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Research Article

Design of an IoT-Based Server Room Temperature Security Monitoring System Using a Microcontroller and Fuzzy Logic Method

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Abstract: PT. Sridatta Prastama Telecommunications (PRASTATEL) as a company in the field of telecommunications service providers must provide non-stop cell phone / VoIP servi-ces. Devices that work 24 hours non-stop by minimizing the damage that occurs, must be supported by monitoring to ensure the system is running properly. If there is a sig-nificant increase in temperature, it can affect system performance or cause damage to the hardware side. The cooler in the server room is felt to be not optimal because the cooler is often constrained by frequent power outages or the cooler turns off and avoids suspicious activities / activities that occur in the server room because the server room administrator is not always on site. From the problems described above, a solution is needed to monitor the system remotely. So that the system is able to know changes in room temperature (Monitoring) in real time and monitor whether there is activity oc-curring in the server room. By using Internet of Things (IoT) technology, the NO-DEMCU ESP-8266 device and the fuzzy logic method which basically maps an input space into an output space that is applied to the server room temperature sensor. This monitoring system uses the Telegram application to receive notifications in the form of text or images. So that it can monitor temperature changes and activities that occur in the server room in real time and accurately. Therefore the server room administrator does not have to be on the site.

Keywords: Fuzzy Logic; Internet of Things (IoT); NodeMCU ESP8266; Real-Time Monitoring; Server Room Temperature.

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1. Introduction

The increasing dependence of organizations on information systems has made server rooms a critical component in supporting business continuity and digital operations. A server room functions as a centralized facility for housing application servers, database servers, networking equipment, and supporting infrastructure such as Uninterruptible Power Supplies (UPS), air conditioning systems, and surveillance devices. Because these facilities store valuable organizational data and provide essential computing services, maintaining their operational reliability is crucial. Environmental factors, particularly temperature and humidity, significantly influence the performance and lifespan of server hardware. Excessive heat may increase the risk of equipment failure, while improper humidity levels can lead to condensation, corrosion, short circuits, and degradation of electronic components. In practice, many organizations still rely on periodic manual inspections to monitor server room conditions. Such approaches are inefficient because administrators cannot continuously supervise environmental conditions and security activities around the clock. Consequently, delays in detecting abnormal situations may increase the risk of service disruption, data loss, and hardware damage, highlighting the need for intelligent and automated monitoring systems [1], [2].

Recent studies have demonstrated the effectiveness of Internet of Things (IoT) technology in supporting real-time environmental monitoring and security management. The integration of microcontrollers, sensors, and internet connectivity enables automatic acquisition and transmission of environmental data without requiring continuous human intervention. Previous research has explored IoT-based monitoring systems for server rooms, focusing primarily on temperature and humidity observation using wireless communication technologies. Other studies have incorporated motion detection sensors to enhance physical security and provide alerts when suspicious activities occur. Although these systems have improved monitoring capabilities, many implementations still rely on fixed threshold values to determine system responses. Such approaches may not adequately represent the uncertainty and dynamic nature of environmental conditions within server rooms. In addition, previous systems often emphasize monitoring functions without integrating adaptive decision-making mechanisms capable of evaluating multiple environmental parameters simultaneously. Therefore, there remains an opportunity to develop a more intelligent monitoring framework that combines real-time data acquisition with flexible decision support using computational intelligence techniques [3], [4].

To address these limitations, this study investigates the implementation of an IoT-based server room monitoring system utilizing the NodeMCU ESP8266 microcontroller, environmental sensors, motion detection technology, and the Telegram messaging platform. The proposed system continuously collects temperature, humidity, and movement data and transmits monitoring information through internet-based communication channels. The main research question concerns how Fuzzy Logic Mamdani can be utilized to improve decision-making accuracy in evaluating server room conditions and generating timely notifications for administrators. Unlike conventional threshold-based systems, fuzzy logic is capable of processing uncertain and overlapping environmental conditions by considering multiple input variables simultaneously. This capability enables the system to produce more adaptive responses according to actual environmental changes. Accordingly, the study aims to design, implement, and evaluate an intelligent monitoring system capable of providing real-time environmental supervision and security alerts while supporting remote monitoring through mobile devices and internet-based communication services [5], [6].

This research contributes to the development of intelligent server room monitoring solutions by integrating IoT technology with Fuzzy Logic Mamdani within a unified framework. The proposed approach not only enables continuous environmental monitoring but also enhances decision-making flexibility by interpreting sensor data using fuzzy inference mechanisms. Furthermore, the integration of Telegram-based notifications provides practical support for administrators by delivering immediate alerts whenever abnormal environmental conditions or unauthorized movements are detected. Compared with conventional monitoring systems, the proposed model offers a more adaptive and responsive mechanism for maintaining server room reliability and security. The findings of this study are expected to provide both theoretical and practical contributions to the fields of IoT-based monitoring, environmental control systems, and intelligent decision support applications. In addition, the developed prototype may serve as a reference for future research seeking to implement low-cost, scalable, and real-time monitoring solutions in server rooms and other critical infrastructure environments [7], [8].

2. Literature Review

Systematic Literature Review

Methodology Survey

This survey methodology is compiled based on PICOC (Population, In-tervention, Comparation, Outcomes, Context) as an identification of information from the sources of previous studies in table 1. namely:

Tabel 1. Review PICOC.

Design an Iot-Based Server Temperature Monitoring System Using Micro-Controllers and Fuzzy Logic Methods	
Population	Fuzzy Logic Mamdani

	How to overcome the difficulty of Server Room Administrator preventing servers from overheating or overheating
Intervention	cold so that it hinders server performance ?
Comparation	-
Outcomes	Makes it easier for Server Room Administrators to remotely monitor server rooms in real time remotely.
Context	Interview Results

Survei Protocol

The survey methodology process in the collection of scientific journals according to the title of the thesis proposal and what is written in PICOC in the Methodology Survey in this table is:

Tabel 2. Review Review Survei Protocol.

