temperature range to 50 to 80 C. One drawback of this research is that, depending on the setpoint (options for 50, 70, and 80 degrees Celsius), the water's temperature in the glass varies by 1 to 3 degrees Celsius)[19]. The following researcher created a Blood Warmer tool employing a DS18B20 Sensor and a Peltier Tec1 12706 Automatic Water Temperature Control System with Temp. Sensing Devices for Hydroponic Plants. This project aims to design a system for managing water flow in hydroponic plant growth using the DS18B20 sensor's capability to precisely monitor water temperature. The test results show that when the hot water has cooled from 38.10 C to 30.31 C (in less than 4 hours) and then to 7.79 C, the ideal temperature for plant development is obtained. Despite the fact that it hasn't yet reached the 28 °C standard for hydroponic water temperature. The DS18B20 sensor used in this investigation has a flaw in that it cannot give a consistent temperature when the temperature drops from about 38.10 C to 30.31 C in four hours[20].

A system based on PID control with an LCD display was constructed on the Blood Warmer device employing DS18B20 and LM35 sensors from a prior study by senior colleagues. Thus, in this study, I improved it by including the MLX90614 sensor for measuring patient temperature, an optocoupler sensor for determining when the fluid is empty, two controls—PID Control and Fuzzy Control—a Nextion TFT display, as well as the ability to measure both patient temperature and blood temperature. This is carried out to check on the patient's health and the blood temps to see if they are stable or not.

The author's study, Fuzzy Logic Temperature Control in Blood Warmers Equipped with Patient Temperature and Blood Temperature, aims to make the incoming blood temperature to the patient can be achieved so that there is no reduction in temperature or decrease in temperature and so that the blood is not allowed to cool. The study is based on the results of the various problems above, where there are many problems in optimizing blood temperature to patients.

II. MATERIALS AND METHODS

One of the control system techniques that is currently widely used in many disciplines, particularly in the field of control systems, is fuzzy logic control (FLC). A mathematical model of the system to be managed is not necessary for FLC design. This turns into one of FLC's benefits—it makes controller design more feasible by relying just on logical rules.

A. EXPERIMENTAL SETUP

This study used a Digital Thermometer and used the HTC-2 Thermometer as a comparison using a temperature setting of 36˚C - 37˚C adjusted to normal human body temperature.

1) DATASHEET DESCRIPTION

The DS18B20 sensor detects blood temperature in the infusion tube via the heater. The DS18B20 sensor has a 12 Bit inter ADC with an accuracy value of +/- 0.5ºC[21]. The MLX90614 sensor detects body temperature, and the optocoupler sensor indicates when the liquid has run out. A digital thermometer and an HTC-2 thermometer are used for comparison. An Arduino ATMEGA-2560 serves as the microcontroller, uses Liquid Glycerin as a blood substitute, uses a heater with a small wattage, uses the Nextion LCD as a display and uses the Fuzzy Logic control as an automatic heater control.

2) DATA COLLECTION

In this study using a temperature setting of 36˚C - 37˚C where the temperature setting adjusts the normal human body temperature by taking 6x experimental data at different times and the results obtained from the PID Control and Fuzzy Control are different then the results will be displayed on the LCD Nextion.

B. DATA ACQUITION

In FIGURE 1 The DS18B20 sensor measures heater temperature, and the MLX90614 sensor measures body temperature. The temperature control setting is inputted into the microprocessor, which then processes it and controls the heater to keep the temperature between 36°C and 37°C. To use the blood warmer, first check the patient's body temperature, then choose a temperature setting by touching the touchscreen on the TFT Nextion in accordance with the patient's temperature condition. Next, choose the preferred control setting. The work of the blood warmer instrument is then processed by the microcontroller. The procedure can be stopped by pressing the reset button. The microcontroller system uses a DS18B20 sensor to measure heater temperature and an MLX90614 sensor to check body temperature. Its main duties include carrying out temperature control operations and assessing input temperature settings. The heater is specifically controlled by the microcontroller to maintain temperatures between 36°C and 37°C. In terms of blood warming capabilities, the system first assesses the patient's body temperature and then decides on an optimal temperature setting in light of this assessment. Interacting with the touchscreen interface on the TFT Nextion display makes this choice easier. The next step is for users to specify their preferred control settings. The blood warmer device is then operated by the microcontroller in accordance with these settings. It's important to note that the system has a reset button that gives consumers the option to stop the entire procedure when necessary.

