HASIL CEK_SUNARDI, ANTON YUDHANA, (Member, IEEE), FURIZAL

by Sunardi, Anton Yudhana, (member, Ieee), Furizal Tsukamoto Fuzzy Inference System On Internet Of Th

IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received 25 December 2022, accepted 5 January 2023, date of publication 11 January 2023, date of current version 20 January 2023.
Digital Object Identifier 10.1109/ACCESS.2023.3236183

RESEARCH ARTICLE

Tsukamoto Fuzzy Inference System on Internet of Things-Based for Room Temperature and Humidity Control

SUNARDI[1], ANTON YUDHANA[1], (Member, IEEE), AND FURIZAL[2]
[1]Department of Electrical Engineering, Universitas Ahmad Dahlan, Yogyakarta 55166, Indonesia
[2]Master Program of Informatics, Universitas Ahmad Dahlan, Yogyakarta 55166, Indonesia
Corresponding author: Furizal (2108048014@webmail.uad.ac.id)

This work was supported by the Universitas Ahmad Dahlan.

ABSTRACT The idea of the Internet of Things (IoT) is utilized to increase the advantages of internet connectivity. As long as the electrical device is still connected to the internet, IoT can be utilized to operate it. This study applies the concept of IoT as a fan control and monitoring of the humidity and room temperature through a mobile-based application, so that the room can be controlled remotely using a smartphone before use. It is necessary to always keep the room comfortable to use, so that users can increase productivity and always avoid potential disease attacks when the temperature is unstable. In addition, the IoT concept also makes it easier to turn off the fan if at any time you forget to turn it off. This fan is integrated with the ESP32 microcontroller which has been equipped with a Wireless Fidelity (WiFi) module to access data changes in the Firebase Realtime Database. Room temperature and humidity are measured with a DHT22 sensor and processed using Tsukamoto's Fuzzy Inference System to produce the appropriate fan speed in the Duty Cycle unit. Tools and applications can work as predicted based on the findings of the research conducted. However, the impact of the fan on a closed room cannot cool the room temperature but the room temperature moves up with a change of 0.3 °C to 0.5 °C within 40-75 minutes. Therefore, in the next study it is recommended to use cooling devices such as Exhaust fans or Air Conditioners.

INDEX TERMS DHT22, duty cycle, ESP32, fan speed, fuzzy inference system Tsukamoto, humidity, Internet of Things, room controllers, temperature.

I. INTRODUCTION

Room temperature is an aspect that can affect the comfort and productivity at work [1]. Hot temperatures can reduce the body's immunity and enthusiasm in activities, especially indoor activities. In addition, hot temperatures can also bring disease to the body if it is felt for a long time [2]. Therefore, this problem must be a concern in an effort to maintain quality activities. This hot temperature cannot disappear in the absence of auxiliary tools to periodically stabilize it [3].

At this time, tools that are often used in cooling and stabilizing the heat temperature in the room are fans and Air Conditioners (AC). But often new problems arise, such as manual speed setting, forgetting to turn off and others. Therefore, an efficient alternative is needed to overcome this problem [4].

This study aims to solve the problems that have been described. The main tool used is a fan that is integrated with the ESP32 microcontroller which has been equipped with a WiFi module [5]. Meanwhile, the indicators in this study are temperature, humidity and human activity as measured by the DHT22 sensor and the Passive InfraRed (PIR) sensor. The results of this measurement were processed using the Tsukamoto Fuzzy Inference System (FIS) method to produce the appropriate fan speed in duty cycle units [6].

The development of technology in the world is increasingly progressing until now, including Indonesia. This rapid growth brings new breakthroughs that no one had previously thought of. IoT is a technology that has been developed for a long time, but in Indonesia the use of IoT is still relatively

The associate editor coordinating the review of this manuscript and approving it for publication was Renato Ferrero.

small and even many Indonesians are still unfamiliar with the term IoT.

IoT is one of the many technologies developed to face the digital era like now to make it easier for people to use it and to overcome digital-based difficulties. Researchers are always developing this technology in order to achieve optimal results in helping human needs.

As the name implies, IoT is the internet that plays an important role in carrying out all activities. This proves that the internet plays an active role in daily digital activities. Basically, IoT is a technological concept that connects other devices with internet media and can be controlled remotely. IoT is a concept in which technology is integrated into physical objects, such as sensors and software, with the aim of connecting, communicating, controlling, and sharing data while still connected to the internet.

IoT is one of the technologies that has a close relationship with the term machine-to-machine (M2M). M2M is a service that enables remote management and control of IT devices over IP and IoT networks is a closely related concept. The tools used in M2M are able to communicate so they are called smart devices. The purpose of creating smart devices is solely to help and become a solution to solving various problems or affairs and tasks owned by humans. IoT utilization can be applied in various areas of life, such as home automation, agriculture, health, transportation, and others [7]. There are several components in this technology but fundamentally there are only four components, namely sensors, connectivity, processed data, and user interface (UI).

A sensor is a tool that serves to retrieve data from an object. The data in question can be information such as temperature, humidity, sound, movement, and light. This data will be sent as information to the user. The process of sending data from sensor measurements requires connectivity in the form of an internet network as a medium. Many connectivity options include cellular networks and Wi-Fi. Each internet source has its own advantages and disadvantages. IoT requires a stable network connection so that the data exchange process can run properly. After going through a shipment that requires connectivity, the data will then go through a processing process before a command occurs. In order for the results of sending this data to be seen by users, users are equipped with UI as a monitoring and control medium. The UI used can be web, mobile, and other platforms.

The way this IoT technology works is very simple, namely by using program instructions. Each command can generate interactions on directly connected devices without the presence of intervention from the user. It can be said that this technology is arranged in such a way as to make it easier for users to carry out remote control of a control object. The main factor in smooth running is the stabilization of the connectivity network, while humans are only the supervisors of every activity of the device when it is executing commands.

Based on the description and comfort that will be obtained using IoT technology, this study will implement IoT by utilizing a mobile-based application to control and monitor room temperature conditions [8]. The application is developed using the flutter framework [9]. The WiFi module contained in the ESP32 is used to access data changes in the database in real time [10]. The database used is Firebase Realtime Database which is a product of the Google company.

The application of IoT in this study aims to make it easier for users to overcome the problems that have been described, such as making it easier to turn off the fan if at any time they forget to turn it off or control the temperature remotely via a smartphone before the room is used for activities [11].

Several IoT-based room temperature and humidity control systems have been created in previous studies with different utilization functions, some use on server rooms [12], greenhouse [13], thermal [14], and others [15]. The application of IoT can provide a great contribution in achieving convenience for its users. This statement is supported by previous researchers who show that the results of IoT implementation are very promising because they can improve the security, safety, intelligence, and comfort of users [16]

Other studies have shown that IoT systems are also a very suitable concept in providing convenience for digital technology users. Any device connected to electricity can be controlled by using the concept of IoT. Improved system efficiency drastically reduces electrical energy consumption by providing central control of the equipment [17].

The use of the ON/OFF concept in the control system can reduce the efficiency of the function of the tool built so that alternative control is needed to overcome this problem. Control systems with proven methods such as the Fuzzy Inference System (FIS) need to be implemented in the system and evaluated to improve the control system. This is supported by previous research that shows the use of fuzzy logic in control systems can provide a more optimal contribution when compared to the ON/OFF base [14]. The ON/OFF base will only give a value of 1 or 0, while the fuzzy base will give values of 0 through 1.

In other studies, a fan control system has also been built with fuzzy logic. The use of fuzzy logic concepts in this study is considered to be an energy-saving solution using artificial intelligence [18].

In one of the studies has applied fuzzy and IoT logic to web-based server rooms and provides notifications via Twitter. In this study, AC was used as a cooling media that was controlled using fuzzy logic and IoT. Based on research testing conducted through the Matlab application, fuzzy logic can be implemented into the microcontroller with the results of simulation testing using obtained values that correspond to the results on the microcontroller and the average value of AC Temperature Set output deviation 0.03500 and the average AC Mode Set output deviation 0.01225. Although there are differences in some output values, researchers claim that the function to control the air conditioner was successfully designed as desired [19].

The use of air conditioning in cooling the room is indeed fairly efficient. But basically, not everyone can use air conditioning due to cost limitations. AC is an electronic device that is fairly expensive in initial installation and in the consumption of electrical power needed in daily use. AC is also a modern air conditioner that is often used by the upper middle class. Meanwhile, the lower middle class people use fans more often because they are considered cheaper so the use of fans needs to be optimized with future research.

Based on the literature review that has been described, this study applies a fuzzy logic method to fan speed control to cool the room. This research is expected to contribute to optimizing fans in controlling temperatures that are a problem in tropical countries, one of which is in the country where this research was conducted, namely Indonesia.

II. THE BASIC CONCEPTS

A. IoT

IoT is a term that refers to the increasing use of the internet, the adoption of computing, mobile connectivity, and its integration into everyday life [20]. IoT is related to the DoT (Disruption of Things) and is used as an illustration of the change or conversion of Internet usage from the previous Internet of People M2M Internet.

B. FIS TSUKAMOTO

Each rule is supported by the same monotonous logic used by FIS Tsukamoto [21]. A fuzzy set with monotonous membership functions should be used to describe any result of the IF-THEN rule [22]. Based on the predicate, the output of the inference result of each rule is explicit (Crisp) [23]. Utilizing defuzzification and the idea of weighted averages, aggregation of the rules is carried out, and the results are then obtained [24].

1) FUZZIFICATION

The fuzzification stage serves to convert the crisp value into a fuzzy value using a fuzzy curve [25]. This study applies two types of curves, namely the triangle curve and the shoulder model.

a: TRIANGULAR MEMBERSHIP CURVE

A triangular curve is a combination of linear ascending and descending linear delimited by a single point of membership value 1 as in Figure 1 [26].

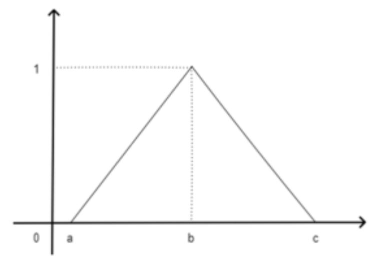

FIGURE 1. Triangular curve.

Based on Figure 1, it can be concluded that the triangle curve has four conditions of the value of the agglomerate. The four conditions will only result in a membership value of 0 to 1. The representation of the triangle curve can be seen in Equation 1.

$$\mu[x] = \begin{cases} 0; & x \leq a \text{ or } x \geq c \\ (x-a)/(b-a) & a < x < b \\ (b-x)/(c-b) & b < x < c \\ 1; & x = b \end{cases} \tag{1}$$

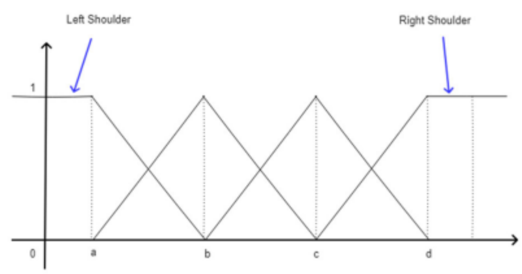

FIGURE 2. Shoulder membership curve.

b: SHOULDER MEMBERSHIP CURVE

The shoulder curve is used to end the variable of a blurred area that has its right or left side unchanged. This type of curve is divided into two models, namely the left shoulder curve and the right shoulder curve as shown in Figure 2 [27].