REVIEW SURVEI PROTOCOL	
Publication year	2018 s/d 2023 (5 Tahun)
Publication Type	(v) Journal ( ) Conference ( ) Proceding ( ) Book Chapter
Searh String	Google Scholar
Final Selected	20 Journal

In conducting a search from research sources, the stages are carried out in obtaining research journals that have been published for it, the Study Selection Strategy or Studies Selection Strategy is carried out, namely carrying out the following stages, namely:

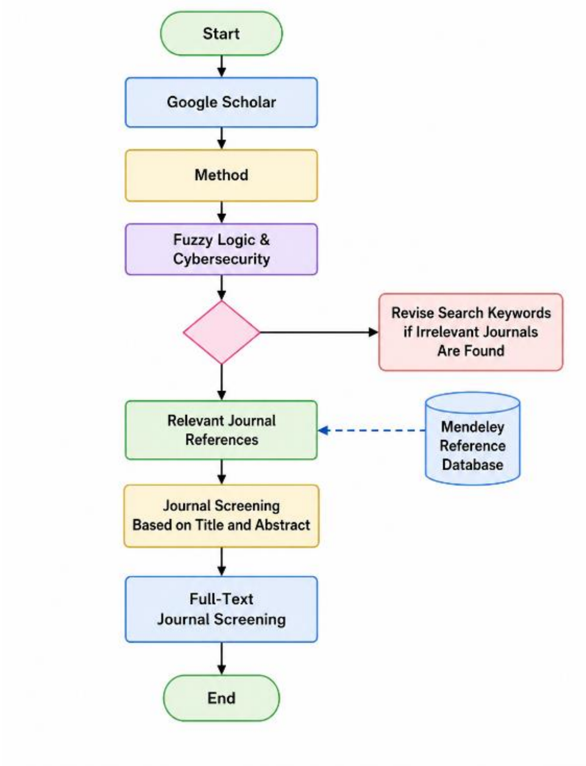


Figure 1. Study Selection.

Definition and Definition

NODEMCU ESP-8266

NodeMCU ESP8266 is an open-source Internet of Things (IoT) platform designed to support the development of smart and connected devices through the integration of hardware and software components. The platform is built on the ESP8266 System-on-Chip (SoC), which provides built-in Wi-Fi connectivity and can be programmed using the Lua programming language or Arduino-based sketches through the Arduino IDE. Due to its compact dimensions of approximately 4.83 cm × 2.54 cm and lightweight design, NodeMCU

ESP8266 is widely utilized for rapid prototyping and IoT application development. The board is equipped with open-source firmware and wireless networking capabilities that enable electronic devices to communicate with internet networks seamlessly through UART serial communication. In addition, NodeMCU provides 17 General Purpose Input/Output (GPIO) pins that can be integrated with various sensors and electronic modules. The microcontroller operates at a voltage range of 3.3V–5V, consumes approximately 10 µA–170 mA of power, and features a processor speed between 80 MHz and 160 MHz. It is also supported by 32 KB + 80 KB RAM and flash memory capacities of up to 16 MB, enabling efficient data processing, communication, and real-time monitoring functions in IoT-based systems [8], [9].

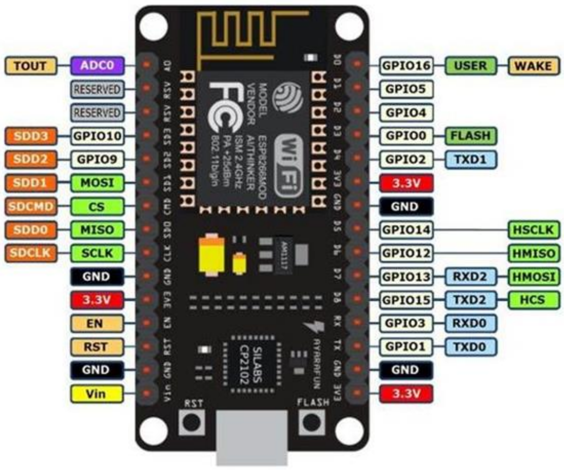


Figure 2. NODEMCU ESP-8266

Table 3. ESP-8266 Specification.

Name	Specifications
Mikrokontroler	ESP 8266
Tegangan Input	3.3 – 5V
GPIO	17 Pin
Flash Memory	16 MB
RAM	32KB+80KB
Konsumsi Daya	10uA – 170mA
Frekuensi	2.4 GHz – 22.5 GHz
USB Port	Micro USB
Wifi	IEEE 802.11b/g/n
Kenal PWM	10 Kanal
USB Chip	CH340G
Clock Speed	40/26/24 MHz

LCD

Liquid crystal display is a type of environment that uses liquid crystals as the main display. LCDs are used in various fields, such as electronic devices such as televisions, calculators or computer screens. In the broadcast program the LCD matrix with only 2 x 16.

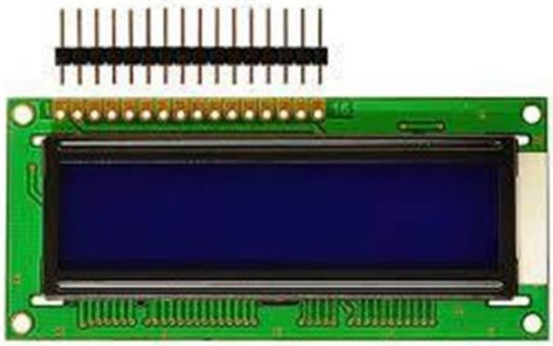


Figure 3. LCD.

Table 4. spesifikasi LCD Display.