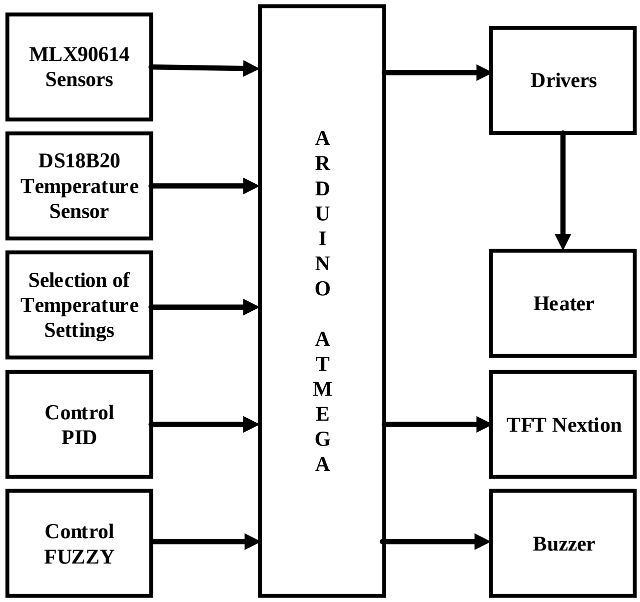

FIGURE 1. Block diagram of the blood warmer system. There are 2 sensors namely the DS18B20 sensor and the MLX90614 sensor which will then be processed by the microcontroller then the results of the sensor output will be displayed on the TFT Nextion. The Block Diagram above also uses 2 controls, namely Fuzzy Control and PID Control.

In FIGURE 2 The circuit above consists of the DS18B20 Sensor, MLX90614 Sensor, Optocoupler Sensor, Nextion and SSR Module. First of all, from the DC supply, enter the SSR module sequence (DC+, DC- and CH1), for CH1, enter pin 2 on Arduino. Then there are DS1 and DS2 sensors where this sensor has 3 legs namely VCC, GND and Data. For the Data pin, go to pin 3 on Arduino. Before entering Arduino pin 3, there is a resistor of 4K7. The DS18B20 Sensor (1) functions as a PID and Fuzzy heater control (according to patient temperature). Furthermore, the MLX90614 sensor has 4 legs namely Vin, GND, SCL, SDA. For the SCL and SDA pins, enter the SCL and SDA pins on Arduino. The MLX90614 sensor functions as a patient temperature monitoring. Then there is the Optocoupler Sensor which has 4 legs namely VCC, GND, A0 and D0. For A0, enter pin A0 on arduino. Optocoupler sensor serves as an indicator when the liquid runs out. Then there is also the Nextion display which has 4 legs namely +5V, TX, RX and GND. For pin TX, it goes to pin RX2 on arduino, whereas for pin RX goes to pin TX2 on arduino, and lastly, there is a buzzer which consists of 2 legs (+ and -) for feet + goes to pin 10 on arduino. The interconnection of diverse sensors and components within the circuit synergistically forms a comprehensive system, adept at concurrently monitoring patient temperature, gauging liquid levels, and relaying crucial data through the Nextion display. Furthermore, the SSR module takes on the pivotal role of regulating a heating element, employing a sophisticated combination of PID and Fuzzy logic methodologies, all based on the input from the DS18B20 temperature sensor. The intricate interlinking of a wide array of sensors and components within the circuit gives rise to a holistic system that excels in its ability to simultaneously oversee patient temperature, measure levels of liquids, and transmit vital information using the Nextion display.