2) SYSTEM INFERENCE

At the inference system level, fuzzy rules based on the fuzzy set theory and fuzzy rules in the form of IF-THEN statements are both used to draw conclusions [22], [28]. Zadeh divides into three basic operators, namely AND, OR, and NOT [29]. The AND is an operator that serves to obtain the minimum elements. While the OR operator is used to search for the maximum element and the NOT operator is used to subtract the value of 1 with the negated fuzzy element [30]. In this study was applied the AND operator to every fuzzy rule formed. The mathematical narrative of the AND operator as shown in Equation 2.

$$\mu A \cap B = \min(\mu A[x], \mu B[x]) \tag{2}$$

3) DEFUZZIFICATION

Defuzzification is the final process of converting a fuzzy output into a crisp value [31]. The equation applied at this stage is the Weighted Average as Equation 3 [32].

$$Z = \frac{\sum \alpha_i z_i}{\sum \alpha_i} \tag{3}$$

C. ESP32

The ESP32 is the successor to the ESP8266 and offers several improvements in every way [33]. The ESP32 supports Bluetooth Low Energy as well as WiFi connections, making the ESP32 more flexible [34]. The ESP32 has 64MB of flash memory for storing programs and data [35].

D. DHT22 SENSOR

The DHT22 sensor is a digital relative temperature and humidity sensor [36]. The DHT22 sensor uses capacitors and thermistors to measure ambient air and send signals to the data pins [37]. The DHT22 claims to have good read quality, judging by its quick response to data collection and its minimalist size, as well as its relatively low price compared to thermometers [38].

E. PIR SENSOR

The PIR sensor is a motion detection sensor [39]. PIR sensors are widely used to determine the presence of human movement in the area that can be reached by PIR sensors [40]. These sensors are small, inexpensive, require little power, and are easy to use. This sensor is also widely used domestically and professionally [41].

F. PWM AC DIMMER

A dimmer is an electronic circuit that converts the shape of a pure AC signal into a truncated signal, which allows the output power to be adjusted [42]. AC signal clippings are useful for light dimming, motor deceleration, heating control and more [43].

G. FLUTTER

Flutter is an open-source framework or SDK developed by Google to create high-performance app interfaces that can be published for Android and iOS platforms from a single codebase [44]. The hot reload feature provided by Flutter eliminates the need to compile or rebuild all changes to see the results [45]. Flutter uses the Dart programming language which certainly feels familiar with the Java or Javascript programming language [46]. Dart is a popular programming language developed by Google [47].

H. FIREBASE

Firebase is a service from Google that is used to help with application development. Firebase Realtime Database enables users to create feature-rich collaborative apps by providing secure database access directly from client-side code [48]. Firebase provides a responsive experience to end users. Data changes occur continuously and in real-time offline. The real-time database synchronizes local data changes with remote updates that occur when the client is offline, so any differences are automatically resolved when device connectivity is restored [49].

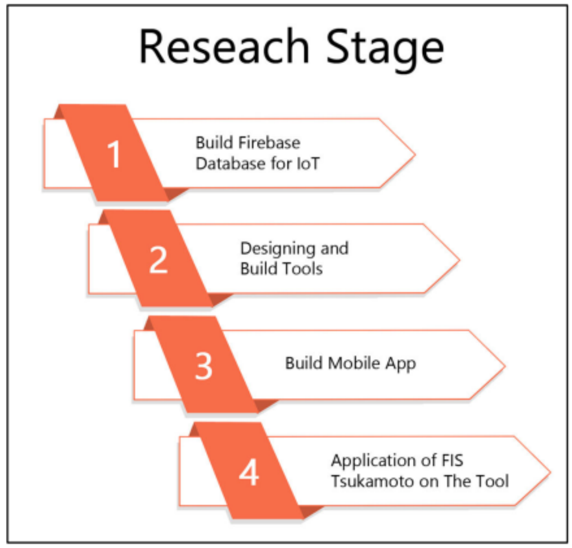

FIGURE 3. Research stage.

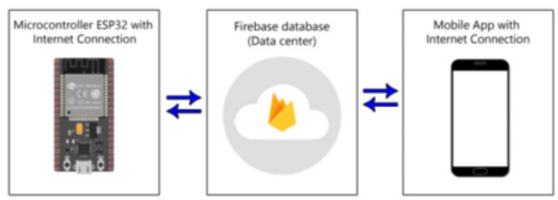

FIGURE 4. Basic concepts of data exchange.

III. RESEARCH STAGE

This research consists of several steps to produce the desired output. The research stage as shown in Figure 3.

Based on the research stage in Figure 3, broadly speaking, there are four stages carried out to produce the expected output. In the first stage, the database is designed and built using firebase database which is a realtime database service from the Google company. This database serves as a data center that will be an indicator of data changes from the tools and mobile applications to be built. These data changes will be accessed reciprocally by tools and mobile applications in real time over a network connection. In simple terms, the basic concept of data exchange is like Figure 4.

Based on Figure 4, data exchange does not occur directly between a mobile application and a microcontroller, but is mediated by a database that acts as a data center. Any changes to this database will be accessed by each device, both changes by the microcontroller and changes by the mobile application.

In the second stage, the tool is designed and built by utilizing one of the microcontrollers, namely the ESP32. The use of this microcontroller is based on the need for a network connection so that with its advantages that are

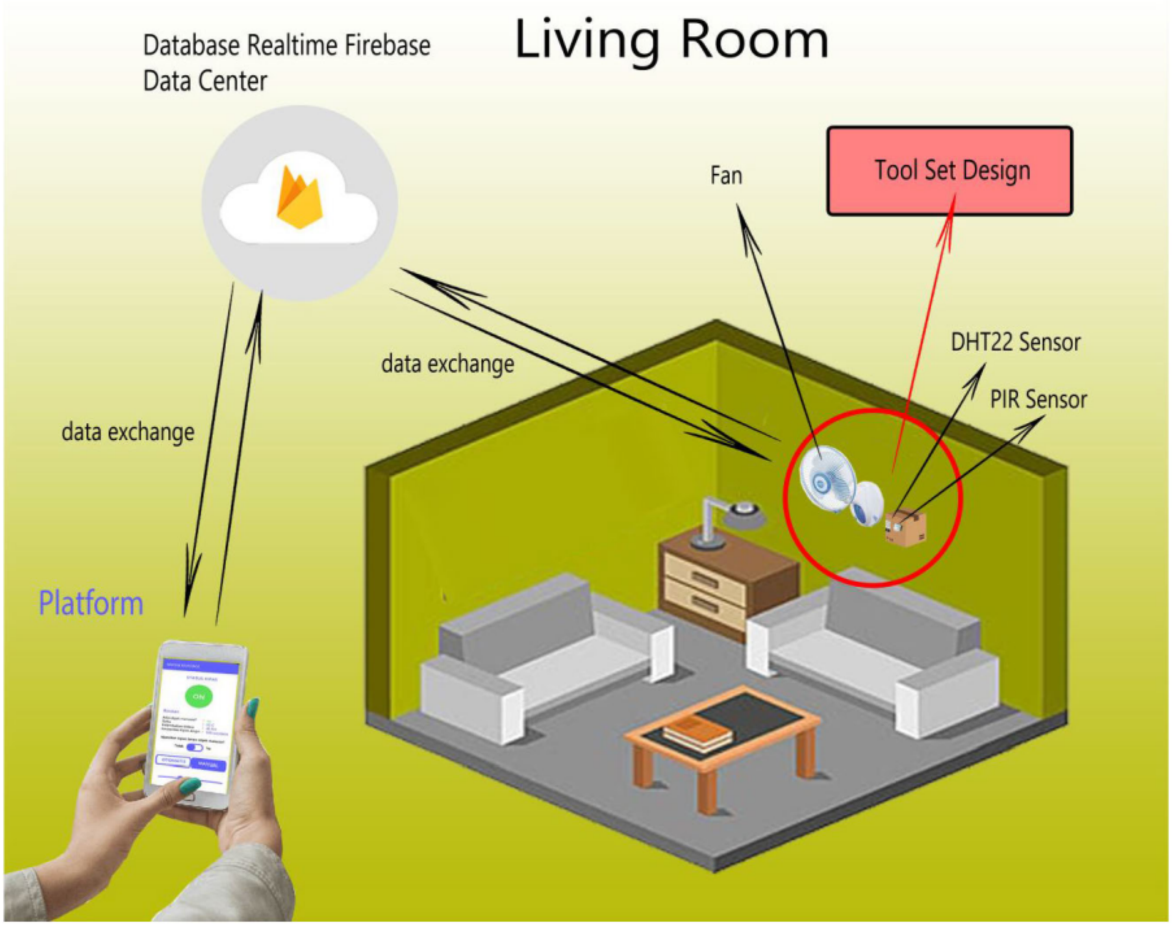

FIGURE 5. Simulation of expected results.

already accompanied by a WiFi module, there is no need to accompany additional WiFi modules anymore. This will save more on the use of the device.

In the third stage, the mobile application is designed and built using the Flutter framework. The flutter framework is one of the Open Source frameworks that is widely used in mobile development. Programmers simply visit, download, and install the flutter package from its official website. Google has provided documentation to be able to use the features that have been provided in this framework. In addition, the development of this application is also assisted by using the Flutter package in Visual Studio Code.

In the fourth stage, the research continued by implementing FIS Tsukamoto. This stage starts from discussing variables, talking universes, sets, and fuzzy domains. Each variable is represented in the form of a fuzzy curve used in the process on the Tsukamoto fuzzy.

Broadly speaking, Tsukamoto fuzzy consists of three stages, namely fuzzification, inference engine, and defuzzification. These stages are used to produce the output of the inputted variable values. The results of this processing are expected to be the most efficient value in controlling room temperature in the studies conducted.

After the discussion process is complete, a manual calculation process is carried out in the Microsoft Excel application. Then the coding or application of the fuzzy method is carried out on the built tool. The results of manual calculations that have been done will be compared with the results of calculations on coding tools. The tool is coded with a programming language with the ino extension using the Arduino IDE application.

After all stages of this research are carried out, the tools and applications are tested for feasibility so as to provide optimal results as expected. If the test results still have errors, they will be reviewed for correction. Based on what has been explained

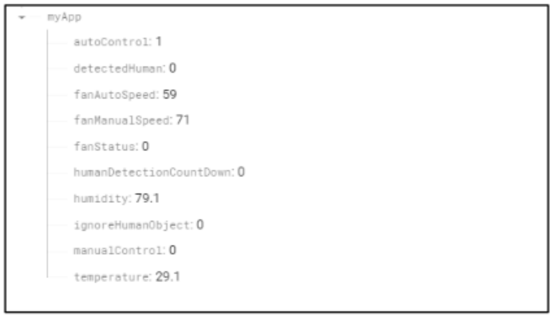

FIGURE 6. Firebase Database data schema.

in the introduction section, the goal to be achieved is a tool that can control the temperature and humidity of the room using a mobile application by applying the IoT concept. The expected simulation as shown Figure 5.

A clearer decipherment related to the stages of research is described as follows:

A. BUILD FIREBASE DATABASE FOR IoT

Based on the understanding that has been described, IoT has very important benefits for human life in building the concept of remote control. This control will also not be separated from data storage [50]. There are many ways that can be done, one of which is by utilizing the realtime database from firebase google [51]. Based on the information on the web firebase database, Google only provides 1 GB of storage for the free version. If you want to get more storage, Google offers a paid version upgrade option. This study only implemented the free version of storage. Therefore, this study uses the data update method (not insert) to overcome storage restrictions set by Google, so that the data in firebase does not increase but only changes the value of each variable field created. This will protect the free version of Firebase from over-data. The Firebase database data schema is built as in Figure 6.

Figure 6 is a data structure in the firebase database that will be an indicator of changes in the action of the built tool. The variables listed on the Figure 6 have their own functions as in Table 1.