No	Name	Specification
1	Blue backlight	I2C
2	Display Format	16 Characters x 4 lines
3	Supply voltage	5V
4	Back lit	Blue with White char color
5	Supply voltage	5V
6	Pcb Size	60mm99mm
7	Contrast Adjust	Potentiometer
8	Backlight Adjust	Jumper

Buzzer

Figure 4. Buzzer.

A buzzer is an electronic component designed to convert electrical energy into audible sound vibrations and is widely used as an indicator or alarm device in various electronic systems. The operating principle of a buzzer is similar to that of a loudspeaker, consisting of a coil attached to a diaphragm. When an electric current flows through the coil, it generates an electromagnetic field that causes the coil to move inward or outward depending on the direction of the current and magnetic polarity. This movement drives the diaphragm to vibrate repeatedly, creating pressure waves in the surrounding air that are perceived as sound. Due to its simple structure, low power consumption, and reliable performance, a buzzer is commonly integrated into monitoring, security, and automation systems to provide immediate audible notifications when specific events occur or abnormal conditions are detected. In practical applications, buzzers are frequently employed as warning devices, process completion indicators, and alarm systems in smart homes, IoT-based monitoring platforms, and security systems, enabling users to receive real-time alerts and respond quickly to potential threats or system failures [3], [10].

Project Board (Breadboard)

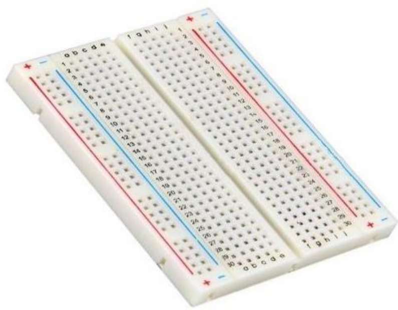


Figure 5. Breadboard.

A breadboard, often referred to as a project board, is a fundamental platform used for constructing and prototyping electronic circuits without requiring permanent connections. In modern electronics development, a breadboard serves as a reusable prototyping board that allows components to be inserted directly into interconnected holes, eliminating the need for soldering and enabling rapid circuit assembly and modification. This solderless design makes breadboards highly suitable for temporary prototypes, testing, troubleshooting, and experimentation during the development phase of electronic systems. A wide range of electronic applications can be implemented using a breadboard, from simple analog and digital circuits to more complex systems involving microcontrollers, sensors, and communication modules. Structurally, the upper and lower sections of the breadboard consist of horizontally connected rows that are commonly used as power distribution lines or communication pathways, while the central area contains vertically connected holes arranged in groups that facilitate component interconnection. The central gap is specifically designed to accommodate integrated circuits (ICs), allowing their pins to be connected across separate conductive strips. Due to its flexibility and ease of use, the breadboard remains an essential tool for developing and validating electronic and IoT-based prototypes [8], [11].

Smartphone

Figure 6. Smartphone.

A smartphone is a mobile communication device equipped with an operating system that enables users to perform functions beyond traditional voice calls and text messaging. Unlike conventional mobile phones, smartphones allow users to install applications, customize system features, access internet-based services, and perform various computing tasks, effectively functioning as portable mini-computers. Today, smartphones have become one of the most widely used communication tools across all age groups, including children, adolescents, adults, and older individuals. Their evolution from simple communication devices into multifunctional platforms has significantly transformed how people access information, communicate, and manage daily activities. According to the communication paradigm proposed by Lasswell, communication involves five essential elements: who, says what, in which channel, to whom, and with what effect [12]. In this context, smartphones serve as a communication channel that facilitates the efficient exchange of information between communicators and recipients. The widespread adoption of smartphones provides numerous benefits, including rapid information dissemination, real-time communication regardless of location, and enhanced support for educational, business, social, and organizational activities, making them an indispensable component of modern digital communication [12], [13].

Aplikasi Telegram

Telegram Messenger is a chat messaging application such as Whatsapp, Line and BBM (Blackberry Messenger). Telegram Messenger uses the MTProto proto-col which has been tested with its level of security due to the end-to-end encryption process used. Just like similar applications, Telegram Messenger can share messages, photos, videos, location tagging between fellow users. Various advantages offered that are very useful in this study such as the existence of a cloud on the Telegram Messenger server that allows to store data such as conversations, photos and videos.

Bot features that have artificial intelligence are features that can be integrated with various services through the internet. With this bot feature, the author will create a system that can be integrated into the boarding house security information system.

Arduino IDE

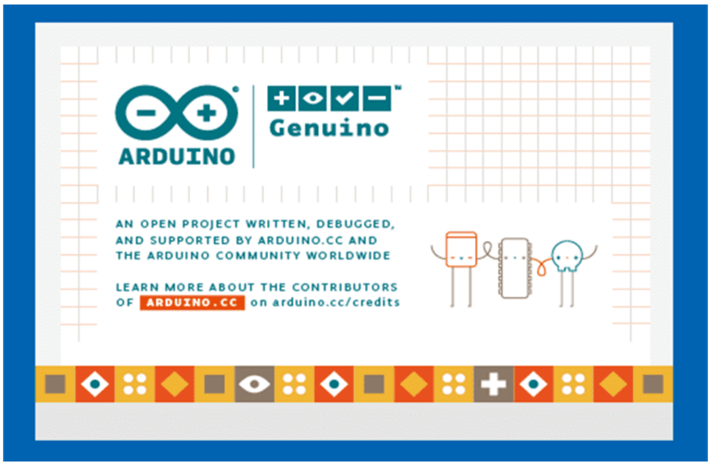


Figure 7. Arduino IDE.