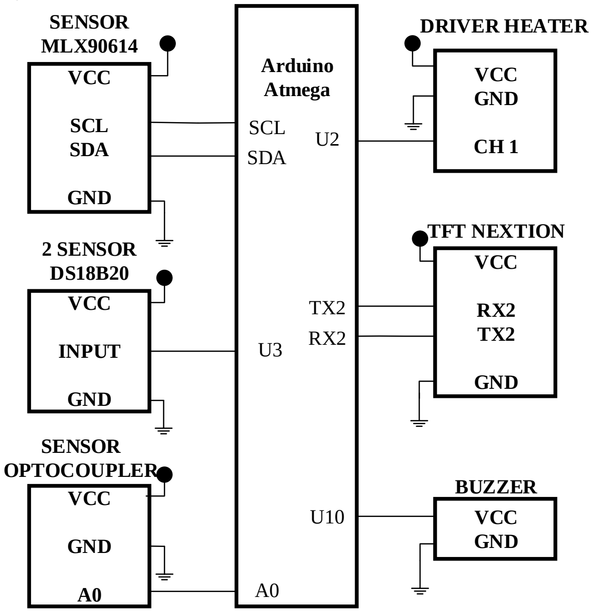

FIGURE 2. Blood Warmer system circuit

C. DATA PROCESSING

In FIGURE 3 The user turns on the microcontroller after initializing the tool, creating the foundation for flawless system operation. This initial phase lays the groundwork for subsequent activities, which are guided by thoughtful assessment and the creation of an optimum temperature configuration tailored specifically to the patient's particular physiological needs. The user's engagement increases after this temperature arrangement as they carefully define PID control parameters for the microcontroller. This painstaking calibration gives the system the ability to recognize even the most subtle temperature differences, supporting a solid foundation for precise and careful temperature administration. The heating mechanism takes off when the PID parameters have been carefully adjusted, setting out on a regulated trajectory to gradually raise the blood's temperature inside the specified chamber. Real-time monitoring of both the fluid's temperature and the patient's body temperature occurs concurrently with this crucial process. These colorful metrics unfold on the TFT Nextion screen, providing an easy way to maintain constant watchfulness and oversight. When the predetermined goal temperature is reached, a smooth transition takes place, and the flow sensor enters operational condition, ready to measure the fluid's flow rate inside the system. Nevertheless, a robust fail-safe mechanism takes over if the watchful sensor notices a halt in fluid motion. The heater, which is essential for maintaining the desired temperature, automatically deactivates to allay any concerns about overheating. When the buzzer is activated, a distinct and audible alert reverberates simultaneously. This audio signal serves as a quick and effective technique, grabbing the user's attention and informing them of the system's liquid reservoir's depletion. A comprehensive and profoundly responsive approach for precise temperature governance and careful fluid management within the context of medical practice is established as a result of the culmination of this complex and layered procedure.

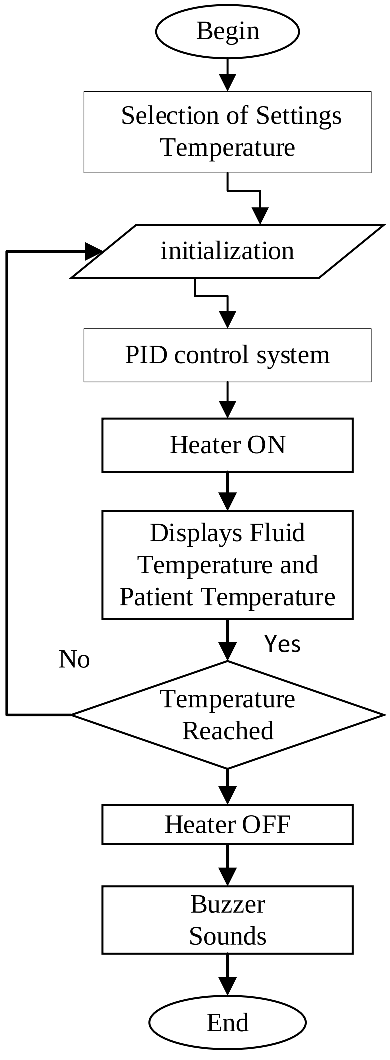

FIGURE 3. The flowchart above is the flowchart of how the Blood Warmer works, where the temperature reading on the Blood Warmer is then processed by the microcontroller which will be displayed on the Nextion LCD.

III. RESULT

In this study, the Blood Warmer tool has tested the sensor and the results of temperature measurements produced using the Digital Thermometer and HTC-2 Thermometer where the results will be displayed to Nextion.