B. DESIGNING AND BUILD TOOLS

This research tool is built using the ESP32 which overall functions almost the same as other microcontrollers such as Arduino, Wemos Mini, and others [52], [53], [54]. The concept of application as a whole is the same, because Arduino code can also be used on ESP32 [55]. In addition, hard tools such as sensors can also be used on the ESP32 using the same source code [56]. The design of the tool is built as in Figure 7.

The details of describing the schema of relationships between devices are described in Table 2.

TABLE 1. Firebase data schema explained.

No	Variable Name	*Data Type*	Function
1	autoControl	*Number*	If it is worth 1, then the fan is controlled automatically by the Fuzzy Tsukamoto algorithm.
2	fanAutoSpeed	*Number*	Stores the fan speed value (duty cycle) when the user selects the automatic control option.
3	manualControl	*Number*	If it is worth 1, then the fan is manually controlled by the user with a duty cycle input between 1 to 100.
4	fanManualSpeed	*Number*	Stores the fan speed value when the user selects the manual control option.
5	fanStatus	*Number*	Fan status indicator is on (1) or OFF (0).
6	temperature	*Number*	Stores temperature values read by the DHT22 sensor.
7	humidity	*Number*	Stores the humidity value of the air read by the DHT22 sensor.
8	detectedHuman	*Number*	A value of 1 indicates that there was a human object detected by the PIR sensor in the last 60 seconds.
9	humanDetection-CountDown	*Number*	Counting down 60 seconds since the last time a human object was detected. If before up to 60 seconds the human object has been detected again, then the value will be changed back to 60. If the countdown shows the number 0, then the value of the detectedHuman variable will be set to the value of 0 (no human object was detected in the last 60 seconds).
10	ignoreHumanObject	*Number*	An indicator that the fan is turned on by ignoring the presence of humans, meaning that the fan will still turn on even if no human object is detected by the PIR sensor.

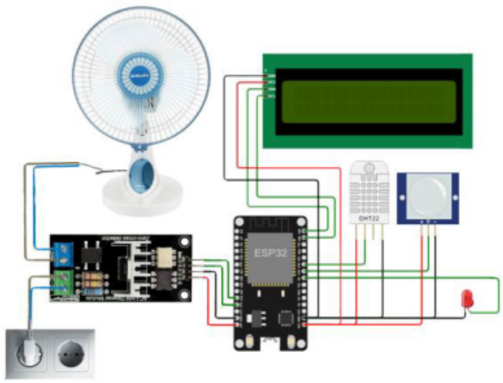

FIGURE 7. Tool design.

TABLE 2. Scheme of relationships between devices.

Relationship Start		Destination	
Device Name	**Port**	**Device Name**	**Port**
ESP32	GND	LCD	GND
ESP32	3V3	LCD	VCC
ESP32	IO D22	LCD	SCL
ESP32	IO D23	LCD	SDA
ESP32	GND	DHT22 Sensor	GND
ESP32	3V3	DHT22 Sensor	VCC
ESP32	IO D19	DHT22 Sensor	SDA
ESP32	GND	PIR Sensor	GND
ESP32	3V3	PIR Sensor	VCC
ESP32	IO D18	PIR Sensor	OUT
ESP32	IO D5	LED	+
ESP32	GND	LED	-
ESP32	GND	PWM AC Dimmer	GND
ESP32	3V3	PWM AC Dimmer	VCC
ESP32	IO D12	PWM AC Dimmer	Z-C
ESP32	IO D14	PWM AC Dimmer	PWM
Power source	(+ & -)	PWM AC Dimmer	AC-IN
Fan	(+ & -)	PWM AC Dimmer	LOAD

C. BUILDING MOBILE APP

The mobile application is an application that can be paired and used on a smartphone [57]. Many frameworks and technologies can be utilized in building mobile applications, including react native, sencha, ionic, flutter and others [58]. In this study, the mobile application was built using the flutter framework. The development cycle starts from collecting and analyzing the data needed to be applied to the application. After that, the application is designed according to the needs needed so that the features in the research can be fulfilled in the application to be built. Once the design is complete, the application begins to build by coding using the flutter framework. The development of this application is adapted to the pre-designed design. After the application has been developed, then the application is then carried out a testing process to ensure that all interfaces and functionalities of the application can run properly as expected. Furthermore, the application will be deployed and maintained during use. To be clear, the lifecycle steps of mobile application development are built as in Figure 8.

This application was created to control and monitor the temperature and humidity conditions around the device that has been built. This application is integrated with the tool through the internet network, so that users can monitor anytime and anywhere as long as the tool and smartphone used are still connected to the internet. The mobile application interface has been built as in Figure 9.

This built application consists of one interface according to the design of the application that has been designed. At the time of controlling the tool, the user can choose several options, namely:

1) Enabling the option ''Turn on the fan without a human object?'' is that the fan can be turned on by ignoring the detection of human presence through the PIR sensor. Because, if you don't activate this option, then the fan will only turn on when the PIR sensor detects human presence.
2) Selecting the ''Automatic'' control option is that the fan speed will be set based on the temperature and humidity read and processed using fuzzy logic.
3) Selecting the ''Manual'' control option is that the fan speed is controlled manually by entering the desired speed value.

D. APPLICATION OF FIS TSUKAMOTO ON THE TOOL

Fuzzy Tsukamoto has three important stages in producing output, namely fuzzification, machine inference, and defuzzification. The illustration is like Figure 10.

The Fuzzy stage in Figure 10 shows that the input in the fuzzy system is a crisp value. This crisp value will be converted into a fuzzy value in the form of a fuzzy membership value through the fuzzification stage using Equation 1. This fuzzification stage is guided by the membership function curve of each input variable, namely the temperature in Figure 11 and the humidity in Figure 12. This membership function curve will be used to obtain the fuzzy membership value of each set.

After the fuzzification stage is complete, the output of this fuzzy membership value will then be processed at the machine inference stage. At this machine inference stage, fuzzy rules are needed to process the fuzzy membership value obtained from the fuzzification stage. The fuzzy rules used are already listed in Table 3. These fuzzy rules will be processed using Equation 2. After the machine inference stage is complete, the process continues at the last stage, namely defuzzification using Equation 3. At this stage of defuzzification, crisp value will be obtained as the final output of the process on Fuzzy Tsukamoto.

Tsukamoto's fuzzy calculation by applying 25 fuzzy rules produces the output as expected [59]. These rules are obtained from a combination of two input variables, namely

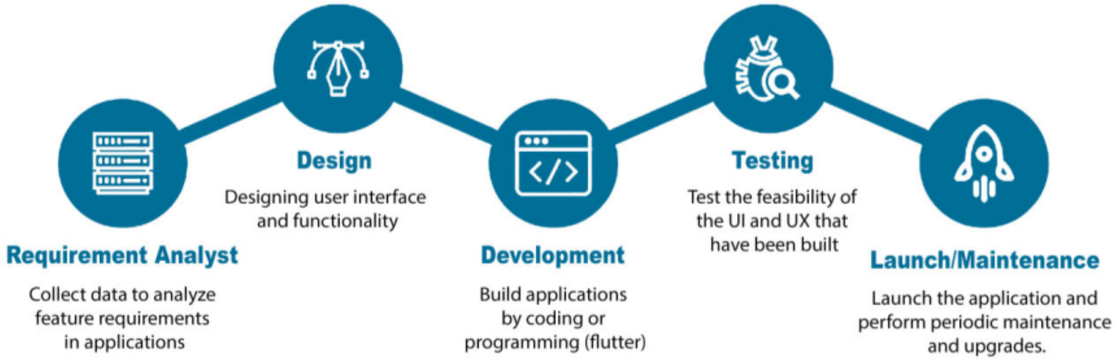

FIGURE 8. Mobile application development lifecycle.

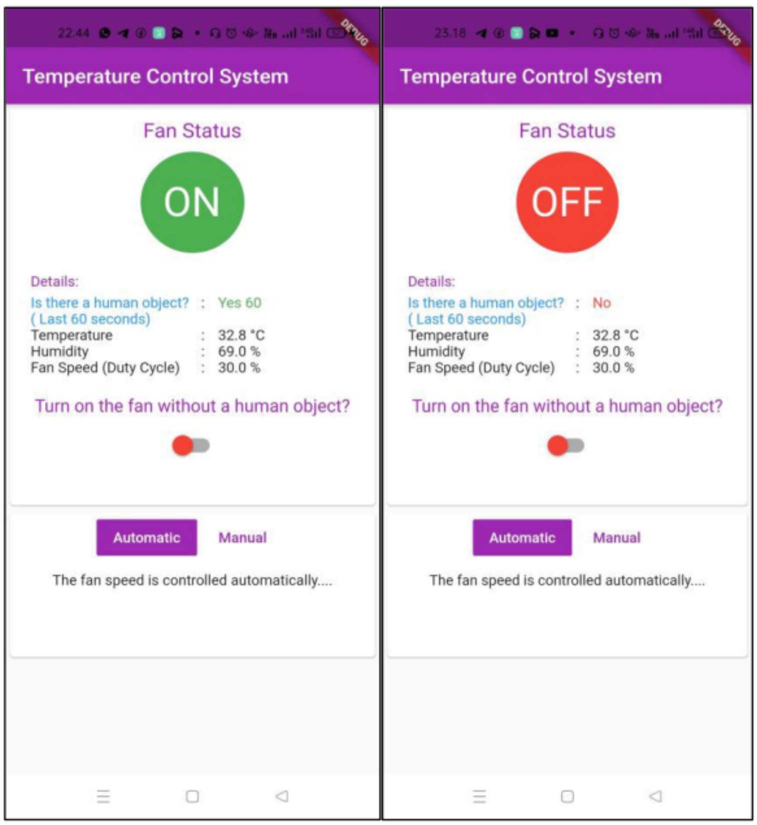

FIGURE 9. Mobile app interface.

temperature and humidity. These two input variables each have five sets. The set of temperature variables is Quite Warm, Warm, Quite Hot, Hot, and Very Hot. While the set of humidity variables are Dry, Normal, Pretty Wet, Wet, and

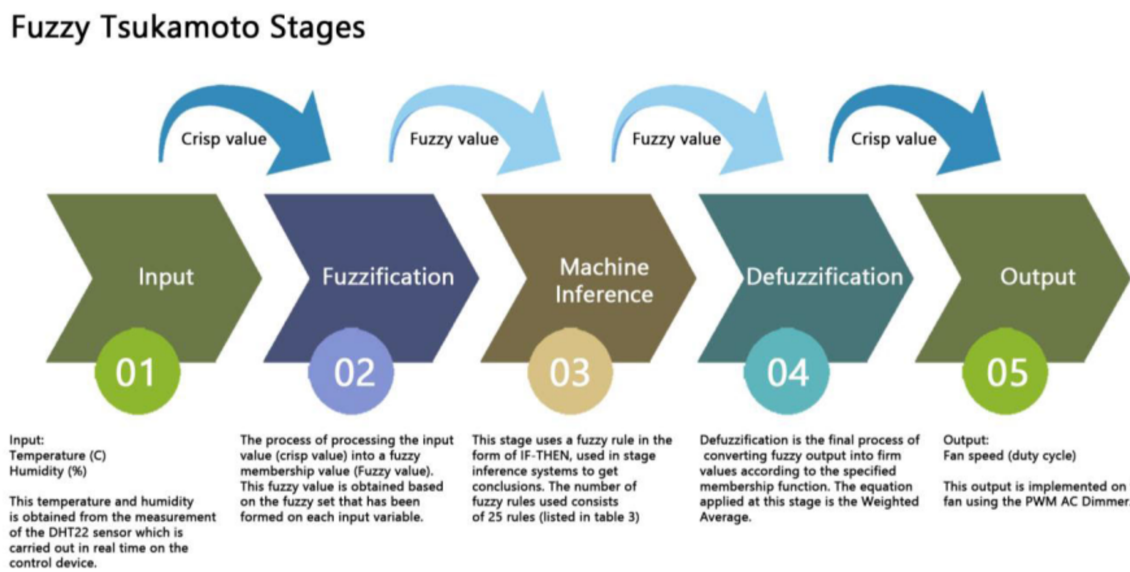

FIGURE 10. Stages of FIS Tsukamoto.