Arduino IDE (Integrated Development Environment) is a software platform used to write, compile, and upload programs to Arduino microcontrollers. It employs a simplified version of the C++ programming language, making it easier for beginners and developers to create embedded system applications. Programs written in Arduino IDE are commonly referred to as sketches. The development environment is built using the Java programming language and incorporates C/C++ libraries known as Wiring, which simplify input and output operations when interacting with sensors, actuators, and other electronic components. Arduino IDE was developed from the Processing software platform and later adapted specifically for Arduino programming and hardware integration. The software provides several essential features that facilitate program development, including the Verify function for compiling code and checking errors, New for creating a new project, Open and Save for managing source code files, and Upload for transferring compiled programs to an Arduino board after configuring the appropriate board type and communication port. Additionally, the Serial Monitor feature enables users to view and monitor data transmitted by the microcontroller through serial communication, supporting debugging, testing, and real-time system monitoring during development and implementation processes [6], [8].

Metode fuzzi Logic

Fuzzy Logic is a computational approach used to represent uncertainty and imprecision in decision-making processes. It was developed as an extension of classical (crisp) logic, which only recognizes binary values such as true or false, black or white. Unlike conventional logic, fuzzy logic allows membership values to exist within a continuous range between 0 and 1, enabling systems to model real-world conditions that are often ambiguous and difficult to classify precisely [5], [14]. In control and monitoring applications, fuzzy logic functions as a knowledge-based system that maps input variables to meaningful outputs through a set of predefined rules. The core components of a fuzzy system include fuzzy variables, fuzzy sets, and membership functions. Fuzzy variables represent observable parameters such as temperature, humidity, or age, while fuzzy sets describe linguistic conditions such as COLD, WARM, and HOT. Each fuzzy set is characterized by a membership function, which defines the degree to which an input belongs to a particular set. A membership function is typically represented as a curve that maps input values to membership degrees ranging from 0 to 1 and serves as the foundation for the inference process used to generate system outputs. Furthermore, membership functions enable the system to evaluate gradual transitions between conditions rather than relying on rigid threshold values, resulting in more flexible and adaptive decision-making capabilities [15], [16].

a) Linear Representation

In linear representations, the mapping of inputs to the degree of membership is modeled as a straight line. This form is the simplest and is a good choice to approach a concept that is less clear. There are two types of linear fuzzy sets, namely: ascending linear representations and descending linear representations.

For the linear representation up as follows:

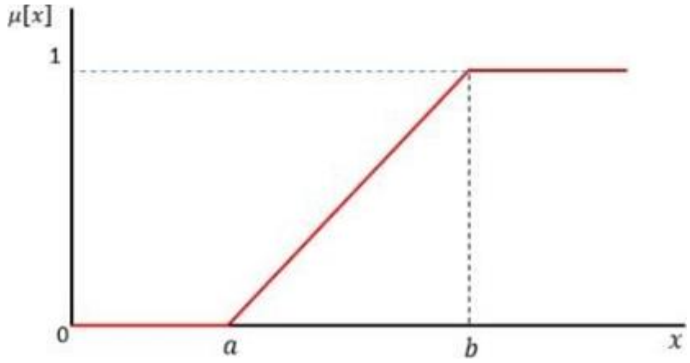


Figure 8. Linear up.

Membership Functions:

$$\mu[x] = \begin{cases} 0 & ; x \leq a \\ \frac{(x-a)}{(b-a)} & ; a \leq x \leq b \\ 1 & ; x \geq b \end{cases} \quad \ldots\ldots \text{(i)}$$

Description:
a : the value of a domain that has a membership degree of one
b : the value of the domain that has a degree of membership zero x : the input value that will be changed into a fuzzy number Then the linear representation goes down, namely:

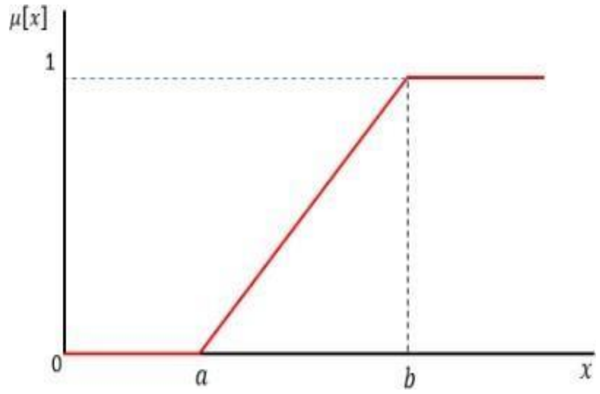


Figure 9. Linear down.

Membership functions:

$$\mu[x] = \begin{cases} 1 & ; x \leq a \\ \frac{(b-x)}{(b-a)} & ; a \leq x \leq b \\ 0 & ; x \geq b \end{cases} \quad \ldots\ldots\ldots\ldots \text{(ii)}$$

a : the value of a domain that has a membership degree of one
b : the value of the domain that has zero membership degree x : the input value to be changed into a fuzzy number

b) Representation of Triangle Curves

Basically, a triangular curve is a combination of two lines (lin-ear). The membership function of a fuzzy set can be said to be a triangular membership function if it has three parameters, namely (a, b, c ε R) with (a ≤ b ≤ c) and expressed by a triangle (x, a, b, c). A representation of a triangular fuzzy set is shown in the figure.

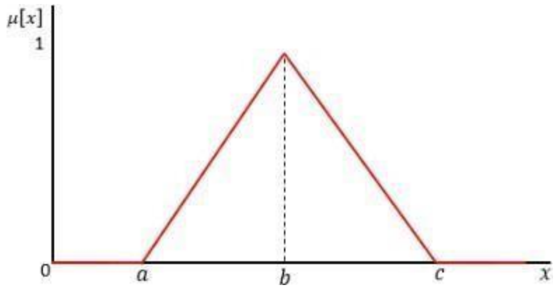


Figure 10. Triangle Curve.