TABLE 1
MLX90614 Sensor Measurement Against Digital Thermometer (PID Control)

Measurement	MLX Tools Display (^{0}C)	Digital Thermometer (^{0}C)	Mis take (%)	Error (%)
Respondent 1	36,69	36,5	0,19	0,05
Respondent 2	36,75	36,3	0,45	0,01
Respondent 3	36,77	36,8	0,03	0,08
Respondent 4	36,71	36,8	0,09	0,02
Respondent 5	36,91	36,7	0,21	0,05
Respondent 6	36,85	36,6	0,25	0,06
Mean			0,20	0,03
Standard Deviation			0,06	0,13
Uncertainty(UA)			0,02	0,05

TABLE 1 is a measurement table for the MLX90614 Sensor against a Digital Thermometer using PID Control. From the results of the data collection above, the data collection was taken 6x at different times, where the highest error value was obtained, namely Respondent 2 of 0.45 and the highest error value was obtained in Respondent 3 of 0.08.

TABLE 2
MLX90614 Sensor Measurement Against Digital Thermometer (Fuzzy Control)

Measurement	MLX Tools Display (^{0}C)	Digital Thermometer (^{0}C)	Mis take (%)	Error (%)
Respondent 1	36,85	36,5	0,35	0,09
Respondent 2	36,71	36,3	0,41	0,01
Respondent 3	36,59	36,6	0,01	0,02
Respondent 4	36,61	36,9	0,29	0,07
Respondent 5	36,81	36,5	0,31	0,08
Respondent 6	36,71	36,8	0,09	0,02
Mean			0,24	0,04
Standard Deviation			0,06	0,04
Uncertainty (UA)			0,02	0,01

TABLE 2 is a measurement table for the MLX90614 Sensor against a Digital Thermometer using PID Control. From the results of the data collection above, the data collection was taken 6x at different times, where the highest error value was obtained, namely Respondent 2 of 0.41 and the highest error value was obtained in Respondent 1 of 0.09.

TABLE 3
DS18B20 Sensor Measurement Against HTC-2 Thermometer (PID Control)

Measurement	Heater (^{0}C)	Thermo Hygrometer HTC-2 (^{0}C)	Mis Take (%)	Error (%)
Respondent 1	36,63	37	0,37	0,01
Respondent 2	36,75	36	0,75	0,02
Respondent 3	36,81	37,1	0,29	0,07
Respondent 4	36,75	37,7	0,95	0,02
Respondent 5	36,94	37,7	0,76	0,02
Respondent 6	36,94	36,3	0,64	0,01
Mean			0,61	0,02
Standart Deviasi			0,25	0,1
Uncertainty (UA)			0,1	0,04

TABLE 3 is a measurement table for the MLX90614 Sensor against a Digital Thermometer using PID Control. From the results of the data collection above, the data collection was taken 6x at different times, where the highest error value was obtained, namely Respondent 4 of 0.95 and the highest error value was obtained in Respondent 3 of 0.07.

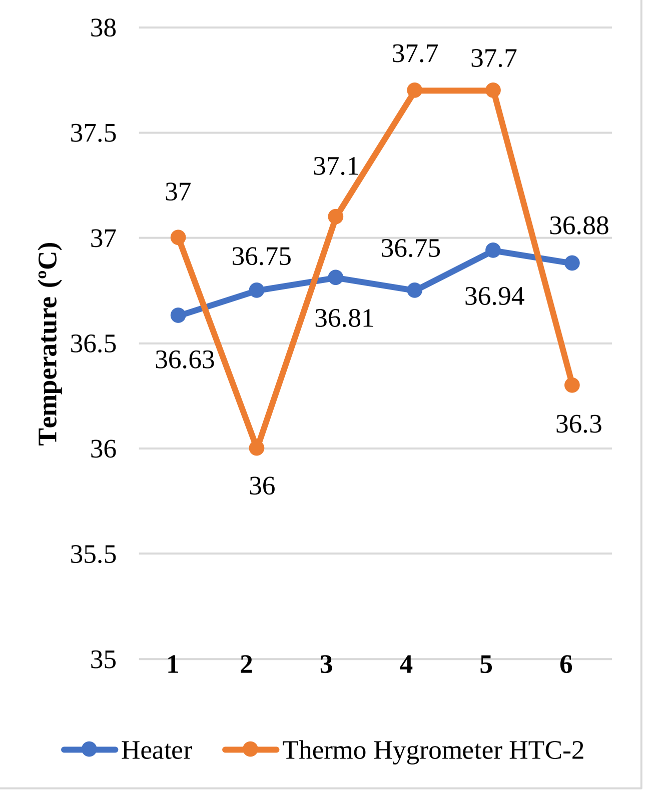

FIGURE 4. **PID control chart with temperature settings that adjust to normal human body temperature. For the PID control the temperature increase is not sequential but to reach the temperature setting it is accelerated compared to the Fuzzy control.**