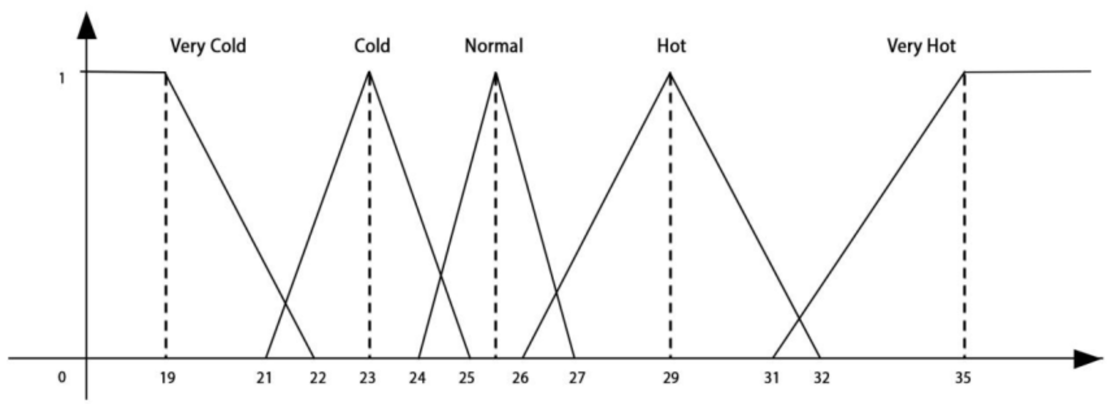

FIGURE 11. Temperature membership function curve.

Very Wet. The combination results of these two variables produce a fan speed output consisting of three sets, namely Slow, Medium and Fast. An example of some of the speed outputs produced by this fuzzy calculation can be seen in Table 6.

IV. EXPERIMENTAL RESULT

A. DHT22 SENSOR CALIBRATION

In this study, the temperature sensor used was the DHT22 sensor. However, this sensor is made and designed for measurement at the location conditions under which it is created that will cause deviations in results at other locations. Therefore, it must be known how the characteristics of this DHT22 sensor in tropical Indonesia and need to be calibrated at the desired local conditions. Sensor calibration is a feasibility test of the sensor to achieve results in accordance with the desired indicators, namely accuracy and precision with the addition of an equation model, so that this goal is achieved. This calibration is done by comparing the temperature and humidity values on the sensor with the temperature and humidity values obtained from manual measurements from the thermometer and hygrometer taken at the same time. The comparison tool used in this calibration process is the Digital HTC-2 Thermometer Hygrometer as in Figure 13.

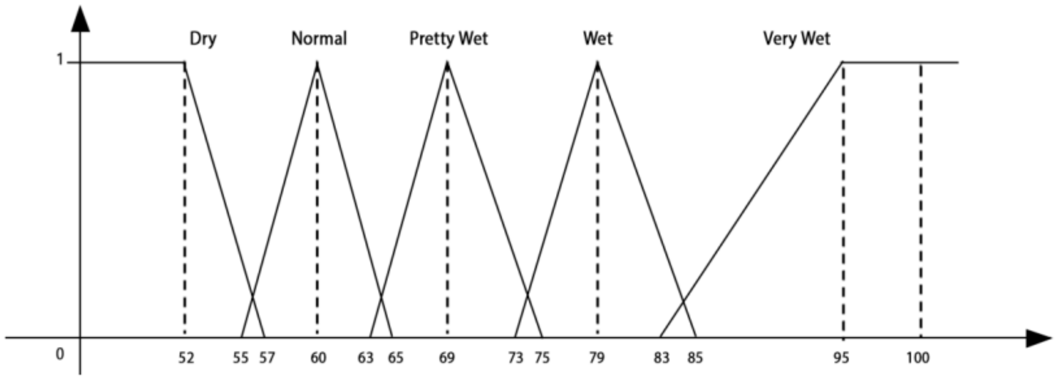

FIGURE 12. Humidity membership function curve.

FIGURE 13. Digital HTC-2 thermometer hygrometer.

This calibration to test the precision level of the DHT22 sensor is done by taking 60 data simultaneously. The results of this test showed a temperature difference of 0.18°C and humidity of 7.78%. The comparison chart of DHT22 and Digital HTC-2 Thermometer Hygrometer temperature measurements is shown in Figure 14. As for the humidity, it is listed in Figure 15.

B. RESPONSE OF TOOLS AND MOBILE APPLICATIONS

The tools in this study have been applied to rooms that are not too spacious. The area of the room tested measured 400 cm × 400 cm wide, while the height was 350 cm. The area of the room can affect the control system that is built. The more spacious the room implemented, the more difficult it is to control its temperature, unless a control fan is implemented in large quantities.

While the mobile application as a control medium has been tested with a fairly good success rate. The results of some tests are listed in Table 5.

Table 5 shows the mobile application's response to changes in data on the server. The mobile application response test is carried out by providing two connection sources, namely WiFi and mobile data. Based on the tests conducted, the mobile application can communicate well as long as it is connected to a network that has stable speed. The fastest result, the application can provide a response of <200 ms with an internet network speed of 29 Mbps. While on an unstable network, the application still provides a response even with a long response time. This application response test is also performed against a missing network connection. If the connection is dropped then the application will not give a response until the connection is available again. Based on this description, it can be concluded that the internet network connection greatly affects the application's response time in accessing data on the server, both when updating data and reading data. Not only mobile applications, the response of built-in ESP32 devices is also affected by network speed conditions. Networking is a major influencing factor when interacting with IoT because all connected devices communicate over the network.

In addition to the internet network, the component that is also needed by the device or tool that is built is the availability

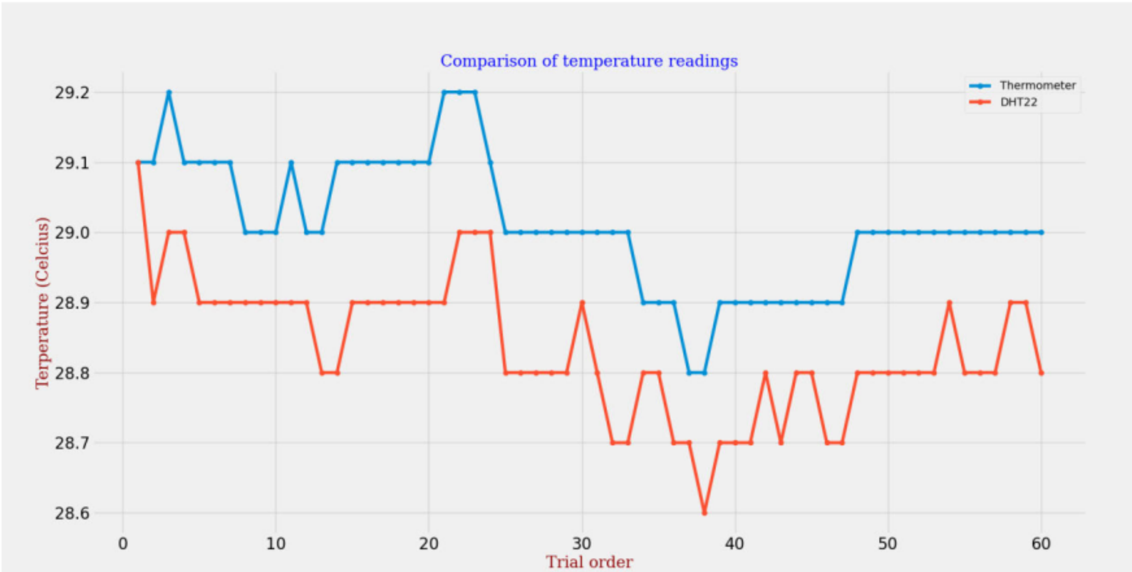

FIGURE 14. Comparison of temperature measurements.

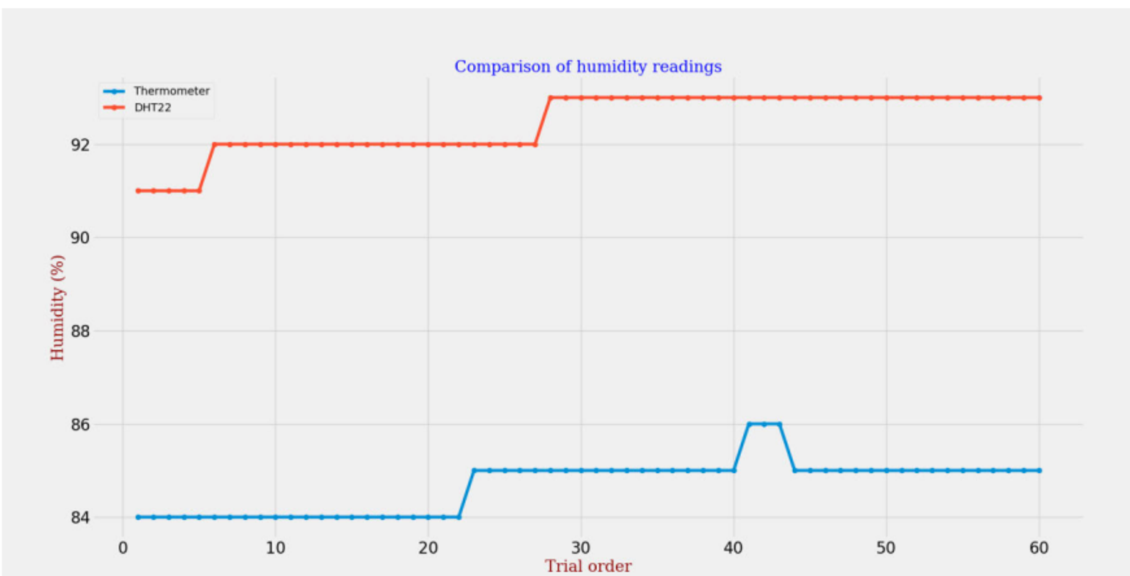

FIGURE 15. Comparison of humidity measurements.

of electrical power sources. In Indonesia, the availability of electricity is often a challenge because there are frequent power outages, especially for areas far from urban areas. The duration of these power outages usually varies, ranging from just a few minutes, a few hours and even a few days. When the power source is off, the tool will automatically turn off. However, the cached change data will still be stored in google's firebase database. Therefore, when the power source is available again, it will access the latest data changes to firebase to give the room action. When the tool accesses data on firebase, it must still reconnect to the internet network connection. The results of the experiment are shown in Table 5, while the results of its execution are as shown in Figure 16.