Fungsi Keanggotaan:

$$\mu[x] = \begin{cases} 0 & ; x \leq a \ atau \ x \geq c \\ \frac{(x-a)}{(b-a)} & ; a \leq x \leq b \\ \frac{(c-x)}{(c-a)} & ; b \leq x \leq c \end{cases} \quad \text{........... (iii)}$$

Description:
A : The value of the smallest domain that has a zero membership degree
b : the value of a domain that has a membership degree of one
C : the value of the largest domain that has zero membership degree
x : the input value to be changed into a fuzzy number

c) Representation of Trapezoidal Curves

Basically, the trapezoidal curve is shaped like a triangle because they are both a combination of two lines (linear), it's just that on the trapezoidal curve there are several points that have a membership value of 1. A representation of the trapezoidal curve is shown in the image.

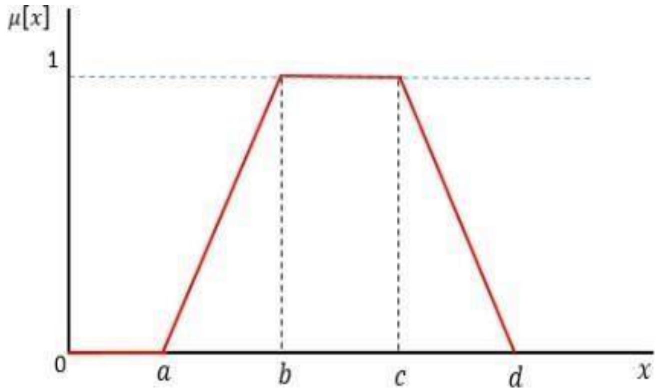


Figure 11. Trapezoidal curve.

Membership:

$$\mu[x] = \begin{cases} 0 & ; x \leq a \ atau \ x \geq d \\ \frac{(x-a)}{(b-a)} & ; a \leq x \leq b \\ 1 & ; b \leq x \leq c \\ \frac{(c-x)}{(c-a)} & ; c \leq x \leq d \end{cases} \quad \text{........... (iv)}$$

Description:
A : The value of the smallest domain that has a zero membership degree
b : the value of the smallest domain that has a membership degree of one
c : the value of the largest domain that has a membership degree of one
d : the value of the largest domain that has a zero membership degree x : the input value to be converted into a fuzzy number.

d) Representation of Shoulder Shape Curve

The shoulder curve is a combination of three curves, the first curve is located in the middle of a variable represented in the form of a rectangular curve, then on the right and left sides there are linear curves going up and down. The left shoulder moves from right to wrong, so does the right shoulder move from wrong to right. A representation of the shoulder curve is shown in the figure.

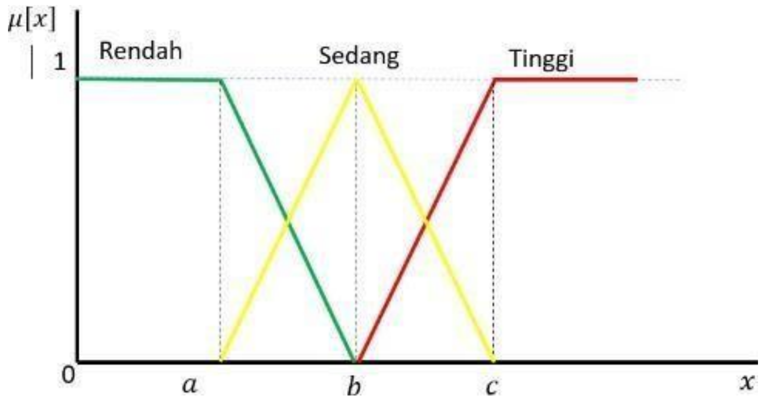


Figure 12. Shoulder shape curve.

Membership Functions:
Cold

$$\mu[x] = \begin{cases} 1 & ; x \leq a \\ \frac{(b-x)}{(b-a)} & ; a \leq x \leq b \\ 0 & ; x \geq b \end{cases} \quad \text{............... (v)}$$

Warm

$$\mu[x] = \begin{cases} 0 & ; x \leq a \text{ atau } x \geq c \\ \frac{(x-a)}{(b-a)} & ; a \leq x \leq b \\ \frac{(c-x)}{(c-b)} & ; b \leq x \leq c \end{cases} \quad \text{.............. (vi)}$$

Hot

$$\mu[x] = \begin{cases} 0 & ; x \leq b \\ \frac{(x-b)}{(c-b)} & ; b \leq x \leq c \\ 1 & ; x \geq c \end{cases} \quad \text{............ (vii)}$$

Description:
a : the value of the smallest domain that has a membership degree of one
b : the value of a domain that has a membership degree of one
c : the value of the largest domain that has a membership degree of one x: the input value to be converted into a fuzzy number

Function Implications

In a Fuzzy Logic system, each rule or proposition within the knowledge base is associated with a specific relationship that connects input variables to output decisions. These rules are generally expressed in the form of IF–THEN statements, where the proposition following the IF clause is referred to as the antecedent, while the proposition following the THEN clause is known as the consequent. Fuzzy rules can involve multiple input variables and may be combined using fuzzy operators such as AND and OR. A typical rule can be represented as: IF (x_1 is A_1) AND/OR (x_2 is A_2) AND/OR ... (x_n is A_n), THEN y is B, where A and B denote fuzzy sets and x and y represent input and output variables. In the Mamdani fuzzy inference method, the implication process commonly employs the MIN (minimum) operator to determine the degree of activation of each rule. This operator effectively truncates the output fuzzy set according to the membership value produced by the antecedent evaluation. The use of fuzzy rules enables the system to model human reasoning and handle uncertainty more effectively, making Fuzzy Logic suitable for decision-making, control, and monitoring applications involving complex and dynamic environments [3], [6].

1) Fuzzy logic is very flexible.
2) Fuzzy logic has a tolerance for very complex data.
3) Fuzzy logic can build and apply experts' experience directly without having to go through a training process.
4) Fuzzy logic can work with conventional control techniques.
5) Fuzzy logic is based on natural language.