TABLE 4
DS18B20 Sensor Measurement Against HTC-2 Thermometer (Fuzzy Control)

Measurement	Heater (⁰C)	Thermo Hygrometer HTC-2 (⁰C)	Mistake (%)	Error (%)
Respondent 1	36,94	36,4	0,54	0,01
Respondent 2	36,75	37	0,25	0,06
Respondent 3	36,63	36,3	0,33	0,09
Respondent 4	36,19	36,8	0,61	0,01
Respondent 5	36	36,3	0,3	0,08
Respondent 6	36,56	37	0,44	0,01
Mean			0,41	0,04
Standard Deviation			0,14	0,03
Uncertainty (UA)			0,05	0,01

TABLE 4 is a measurement table for the MLX90614 Sensor against a Digital Thermometer using PID Control. From the results of the data collection above, the data collection was taken 6x at different times, where the highest error value was obtained, namely Respondent 4 of 0.61 and the highest error value was obtained in Respondent 3 of 0.09.

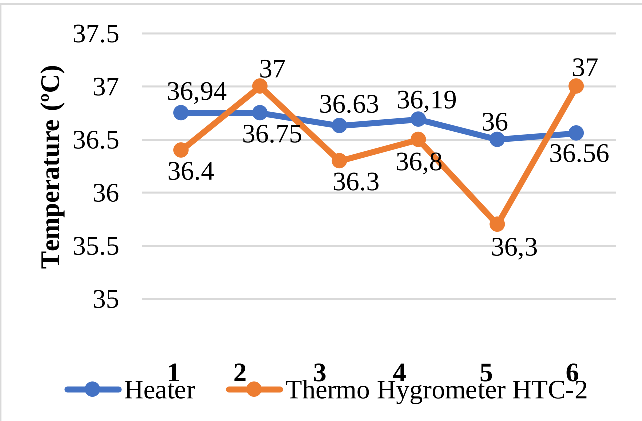

FIGURE 5. Fuzzy control chart with temperature settings which adjust to normal human body temperature. For Fuzzy control the temperature increases sequentially but cannot reach the setting temperature. Decrease occurred at a temperature of 36.3.

After obtaining the results above, there are response time and overshoot results for PID Control and Fuzzy Control as follows:

TABLE 5
PID Control and Fuzzy Response Time

Control	MLX Tools Display (⁰C)	Time to Reach Set Point (s)
	36.69	147 second
PID	36.75	186 second
	36.77	174 second
	36.71	172 second
	36.91	117 second
	36.85	177 second
FUZZY	36.85	179 second
	36.71	171 second
	36.59	185 second
	36.61	211 second
	36.81	194 second
	36.71	214 second

TABLE 5 From the results of the data collection above for the two controls, namely the PID Control and Fuzzy Control, it was taken 6x at different times, where the response time for the PID control was faster than the Fuzzy control.

TABLE 6
PID Control Overshoot and Fuzzy

Control	Measurement or Respodent	Overshoot (⁰C)
PID	Respondent 1	0,06
	Respondent 2	0
	Respondent 3	0,04
	Respondent 4	0,04
	Respondent 5	0,03
	Respondent 6	0,09
FUZZY	Respondent 1	0,09
	Respondent 2	0,04
	Respondent 3	0,04
	Respondent 4	0,4
	Respondent 5	0,8
	Respondent 6	0,15

TABLE 6 From the results of the above data collection for the two controls, namely the PID Control and Fuzzy Control, it was taken 6x at different times, where the data collection for the Fuzzy control had a higher overshoot compared to the Fuzzy control.

IV. DISCUSSION

Following testing of the Blood Warmer device, data was gathered using an HTC-2 digital thermometer and thermo hygrometer six times each, with PID control and fuzzy control. The analysis results from the experiment above were used in the creation of this tool, and they show that the PID Control is faster at reaching the set point but has a higher overshoot than the Fuzzy Control, whose temperature reading is smoother but also has a lower overshoot and takes longer to reach the set point. This fuzzy control employs the Fuzzyfication, Rule Evaluation, and Defuzyfication methods, yielding less-than-ideal results including significant overshoot and slower approach of the target point, but consecutive temperature increases. To prevent the red blood cells from being harmed, a heater with a low wattage is also used in the creation of this equipment. In blood banks, blood is typically kept between 1-6 oC in temperature. This permits extended storage times, prevents red blood cells from degrading metabolically, and stops any pathogens from growing[22].