These control tools are designed and built by applying the needs to network connections. If the ESP32 device is not connected to the internet network, the tool automatically

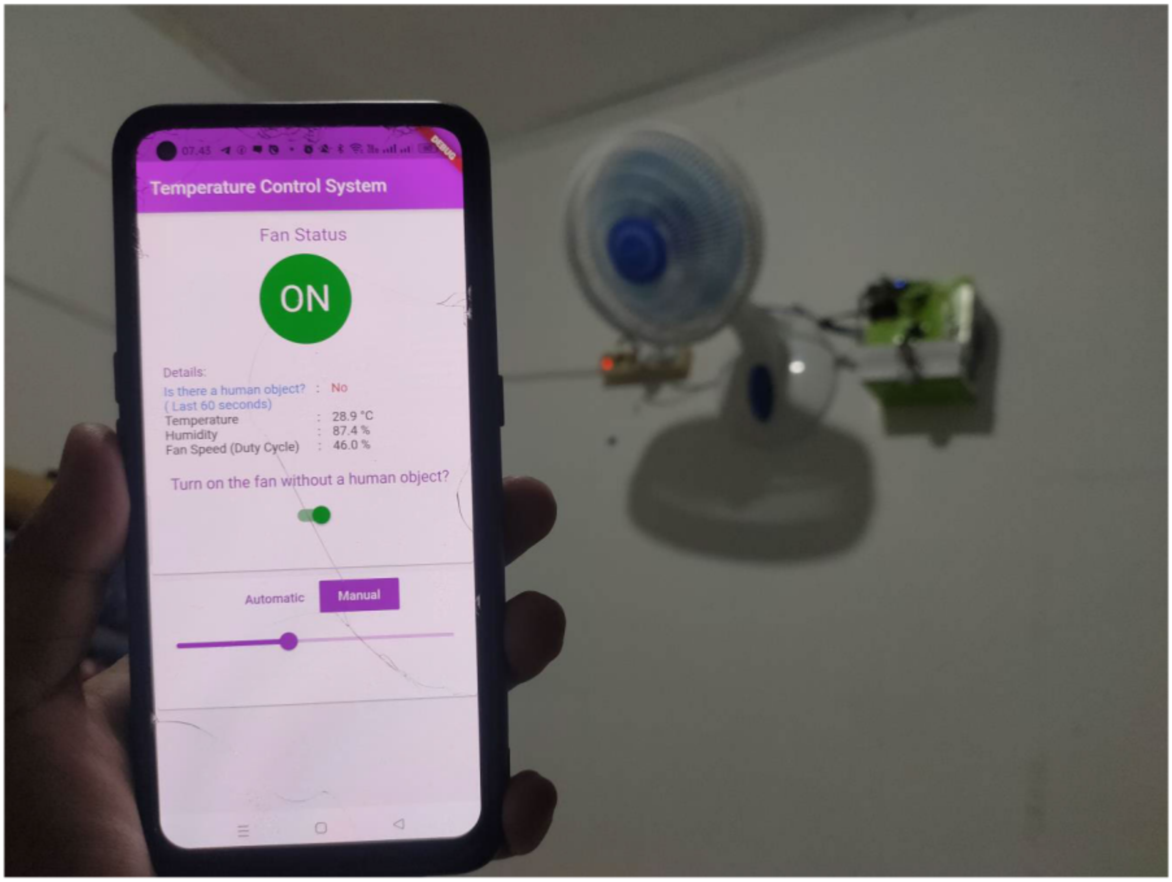

FIGURE 16. Application to the room.

cannot access data changes in the database. However the flow chart on the program code of the tool is created independent of the internet connection. When the internet connection on the tool is lost, the tool will turn off the ''Turn on the fan without a human object'' mode and the ''Manual Control'' mode. After that, the tool will check the presence of humans and check the temperature and humidity of the air in the room offline / locally. If in the room there are human activities and temperature conditions above normal conditions, then the tool will activate the ''Automatic Control'' mode by applying fuzzy logic calculations to produce the ideal fan speed in controlling temperature needs in the room.

In this condition, users cannot monitor the device remotely on a smartphone / mobile application because the tool cannot update data changes in the database. Therefore, indirectly the mobile application also cannot be synchronized with the tool. Even so, users can still see the fan status (ON/OFF), fan speed, temperature, and humidity in real time on the LCD attached to the device set. This condition is not permanent, because if the tool is connected to the network, the tool will be able to access data changes on the database again. The workflow of this tool is shown in Figure 17.

An internet connection not only affects the control tools built in, but also affects the mobile applications that are designed. If the smartphone connection is lost, the user is also unable to monitor and control the device remotely. This condition will end when the application reconnects to the network. The mobile app flowchart is listed in Figure 18.

C. TESTING THE IMPACT OF THE TOOL ON THE ROOM

This temperature and humidity control device is tested by placing a DHT22 sensor (temperature and humidity gauge) in three different places. This test aims to provide information related to the influence of devices that expect a decrease in heat temperature in the room. Visually, the placement position can be seen in Figure 19.

These three DHT22 sensor positions will be tested to determine the effect of this control device on room temperature, whether exposed to fan blowing or not. For more details,

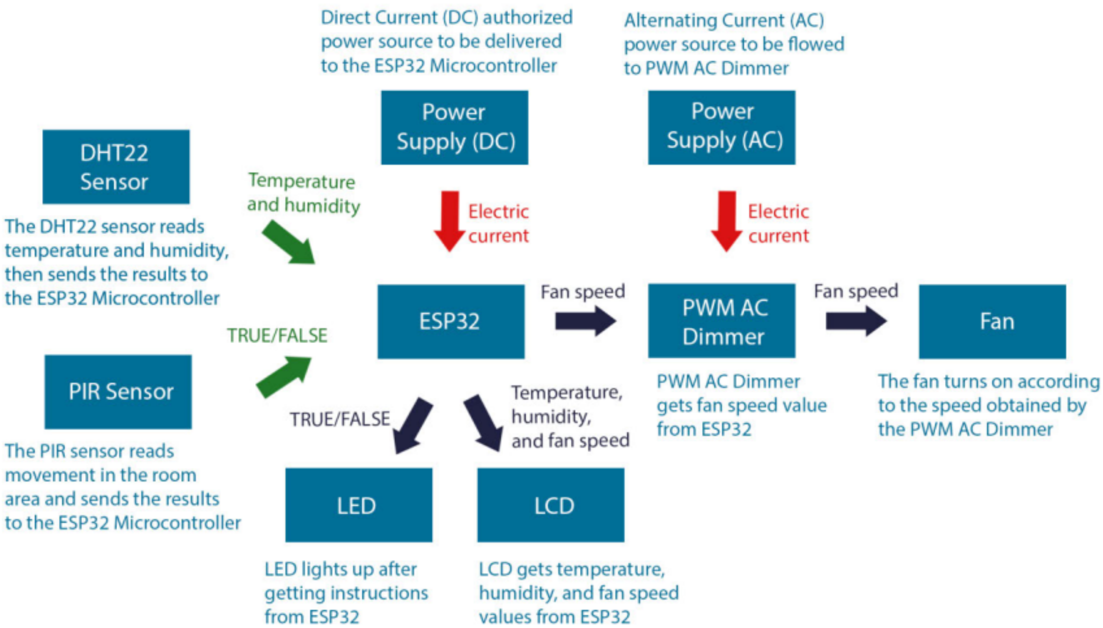

FIGURE 17. Tool working flowchart.

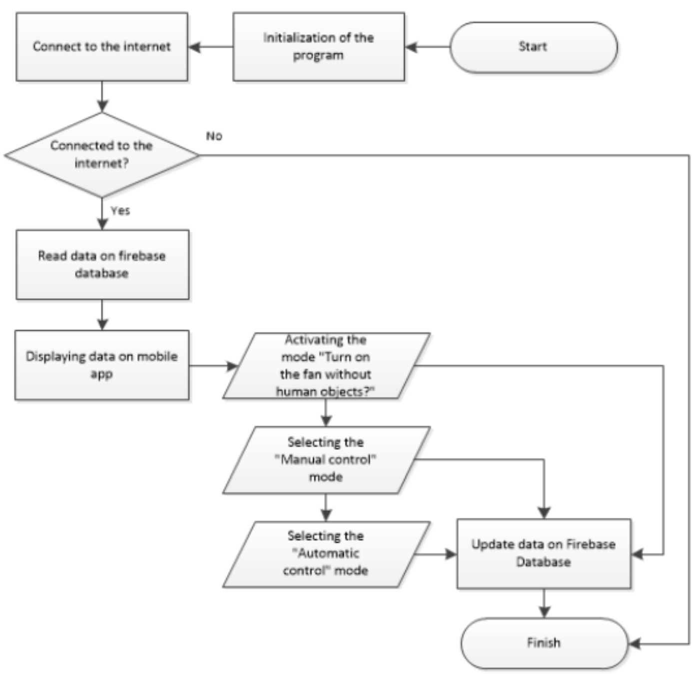

FIGURE 18. Mobile app working flowchart.

Figure 20 is an illustration of the position of the fan and DHT22 sensor which is included with the size of the room on each side of the room which is viewed through the 4th side based on the illustration listed in Figure 19.

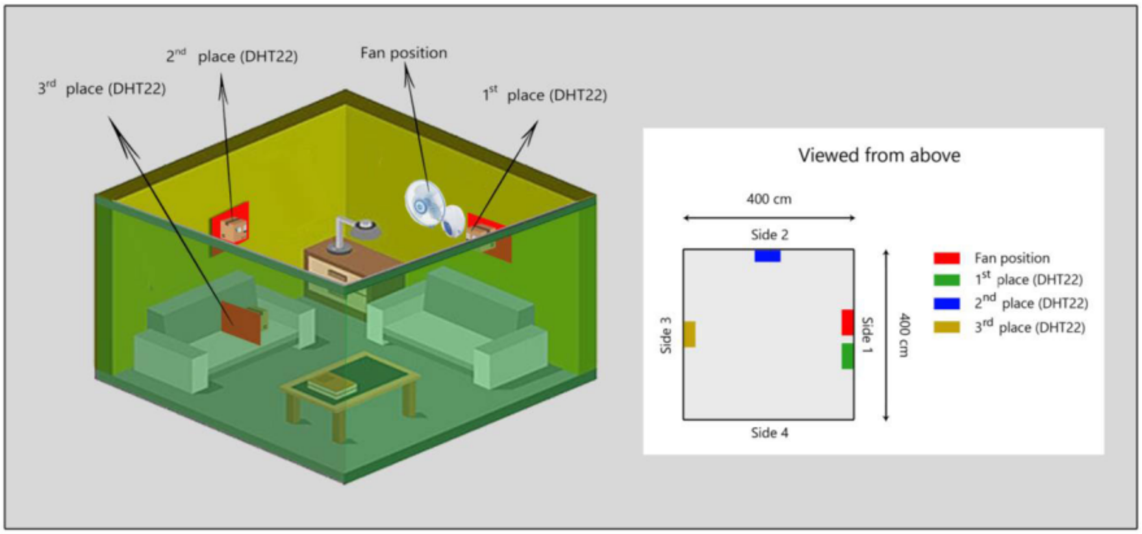

FIGURE 19. Simulated position of the fan and DHT22 sensor.

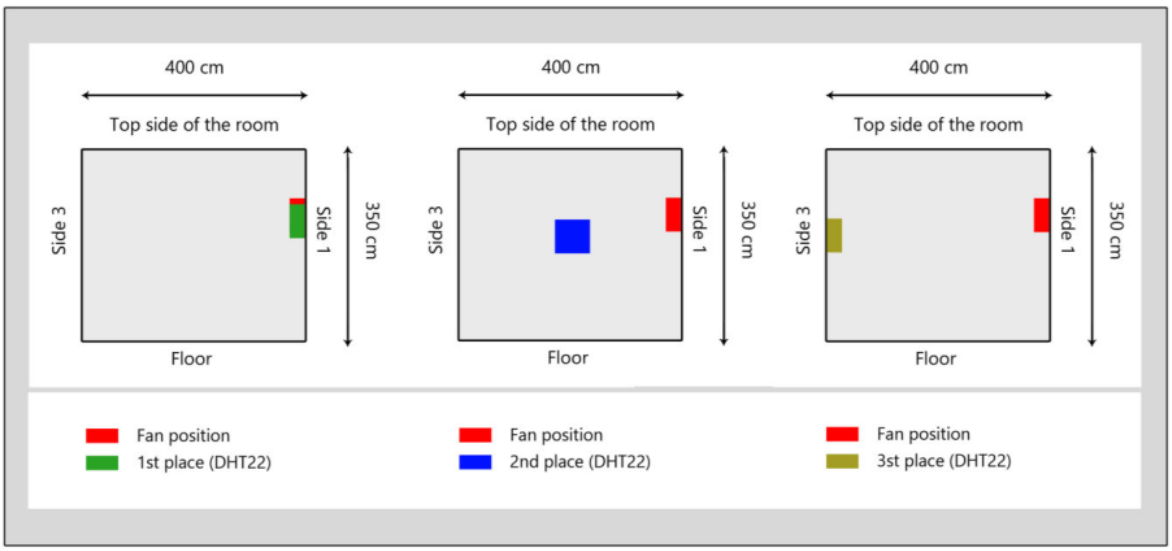

FIGURE 20. Position of the DHT22 sensors and fan when viewed from side 4.