Fuzzy Logic Mamdani

The Fuzzy Logic Mamdani method, also known as the Min–Max method, was introduced by Ebrahim Mamdani in 1975 and has become one of the most widely used fuzzy inference techniques for decision-making and control systems. This method employs the minimum (MIN) operator during the implication process to determine the membership degree of rules connected by the AND operator, while the aggregation of multiple rules is performed using the maximum (MAX) operator because each rule is treated independently [6]. The Mamdani approach consists of four main stages: fuzzification, implication, rule composition, and defuzzification. During the fuzzification stage, input and output variables are transformed into one or more fuzzy sets. The implication stage evaluates the degree of rule activation using the MIN operator, while the rule composition stage combines the outputs of all activated rules through methods such as Maximum (MAX), Additive (SUM), and Probabilistic OR. Among these, the MAX method is the most commonly applied because it selects the highest membership value from all rules to construct the resulting fuzzy output set. The final stage, defuzzification, converts the fuzzy output into a crisp value using methods such as Centroid, Bisector, Mean of Maximum (MOM), Largest of Maximum (LOM), and Smallest of Maximum (SOM). The Centroid method is the most frequently adopted because it determines the center point of the aggregated fuzzy area, producing a representative output value. The Mamdani method offers several advantages, including ease of implementation, suitability for nonlinear systems, and the ability to represent expert knowledge in a manner that closely resembles human reasoning. However, it also has limitations, such as requiring comprehensive antecedent rules to cover all possible input conditions and imposing relatively higher computational costs compared to some other fuzzy inference methods [6], [17].

Black-Box Testing

Black-box testing is a software testing method that evaluates the functionality of an application by examining its inputs and outputs without requiring knowledge of the internal source code or program structure. This approach focuses on verifying whether the software behaves according to specified requirements and user expectations. In black-box testing, test cases are designed to assess system functionality, identify defects, and validate that each feature operates correctly under various conditions. Previous studies have indicated that comprehensive and accurate software evaluation often requires the combination of multiple testing techniques to maximize defect detection and improve overall testing effectiveness. Furthermore, a high level of efficiency in a particular testing technique does not necessarily guarantee the discovery of a large number of software defects. Test analysts must therefore consider both the effectiveness and implementation costs of each testing strategy. Research findings also suggest that many defects are identified through negative test cases, where invalid or unexpected inputs are intentionally introduced to evaluate system robustness. Additionally, error correction does not always require modifications to the source code, as some issues may originate from configuration, data handling, or operational processes rather than programming errors themselves [6].

DHT11

The DHT22, also known as the AM2302, is a digital sensor designed to measure temperature and humidity with higher accuracy and a wider operating range than its predecessor, the DHT11. Similar to the DHT11, the DHT22 features four pins: VCC (power supply), Data, NC (Not Connected), and Ground. The VCC pin is connected to a power source, typically 5V or 3.3V depending on the microcontroller used, while the Data pin is connected to a microcontroller to transmit temperature and humidity measurements in digital form. The NC pin is intentionally left unconnected and should not be attached to any circuit component during operation. The Ground pin is connected to the system ground to complete the electrical circuit. Due to its ability to provide reliable environmental measurements, the DHT22 sensor is widely utilized in monitoring and control systems, particularly in Internet of Things (IoT) applications that require real-time environmental data acquisition. Its capability to accurately measure temperature and humidity makes it suitable for server room monitoring, smart home systems, and environmental control applications where maintaining stable conditions is essential for operational reliability [4].

Gambar 13. DHT11.

The Technical Specifications of DHT11 as a whole can be described as:

1) Power supply range: 3.3 - 6 Volt DC (typical 5 VDC)
2) Current consumption at the time of measurement between 1 to 1.5 mA
3) Output signal: digital single bus pass at 5 ms/operation (MSB-first)
4) Detection element: polymer capacitor
5) Sensor type: capacitive sensing
6) Humidity sensing detection range: 0-100% RH (accuracy
7) ±2% RH)
8) Temperature sensing range: -40°~+80° Celsius (accuracy ±0.5°C)
9) Sensitivity resolution: 0.1%RH; 0.1°C
10) Repeatability: ±1% RH; ±0.2°C
11) Moisture hysteresis: ±0.3% RH

Long-term stability: ±0.5% RH/year 12. Average scan period: 2 seconds 13. Dimensions: 25.1 x 15.1 x 7.7 mm

Fan (Blower)

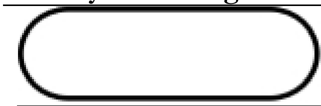
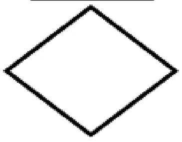
Gambar 14. Blower.

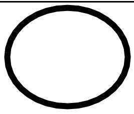
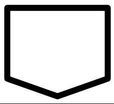
A fan is an electromechanical device used to regulate air circulation and control temperature within an enclosed environment by moving air and dissipating accumulated heat. Its primary function is to maintain a comfortable and stable thermal condition, preventing excessive temperature buildup and ensuring adequate airflow throughout a room or system. Fans are widely utilized in various applications, including air cooling, ventilation, air circulation, and drying processes. In electronic and industrial environments, fans play an essential role in preventing overheating of equipment and maintaining optimal operating conditions. Based on the direction of airflow generated, fans can generally be classified into two main types: centrifugal fans and axial fans. Centrifugal fans direct airflow outward at an angle relative to the fan shaft, generating higher pressure and making them suitable for ventilation systems requiring stronger airflow control. In contrast, axial fans move air parallel to the fan shaft and are commonly used in cooling applications due to their ability to deliver large volumes of airflow efficiently. Because of their effectiveness in temperature regulation and heat dissipation, fans are frequently integrated into environmental monitoring and control systems, including server room cooling applications and IoT-based automation systems [18].