The results of the study showed that automatic temperature performance testing on the quality of fuzzy-based oyster mushrooms and humidity control systems produced an average mass of 132.33 g and an average stem length of 6.23 cm, according to some studies that we found for PID control each value is different for each plant. Conclusion: Fuzzy control system improves mushroom productivity and is more energy- and environmentally-friendly[23]. The design of the Server Room Temperature and Humidity Design using Fuzzy Logic Control was successfully designed and implemented into the microcontroller with the results of simulation tests using Matlab obtained values that match the results on the microcontroller with AC average Temperature Set output deviation 0, 03500 and Average AC Mode Set output deviation 0.01225. This information was found in a journal that was researching the topic[12]. Results for the earlier journal with the title "A Proposed Another Research for PID" In order to reduce the energy used by indoor temperature and humidity monitoring systems, this paper suggests a fuzzy logic-based method that filters data sent to servers based on a variety of external factors, such as the time of data recording and the current energy consumption amount, while maintaining constant monitoring. The proposed fuzzy-based approach successfully lowers energy usage in temperature and humidity monitoring systems by 11.8%, according to the Appliances Energy Prediction dataset. It is obvious what the proposed strategy is in terms of reducing energy use by contrasting it with the earlier method of monitoring temperature and humidity that sent data to external storage[8].

There are flaws in how this tool was made, including the poor design of the tool on the heater hose, the messy placement of the optocoupler sensor, the difficulty of applying the MLX90614 sensor to the patient's hand so that it can adjust to the patient's body temperature, and the fact that PID control still overshoots and fuzzy control has a harder time getting to the target temperature (the patient's body temperature). Because wrist skin temperature is monitored to gauge patients' subjective thermal feelings, the positioning of the MLX90614 sensor used to detect the patient's body temperature is erroneous because core temperature can rise in reaction to skin chilling and fall in response to skin heating[24].

The community can gain from the development of this tool by making it easier to use the Blood Warmer device to monitor patient temperature and blood temperature during blood transfusions. A Nextion TFT display and sensors to measure blood and patient temperatures are also included with the gadget. As a result, this tool is essential for helping the community administer blood transfusions. RBC transfusions, which account for about 100 million worldwide each year, are a crucial therapeutic intervention to lower morbidity and death. The World Health Organization has identified red blood cell transfusions as posing a risk to patient safety because of the frequency and severity of adverse reactions, including hemolysis, that may result from potential cell damage during the donation, handling, storage, and/or administration of RBC units[25].

V. CONCLUSION

Create a microcontroller circuit, use PID control as a temperature control on an automatic heater, and display patient temperature and fluid temperature on the Nextion LCD are the goals of this tool's design, which aims to warm glycerin liquid (as a substitute for blood) to a temperature of 36°C to 37°C (adjusting to the normal human body temperature). After building the instrument, it was determined that the Blood Warmer could be created using two sensors, the DS18B20 sensor for measuring blood temperature and the MLX90614 sensor for measuring skin temperature, with a reading difference of 0.20C compared to the thermogun that uses the TFT Nextion display. The Nextion screen displays the results of the experiment above using fuzzy logic control for temperature readings. The manufacture of this tool also uses two controls, namely PID Control and Fuzzy Control. You can adjust the temperature settings in accordance with the patient's body temperature using these two controls, namely PID Control and Fuzzy Control. Although it is smoother, it also has less overshoot and takes longer to reach the target point. The results of using this fuzzy control as a heater control are then shown on the Nextion TFT. The findings of this investigation had the highest overshoot value of 0.8 and the highest error value of 0.09, with an average error value of 0.04. Smaller sensors can be used to further refine this gadget in the future, allowing for the production of easier-to-use instruments that can be continuously monitored from a distance. The heating hose cover can also be improved to ensure better functionality. The accuracy of sensor readings can be improved by carefully planning where to place the MLX90614 sensor on the patient. The positioning of the optocoupler sensor can also be adjusted for an even more tidy appearance.

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