These three sensor positions are exposed to different wind gusts of force, ranging from those that are hardly exposed to the slightest wind to those that are directly exposed to the wind. The DHT22 sensor at each of these positions will be tested to provide information regarding the effect of fan rotation that has been set with fuzzy logic on room temperature and humidity. A description of the wind touch at each position of the DHT22 sensor is shown in Table 6.

The test is carried out in the conditions of a closed room, so that there is no air cycle in and out of the house. Testing in the first position, the rotation of the fan did not make a significant impact. The test results show the temperature graph of some tests cannot be inferred. Because some tests show the temperature is moving up. Meanwhile, several other tests showed temperatures moving down. The temperature changes in rise and fall are also not very significant, which only ranges from 0.3-0.5°C. The graph of the first few test positions is shown in Figure 21.

The test at the second position showed that the temperature continued to rise as evidenced by the form of its test graph.

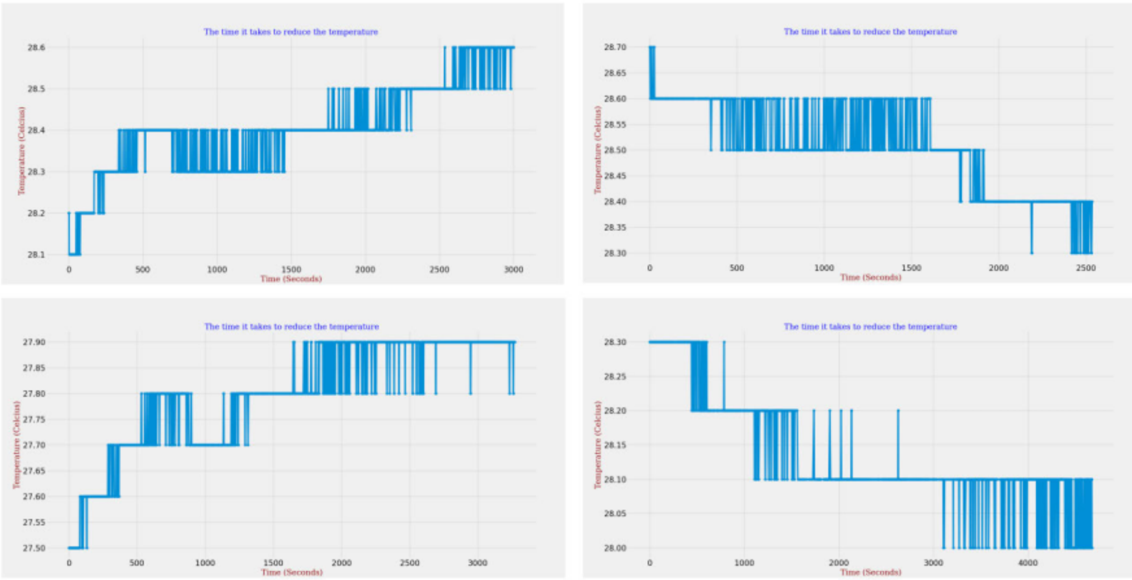

FIGURE 21. First position test (behind the fan).

TABLE 3. Fuzzy rule base.

Rule		Temperature		Humidity		Fan Speed
[R1]		QUITE WARM		DRY		SLOW
[R2]		QUITE WARM		NORMAL		SLOW
[R3]		QUITE WARM		PRETTY WET		SLOW
[R4]		QUITE WARM		WET		SLOW
[R5]		QUITE WARM		VERY WET		SLOW
[R6]		WARM		DRY		SLOW
[R7]		WARM		NORMAL		SLOW
[R8]		WARM		PRETTY WET		SLOW
[R9]		WARM		WET		MEDIUM
[R10]		WARM		VERY WET		MEDIUM
[R11]		QUITE HOT		DRY		MEDIUM
[R12]	IF	QUITE HOT	AND	NORMAL	THEN	MEDIUM
[R13]		QUITE HOT		PRETTY WET		MEDIUM
[R14]		QUITE HOT		WET		FAST
[R15]		QUITE HOT		VERY WET		FAST
[R16]		HOT		DRY		MEDIUM
[R17]		HOT		NORMAL		MEDIUM
[R18]		HOT		PRETTY WET		FAST
[R19]		HOT		WET		FAST
[R20]		HOT		VERY WET		FAST
[R21]		VERY HOT		DRY		MEDIUM
[R22]		VERY HOT		NORMAL		FAST
[R23]		VERY HOT		PRETTY WET		FAST
[R24]		VERY HOT		WET		FAST
[R25]		VERY HOT		VERY WET		FAST

TABLE 4. Fan speed decision-making test data.

No	Input		Output
	Temperature (°C)	Humidity (%)	Fan Speed (Duty Cycle %)
1	29.8	79.0	47.88
2	29.8	78.7	47.88
3	29.9	78.9	48.67
4	29.9	78.5	48.67
5	29.9	78.4	48.67
6	29.9	78.2	48.67
7	30.0	78.2	49.50
8	30.0	78.3	49.50
9	30.0	78.4	49.50
10	30.0	78.1	49.50
11	30.0	78.0	49.50
12	30.0	77.8	49.50
13	30.0	77.9	49.50
14	30.1	77.9	50.37
15	30.1	76.6	50.37
16	30.1	77.8	50.37
17	30.1	77.7	50.37
18	30.1	77.6	50.37
19	30.2	76.1	50.33
20	30.2	76.3	50.70

This temperature rise ranges from 0.3-0.4°C only. If it is rotated for a longer time, the temperature decreases again. But this temperature drop is not too drastic. This second position test chart is as in Figure 22.

In the third position, the results of all tests show that the temperature continues to rise, which results are almost the same as those in the second position. The temperature changes that occur also range from 0.3-0.5°C. The third position testing graph is shown in Figure 23.

Tests that have been carried out on the three fan positions show that the temperature will change if a fan is applied.

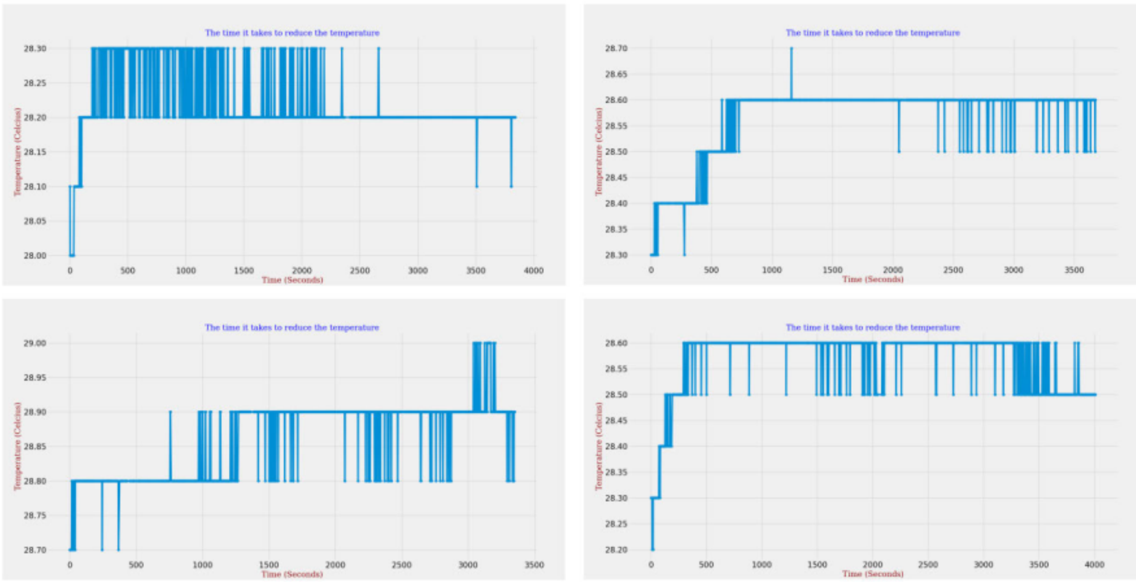

FIGURE 22. Second position test (next to the fan).

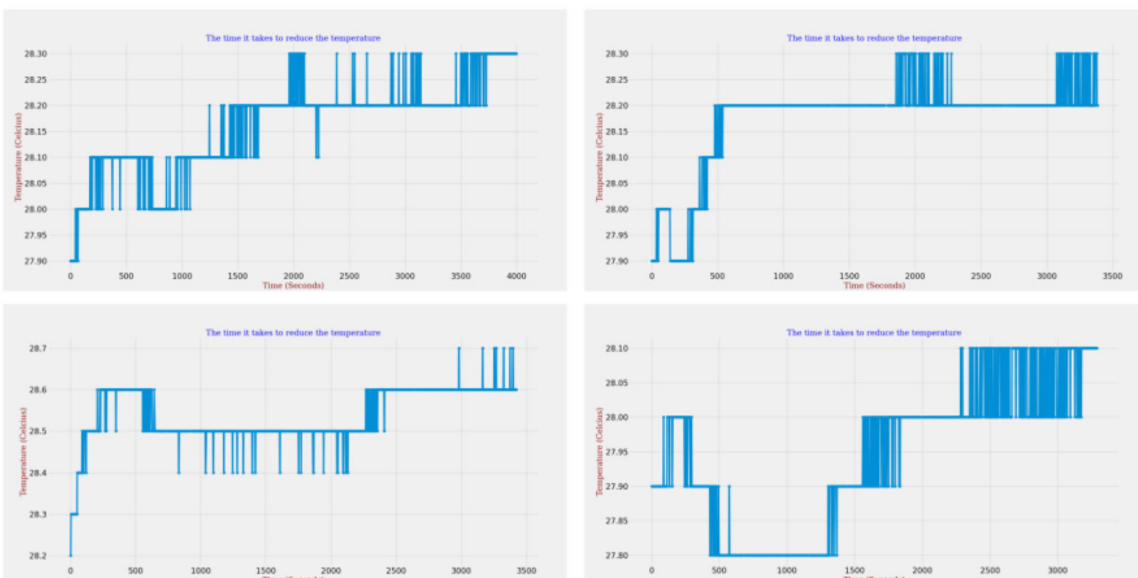

FIGURE 23. Third position test (facing the fan).

Based on several tests carried out, the temperature changes that occur are contrary to the objectives of this study. The temperature does not move down but moves up. The time used in this test ranged from 40-75 minutes. The results obtained from the test within 40-75 minutes showed a temperature change of only around 0.3-0.5°C.

Overall, this study shows that the temperature will move up when the closed room is fanned by a fan. This is caused by air circulation which does not change with fresh air from outside so that only the air in the room is continuously fanned by the fan. Therefore, a new problem arises, namely to provide a change in hot temperature to decrease and fresh, air

TABLE 5. Mobile application response testing.