Flowchart

A flowchart is a graphical representation used to illustrate the sequence of steps, decisions, and processes involved in the execution of a program or system. Each stage of the process is represented by a specific symbol and connected using lines or arrows that indicate the direction of workflow and logical progression. Flowcharts play a significant role in system analysis, software development, and program design because they provide a clear visual description of how a process operates before implementation. They are particularly useful in collaborative projects involving multiple developers, as they help standardize understanding and facilitate communication among team members. Furthermore, flowcharts simplify complex procedures by presenting them in a structured and concise format, reducing the likelihood of misinterpretation and design errors. In software engineering and information system development, flowcharts also serve as an effective bridge between technical and non-technical stakeholders by translating system requirements into an easily understandable visual model. Various standardized symbols are commonly used in flowchart design to represent processes, decisions, inputs, outputs, and data flow, enabling systematic documentation and analysis of program logic and operational procedures [13].

Table 5. Flowchart.

Symbol Images	Nama Sim-Pain	Remarks
	*Terminator*	Symbols used to describe the beginning or end of a process in a system.
	Process	Symbols used to describe the computerized process of a system.
	Input/Output	Input/Output process data, parameters, information.
	*Preparation*	The process of initializing or pricing the initial price.
	*Decision*	This symbol is used to show the conditioning process of a process and then the results are in the form of yes or no
	*Flow*	Symbols used to describe the direction or course of a process in the system.
	Sub Program	The process of running a sub-program.

	*On Page Con-nector*	Connecting parts flowchar which is on one page.
	*Off Page Con-nector*	Link flowchar sections that are on different pages

3. Materials and Method

Research Data

Data collection in this study was conducted to obtain comprehensive information required for the design and development of an IoT-based server room monitoring system. The research utilized both primary and secondary data sources. Primary data were collected through direct observation and interviews. The observation stage involved examining the server monitoring activities performed by the server administrator at a data center located in Duren Tiga, South Jakarta, Indonesia. This process aimed to understand existing monitoring practices and identify challenges related to supervising temperature, humidity, and movement within the server room, particularly when administrators were unable to perform continuous on-site monitoring. In addition, semi-structured interviews were conducted with the server administrator to gather detailed information regarding system requirements, operational needs, and expectations for automated monitoring and notification features. Secondary data were obtained through a literature review process involving books, scientific journals, conference proceedings, and online resources related to Internet of Things (IoT), environmental monitoring systems, server room security, and Fuzzy Logic applications. The combination of observation, interviews, and literature studies provided a strong foundation for understanding the problem domain and defining system requirements effectively.

Methodology Implementation

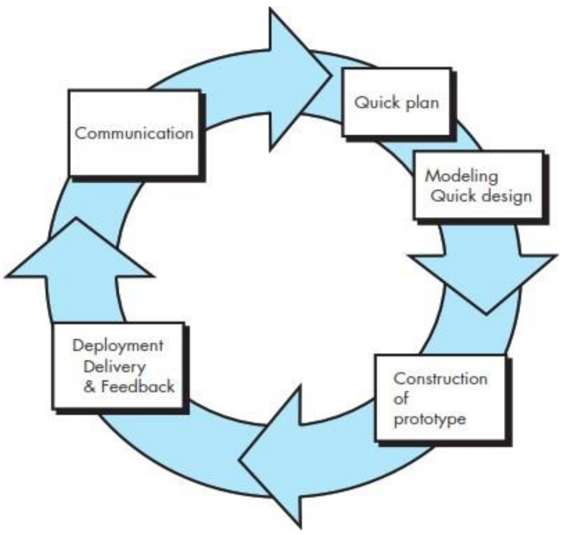


Figure 15. Prototype Flow.

This study employed the prototyping methodology to develop an IoT-based server room monitoring and security system. The prototyping approach was selected because it facilitates iterative development and continuous refinement based on user requirements and system evaluation. The methodology consisted of five main stages: communication, requirements gathering, system development, system coding, and system testing. During the communication stage, information related to server room security, temperature monitoring, humidity control, and motion detection was collected from scientific literature, online resources, and consultations with academic supervisors to identify research problems and determine appropriate solutions. The requirements gathering stage involved interviews, literature studies, and analysis of hardware and software specifications needed for system implementation. Subsequently, the system development stage focused on designing the Fuzzy

Logic algorithm and integrating sensors, NodeMCU ESP8266, and internet-based notification services. System coding was performed using the C programming language within the Arduino environment and integrated with Android-based notification functionality. Finally, system evaluation was conducted through black-box testing to verify functional performance, module integration, and overall system reliability in monitoring server room temperature, humidity, and unauthorized movement under real operating conditions.