No	Connection Source	Internet Speed	Response Time
1	WiFi	30 Mbps	<200 ms
2	WiFi	29 Mbps	<200 ms
3	Mobile data	6.8 Mbps	<292 ms
4	Mobile data	5.8 Mbps	<301 ms
5	Mobile data	2.4 Mbps	<656 ms
6	Mobile data	70 Kbps	11918 ms
7	Mobile data	25 Kbps	10653 ms
8	Mobile data	18 Kbps	20071 ms
9	Mobile data	13 Kbps	13589 ms
10	No Connection	Loss	Not Response

TABLE 6. Description of the position and wind touch of the fan.

DHT22's Positions	Description of the position and wind touch of the fan
1st place	This position is a position that is almost not exposed to gusts of wind from the fan, either directly or indirectly (the reflection of surrounding objects). The position is right next to the fan leg stuck in the wall, which is on the same side (side 1).
2nd place	This position is the position that is not exposed to gusts of wind from the fan directly. But it is only exposed to the reflection of the wind from the walls of the room and surrounding objects. The position is on the wall to the right of the fan (side 2).
3rd place	This position is the position that is directly exposed to gusts of wind from the fan. The position is right opposite the position of the fan (side 3).

circulation is needed so that outside air can enter the room. This can be done by using ventilation or using an exhaust fan. However, if the room is difficult to reach the temperature from the outside, using an air conditioner may be more efficient than using a fan in a room without air circulation.

V. CONCLUSION

In this study, the fuzzy method can play a good role. The fan speed output can be adjusted according to the temperature and humidity conditions of the room in real time. However, the results of the fan are not able to reduce the room temperature but the temperature rises. These results indicate that a room that is fanned in a closed state without ventilation or air circulation will make the temperature hotter. Tests carried out within 40-75 minutes showed an average temperature rise of 03-05°C. Even though the temperature increase is not very significant, this result gives an output that is not as expected. So with that, through this research the authors suggest in further research to replace the cooling media using exhaust fans or air conditioners. Meanwhile, the IoT-based mobile applications that are built can function properly as long as the tools and applications are still connected to a stable internet network.

REFERENCES

[1] G. Lamberti, "Thermal comfort in the built environment: Current solutions and future expectations," in *Proc. IEEE Int. Conf. Environ. Electr. Eng. IEEE Ind. Commercial Power Syst. Eur. (EEEIC/I&CPS Eur.)*, Jun. 2020, pp. 1–6, doi: 10.1109/EEEIC/ICPSEurope49358.2020.9160558.

[2] P. Wolkoff, K. Azuma, and P. Carrer, "Health, work performance, and risk of infection in office-like environments: The role of indoor temperature, air humidity, and ventilation," *Int. J. Hygiene Environ. Health*, vol. 233, Apr. 2021, Art. no. 113709, doi: 10.1016/j.ijheh.2021.113709.

[3] L. J. L. Ruiz, M. Ridder, D. Fan, J. Gong, B. M. Li, A. C. Mills, E. Cobarrubias, J. Strohmaier, J. S. Jur, and J. Lach, "Self-powered cardiac monitoring: Maintaining vigilance with multi-modal harvesting and E-textiles," *IEEE Sensors J.*, vol. 21, no. 2, pp. 2263–2276, Jan. 2021, doi: 10.1109/JSEN.2020.3017706.

[4] J.-H. Huh and M. J. Brandemuehl, "Optimization of air-conditioning system operating strategies for hot and humid climates," *Energy Buildings*, vol. 40, no. 7, pp. 1202–1213, Jan. 2008, doi: 10.1016/j.enbuild.2007.10.018.

[5] A. Zare and M. T. Iqbal, "Low-cost ESP32, raspberry pi, node-red, and MQTT protocol based SCADA system," in *Proc. IEEE Int. IoT, Electron. Mechatronics Conf. (IEMTRONICS)*, Sep. 2020, pp. 1–4, doi: 10.1109/IEMTRONICS51293.2020.9216412.

[6] D. Yolanda, L. Arief, T. A. Sundara, M. Deza, and D. Oktavia, "Control of electrical conductivity for NFT hydroponic systems using fuzzy logic and Android environment," in *Proc. Int. Conf. Inf. Technol. Syst. Innov. (ICITSI)*, Oct. 2018, pp. 508–514, doi: 10.1109/ICITSI.2018.8695923.

[7] Y. Perwej, K. Haq, F. Parwej, and M. M., "The Internet of Things (IoT) and its application domains," *Int. J. Comput. Appl.*, vol. 182, no. 49, pp. 36–49, Apr. 2019, doi: 10.5120/ijca2019918763.

[8] M. N. Bhuiyan, M. M. Rahman, M. M. Billah, and D. Saha, "Internet of Things (IoT): A review of its enabling technologies in healthcare applications, standards protocols, security, and market opportunities," *IEEE Internet Things J.*, vol. 8, no. 13, pp. 10474–10498, Jul. 2021, doi: 10.1109/JIOT.2021.3062630.

[9] R. Mamoun, M. Nasor, and S. H. Abulikailik, "Design and development of mobile healthcare application prototype using flutter," in *Proc. Int. Conf. Comput., Control, Electr., Electron. Eng. (ICCCEEE)*, Feb. 2021, pp. 1–6, doi: 10.1109/ICCCEEE49695.2021.9429595.

[10] M. Babiuch, P. Foltynek, and P. Smutny, "Using the ESP32 microcontroller for data processing," in *Proc. 20th Int. Carpathian Control Conf. (ICCC)*, May 2019, pp. 1–6, doi: 10.1109/CarpathianCC.2019.8765944.

[11] M. Muslih, Somantri, D. Supardi, E. Multipi, Y. M. Nyaman, A. Rismawan, and Gunawansyah, "Developing smart workspace based IoT with artificial intelligence using telegram chatbot," in *Proc. Int. Conf. Comput., Eng., Design (ICCED)*, Sep. 2018, pp. 230–234, doi: 10.1109/ICCED.2018.00052.

[12] M. O. Onibonoje, P. N. Bokoro, N. I. Nwulu, and S. L. Gbadamosi, "An IoT-based approach to real-time conditioning and control in a server room," in *Proc. Int. Artif. Intell. Data Process. Symp. (IDAP)*, Sep. 2019, pp. 1–6, doi: 10.1109/IDAP.2019.8875880.

[13] A. F. Subahi and K. E. Bouazza, "An intelligent IoT-based system design for controlling and monitoring greenhouse temperature," *IEEE Access*, vol. 8, pp. 125488–125500, 2020, doi: 10.1109/ACCESS.2020.3007955.

[14] R. Rakhmawati, Irianto, F. D. Murdianto, A. Luthfi, and A. Y. Rahman, "Thermal optimization on incubator using fuzzy inference system based IoT," in *Proc. Int. Conf. Artif. Intell. Inf. Technol. (ICAIIT)*, Mar. 2019, pp. 464–468, doi: 10.1109/ICAIIT.2019.8834530.

[15] M. F. H. Hambali, R. K. Patchmuthu, and A. T. Wan, "IoT based smart poultry farm in Brunei," in *Proc. 8th Int. Conf. Inf. Commun. Technol. (ICoICT)*, Jun. 2020, pp. 1–5.

[16] A. W. Jabbar, "Design and fabrication of smart home with Internet of Things enabled automation system," *IEEE Access*, vol. 7, pp. 144059–144074, 2017, doi: 10.1109/ACCESS.2017.

[17] A. K. Gupta and R. Johari, "IoT based electrical device surveillance and control system," in *Proc. 4th Int. Conf. Internet Things, Smart Innov. Usages (IoT-SIU)*, Apr. 2019, pp. 1–5.

[18] Arlenny and D. Setiawan, "Optimization of electrical energy in the fan using fuzzy logic controllers," *IOP Conf. Ser., Earth Environ. Sci.*, vol. 1041, no. 1, Jun. 2022, Art. no. 012025, doi: 10.1088/1755-1315/1041/1/012025.

[19] F. H. Purwanto, E. Utami, and E. Pramono, "Design of server room temperature and humidity control system using fuzzy logic based on microcontroller," in *Proc. Int. Conf. Inf. Commun. Technol. (ICOIACT)*, Mar. 2018, pp. 390–395, doi: 10.1109/ICOIACT.2018.8350770.

[20] G. Aceto, V. Persico, and A. Pescapé, "Industry 4.0 and health: Internet of Things, big data, and cloud computing for healthcare 4.0," *J. Ind. Inf. Integr.*, vol. 18, Jun. 2020, Art. no. 100129, doi: 10.1016/j.jii.2020.100129.

[21] A. Rusmardiana, T. Y. Akhirina, D. Yulistyanti, and U. Pauziah, "A web-based high school major decision support system in banten using Tsukamoto's fuzzy method," in *Proc. Int. Seminar Intell. Technol. Its Appl. (ISITIA)*, Aug. 2018, pp. 233–238, doi: 10.1109/ISITIA.2018.8711337.

[22] M. Marbun, W. Ramdhan, D. Priyanto, M. Zarlis, and Z. Nasution, "Philosophy of fuzzy logic as fundamental of decision making based on rule," *J. Phys., Conf. Ser.*, vol. 1230, no. 1, Jul. 2019, Art. no. 012021, doi: 10.1088/1742-6596/1230/1/012021.

[23] B. Saleha, S. M. Nasution, and A. L. Prasasti, "Design of IoT-based smart laundry applications using fuzzy algorithms," in *Proc. Int. Conf. Inf. Technol. Syst. Innov. (ICITSI)*, Oct. 2020, pp. 393–397, doi: 10.1109/ICITSI50517.2020.9264936.

[24] L. T. H. Lan, T. M. Tuan, T. T. Ngan, L. H. Son, N. L. Giang, V. T. Nhu Ngoc, and P. V. Hai, "A new complex fuzzy inference system with fuzzy knowledge graph and extensions in decision making," *IEEE Access*, vol. 8, pp. 164899–164921, 2020, doi: 10.1109/ACCESS.2020.3021097.

[25] A. Lipare, D. R. Edla, and S. R. Parne, "Fuzzy rule-based system for energy efficiency in wireless sensor networks," *J. Supercomput.*, vol. 77, no. 9, pp. 9947–9970, Sep. 2021, doi: 10.1007/s11227-021-03668-w.

[26] T. Sutikno, A. C. Subrata, and A. Elkhateb, "Evaluation of fuzzy membership function effects for maximum power point tracking technique of photovoltaic system," *IEEE Access*, vol. 9, pp. 109157–109165, 2021, doi: 10.1109/ACCESS.2021.3102050.

[27] S. N. Putri and D. R. S. Saputro, "Construction fuzzy logic with curve shoulder in inference system Mamdani," *J. Phys., Conf. Ser.*, vol. 1776, no. 1, Feb. 2021, Art. no. 012060, doi: 10.1088/1742-6596/1776/1/012060.

[28] Y. Kravchenko, O. Leshchenko, N. Dakhno, V. Deinega, H. Shevchenko, and O. Trush, "Intellectual fuzzy system air pollution control," in *Proc. IEEE 2nd Int. Conf. Adv. Trends Inf. Theory (ATIT)*, Nov. 2020, pp. 186–191, doi: 10.1109/ATIT50783.2020.9349334.

[29] P. G. Singerman, S. M. ORourke, R. M. Narayanan, and M. Rangaswamy, "Language-based cost functions: Another step toward a truly cognitive radar," *IEEE Trans. Aerosp. Electron. Syst.*, vol. 57, no. 6, pp. 3827–3843, Dec. 2021, doi: 10.1109/TAES.2021.3082714.

[30] A. Krol and G. Sierpinski, "Application of a genetic algorithm with a fuzzy objective function for optimized siting of electric vehicle charging devices in urban road networks," *IEEE Trans. Intell. Transp. Syst.*, vol. 23, no. 7, pp. 8680–8691, Jul. 2022, doi: 10.1109/TITS.2021.3085103.

[31] Y. M. Tashtoush and D. A. Al Aziz Orabi, "Tweets emotion prediction by using fuzzy logic system," in *Proc. 6th Int. Conf. Social Netw. Anal., Manage. Secur. (SNAMS)*, Oct. 2019, pp. 83–90, doi: 10.1109/SNAMS.2019.8931878.

[32] O. M. Olabanji and K. Mpofu, "Hybridized fuzzy analytic hierarchy process and fuzzy weighted average for identifying optimal design concept," *Heliyon*, vol. 6, no. 1, Jan. 2020, Art. no. e03182, doi: 10.1016/j.heliyon.2020.e03182.

[33] K. B. R. Teja, M. Monika, C. Chandravathi, and P. Kodali, "Smart monitoring system for pond management and automation in aquaculture," in *Proc. Int. Conf. Commun. Signal Process. (ICCSP)*, Jul. 2020, pp. 204–208, doi: 10.1109/ICCSP48568.2020.9182187.

[34] L. O. Aghenta and M. T. Iqbal, "Low-cost, open source IoT-based SCADA system design using thinger.IO and ESP32 thing," *Electronics*, vol. 8, no. 8, pp. 1–24, 2019, doi: 10.3390/electronics8080822.

[35] E. Vavrinsky, T. Zavodnik, T. Debnar, L. Cernaj, J. Kozarik, M. Micjan, J. Nevrela, M. Donoval, M. Kopani, and H. Kosnacova, "Research and development of a COVID-19 tracking system in order to implement analytical tools to reduce the infection risk," *Sensors*, vol. 22, no. 2, p. 526, Jan. 2022, doi: 10.3390/s22020526.

[36] S. N. Khine and Z. Tun, "Mongodb on cloud for weather data (temperature and humidity) in sittway," in *Proc. IEEE Conf. Comput. Appl. (ICCA)*, Feb. 2020, pp. 1–6, doi: 10.1109/ICCA49400.2020.9022825.

[37] H. Jamal, M. Huzaifa, M. A. Sodunke, and J. O. Odiete, "Smart heat stress and toxic gases monitoring instrument with a developed graphical user interface using IoT," in *Proc. Int. Conf. Electr., Commun., Comput. Eng. (ICECCE)*, Jul. 2019, pp. 24–25, doi: 10.1109/ICECCE47252.2019.8940738.

[38] F. Salamone, G. Chinazzo, L. Danza, C. Miller, S. Sibilio, and M. Masullo, "Low-cost thermohygrometers to assess thermal comfort in the built environment: A laboratory evaluation of their measurement performance," *Buildings*, vol. 12, no. 5, p. 579, Apr. 2022, doi: 10.3390/buildings12050579.

[39] P. De, A. Chatterjee, and A. Rakshit, "PIR sensor-based AAL tool for human movement detection: Modified MCP-based dictionary learning approach," *IEEE Trans. Instrum. Meas.*, vol. 69, no. 10, pp. 7377–7385, Oct. 2020, doi: 10.1109/TIM.2020.2981106.

[40] L. Wu and Y. Wang, "A low-power electric-mechanical driving approach for true occupancy detection using a shuttered passive infrared sensor," *IEEE Sensors J.*, vol. 19, no. 1, pp. 47–57, Jan. 2019, doi: 10.1109/JSEN.2018.2875659.

[41] M. Jacoby, "Whisper: Wireless home identification and sensing platform for energy reduction," *J. Sensor Actuator Netw.*, vol. 10, no. 4, pp. 1–33, 2021, doi: 10.3390/jsan10040071.

[42] J. C. Kim, D. O. Neacsu, R. Ball, and B. Lehman, "Clearing series AC arc faults and avoiding false alarms using only voltage waveforms," *IEEE Trans. Power Del.*, vol. 35, no. 2, pp. 946–956, Apr. 2020, doi: 10.1109/TPWRD.2019.2931276.

[43] M. A. Hannan, J. A. Ali, A. Mohamed, and A. Hussain, "Optimization techniques to enhance the performance of induction motor drives: A review," *Renew. Sustain. Energy Rev.*, vol. 81, no. 2, pp. 1611–1626, Jun. 2017, doi: 10.1016/j.rser.2017.05.240.

[44] S. Boukhary and E. Colmenares, "A clean approach to flutter development through the flutter clean architecture package," in *Proc. Int. Conf. Comput. Sci. Comput. Intell. (CSCI)*, Dec. 2019, pp. 1115–1120, doi: 10.1109/CSCI49370.2019.00211.

[45] P. Nawrocki, K. Wrona, M. Marczak, and B. Sniezynski, "A comparison of native and cross-platform frameworks for mobile applications," *Computer*, vol. 54, no. 3, pp. 18–27, Mar. 2021, doi: 10.1109/MC.2020.2983893.

[46] J. Z. Blanco and D. Lucrédio, "A holistic approach for cross-platform software development," *J. Syst. Softw.*, vol. 179, Sep. 2021, Art. no. 110985, doi: 10.1016/j.jss.2021.110985.

[47] G. I. Arb and K. Al-Majdi, "A freights status management system based on dart and flutter programming language," *J. Phys., Conf. Ser.*, vol. 1530, no. 1, May 2020, Art. no. 012020, doi: 10.1088/1742-6596/1530/1/012020.

[48] S. Choi, E. Salter, X. Zhang, and B. C. Wunsche, "Bird eyes: A cloud-based object detection system for customisable surveillance," in *Proc. Int. Conf. Image Vis. Comput. New Zealand (IVCNZ)*, Nov. 2018, pp. 1–6, doi: 10.1109/IVCNZ.2018.8634751.

[49] R. R. Singh, "IoT embedded cloud-based intelligent power quality monitoring system for industrial drive application," *Future Gener. Comput. Syst.*, vol. 112, pp. 884–898, Nov. 2020, doi: 10.1016/j.future.2020.06.032.

[50] D. Gupta, S. Bhatt, M. Gupta, O. Kayode, and A. S. Tosun, "Access control model for Google cloud IoT," in *Proc. IEEE IEEE 6th Int. Conf. Big Data Secur. Cloud (BigDataSecurity) Int. Conf. High Perform. Smart Comput., (HPSC) IEEE Int. Conf. Intell. Data Secur. (IDS)*, May 2020, pp. 198–208, doi: 10.1109/BigDataSecurity-HPSC-IDS49724.2020.00044.

[51] K. E. Adetunji and M. K. Joseph, "Development of a cloud-based monitoring system using 4Duino: Applications in agriculture," in *Proc. Int. Conf. Adv. Big Data, Comput. Data Commun. Syst. (icABCD)*, Aug. 2018, pp. 4849–4854, doi: 10.1109/ICABCD.2018.8465418.

[52] A. Yudhana and Priyatno, "Development of door safety fingerprint verification using neural network," *J. Phys., Conf. Ser.*, vol. 1373, no. 1, Nov. 2019, Art. no. 012053, doi: 10.1088/1742-6596/1373/1/012053.

[53] A. Yudhana, S. Mukhopadhyay, O. D. A. Prima, S. A. Akbar, F. Nuraisyah, I. Mufandi, K. H. Fauzi, and N. A. Nasyah, "Multi sensor application-based for measuring the quality of human urine on first-void urine," *Sens. Bio-Sens. Res.*, vol. 34, Dec. 2021, Art. no. 100461, doi: 10.1016/j.sbsr.2021.100461.

[54] A. Yudhana, D. Sulistyo, and I. Mufandi, "GIS-based and Naïve Bayes for nitrogen soil mapping in lendah, Indonesia," *Sens. Bio-Sens. Res.*, vol. 33, Aug. 2021, Art. no. 100435, doi: 10.1016/j.sbsr.2021.100435.

[55] A. Yudhana, J. Rahmawan, and C. U. P. Negara, "Flex sensors and MPU6050 sensors responses on smart glove for sign language translation," *IOP Conf. Ser., Mater. Sci. Eng.*, vol. 403, Oct. 2018, Art. no. 012032, doi: 10.1088/1757-899X/403/1/012032.

[56] N. H. Wijaya, A. Yudhana, Robiyansah, and D. Sukwono, "X-ray machine control with wireless based on mA parameters," *IOP Conf. Ser., Mater. Sci. Eng.*, vol. 1088, no. 1, Feb. 2021, Art. no. 012080, doi: 10.1088/1757-899x/1088/1/012080.

[57] A. Kashevnik, I. Lashkov, and A. Gurtov, "Methodology and mobile application for driver behavior analysis and accident prevention," *IEEE Trans. Intell. Transp. Syst.*, vol. 21, no. 6, pp. 2427–2436, Jun. 2020, doi: 10.1109/TITS.2019.2918328.

[58] C. Rieger and T. A. Majchrzak, "Towards the definitive evaluation framework for cross-platform app development approaches," *J. Syst. Softw.*, vol. 153, pp. 175–199, Jul. 2019, doi: 10.1016/j.jss.2019.04.001.

[59] R. Siregar, M. Zarlis, and Z. Situmorang, "Tsukamoto's fuzzy logic development analysis to predict caesarean or normal delivery," in *Proc. 3rd Int. Conf. Mech., Electron., Comput., Ind. Technol. (MECnIT)*, Jun. 2020, pp. 152–157, doi: 10.1109/MECnIT48290.2020.9166594.

SUNARDI received the bachelor's degree from Universitas Gadjah Mada, Yogyakarta, Indonesia, in 1999, the master's degree from the Institut Teknologi Bandung, Bandung, Indonesia, in 2003, and the Ph.D. degree from Universiti Teknologi Malaysia, Johor Bahru, Malaysia, in 2011, all in electrical engineering. Currently, he is an Associate Professor with the Department of Electrical Engineering, Universitas Ahmad Dahlan, Yogyakarta. His research interests include data, information, and communication.

ANTON YUDHANA (Member, IEEE) received the B.Eng. degree in electrical engineering from the Institut Teknologi Sepuluh Nopember, in 2001, the M.Eng. degree in electrical engineering from Universitas Gadjah Mada, Indonesia, in 2005, and the Ph.D. degree from Universiti Teknologi Malaysia, in 2011. He is currently an Associate Professor with the Department of Electrical Engineering, Universitas Ahmad Dahlan, Indonesia, and the Leader with the Center for Electrical and Electronic Research and Development (CEERD). His current research interests include agriculture precision, biomedic engineering, and food engineering based on the Internet of Things.

FURIZAL was born in Kesra, Riau, Indonesia, in 1999. He received the B.Eng. degree in informatics engineering from Universitas Islam Riau, Indonesia, in 2022. He is currently pursuing the master's degree in informatics with Universitas Ahmad Dahlan, Yogyakarta, Indonesia. From 2017 to 2018, he was an Instructor of computer courses at Yuri Computer. Since 2021, he has been a Web Developer with the Faculty of Engineering, Universitas Islam Riau. His research interests include artificial intelligence, decision support systems, the Internet of Things, and web and mobile development.

HASIL CEK_SUNARDI, ANTON YUDHANA, (Member, IEEE), FURIZAL

ORIGINALITY REPORT

10%	11%	3%	7%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	doaj.org Internet Source	9%
2	Submitted to School of Business and Management ITB Student Paper	1%
3	files.osf.io Internet Source	1%

Exclude quotes On
Exclude bibliography On
Exclude matches < 1%