Methodology Implementation

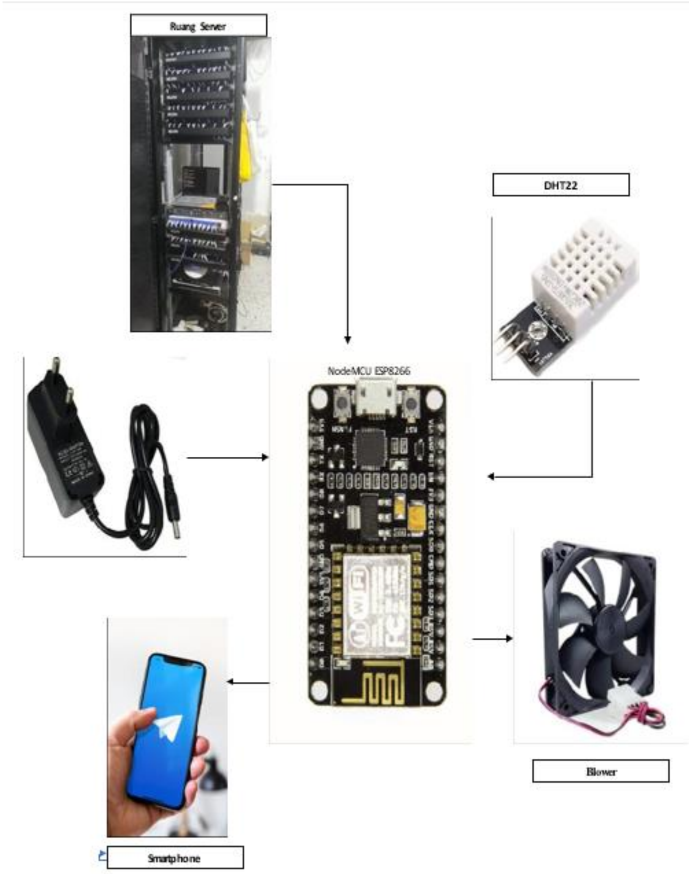


Figure 16. Design Design.

The methodology implementation included the design, development, coding, and testing of an IoT-based server room monitoring system intended to assist administrators in monitoring environmental conditions remotely and in real time. The system architecture was designed using a NodeMCU ESP8266 microcontroller integrated with a DHT11 sensor for temperature and humidity monitoring and a PIR sensor for motion detection. The monitoring process begins when the system is activated, enabling continuous acquisition of environmental data from the server room. Temperature and humidity readings are processed by the microcontroller and transmitted through an internet connection to a Telegram bot, allowing administrators to access real-time information using a smartphone. In addition, motion events detected by the PIR sensor trigger automatic notifications to alert administrators of potential unauthorized activities. The implementation of Fuzzy Logic Mamdani involved four stages: fuzzification, implication, rule composition, and defuzzification, with the Centroid method used to generate crisp output values. System evaluation was conducted through functional and performance testing to verify the reliability of sensor readings, notification delivery, fuzzy inference processing, and overall system operation under actual monitoring conditions.

4. Results and Discussion

Research Tools

To support this research, several hardware and software were used to facilitate testing, data collection, and in-depth analysis in this study. Here is a list of the equipment used in this study:

Table 6. Hardware.

no	Module	Quantity	Uses
	NodeMCU ESP8266	1	As the brain of the system that can process data and perform the entire process on System
1	Temperature sensor DHT11	1	To detect temperature and Humidity in the server room
3	Blower/*fan*	1	Helps air circulation and Cooling in server space
4	Relay	1	As a breaker and hub for the power current to the blower/fan
	Buzzer	1	As an alarm if the room temperature Exceeding the predetermined limit

The following is a table of the types of software used in this study:

Table 7. Software.

No	Name *Software / tools*	Uses
1	Arduino IDE	Used to write pro-gram code containing the commands required to be uploaded on the arduino uno microprocessor
2	Fritzing	To create a schema of the server monitoring system
3	visio	To create a flowchart schema

Implementation and Testing

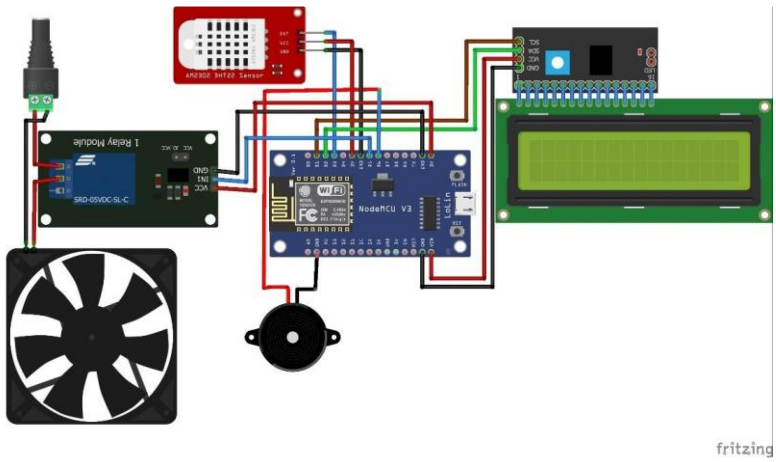


Figure 17. Schematic of System Development.

The implementation phase focused on developing and integrating an IoT-based server room monitoring system capable of monitoring temperature, humidity, and motion activity in real time. The hardware architecture consisted of a NodeMCU ESP8266 microcontroller connected to a DHT11 sensor for temperature and humidity measurement, a PIR sensor for motion detection, a relay module, a cooling fan, a buzzer, and internet connectivity for remote communication. The system was programmed using the Arduino IDE and integrated with a Telegram bot to enable remote monitoring and notification delivery through smartphones. Several commands were implemented within the Telegram interface, allowing administrators to retrieve temperature and humidity information, as well as activate or deactivate automatic warning notifications. The Fuzzy Logic Mamdani algorithm was implemented through four stages: fuzzification, implication, rule composition, and defuzzification. Temperature and humidity values were classified into five fuzzy membership sets, processed using the MIN implication method, aggregated using the MAX operator, and converted into crisp output values through the Centroid defuzzification method to determine fan speed. Furthermore, Wi-Fi and Telegram integration enabled real-time data transmission and automatic alerts whenever abnormal environmental conditions or unauthorized movements were detected. System testing was conducted to evaluate hardware functionality, communication performance, fuzzy inference processing, and the reliability of notification delivery under operational conditions.

Final Testing Results

Table 8. UAT Basic Function.

User Acceptance Test			
System Name	IoT-based server room security system uses microcontrollers and fuzzy logic methods		
Testing topics	Usability test		
Test Date	15/07/2023		
Tester Name	Mr. Adi		
No	Main Functions	Suitable	
		ya	no
1	Room temperature detected	V	-
2	PIR sensor detects germination	V	-
3	The blower works according to the results fuzzy	V	-
4	Opening the BOT telegram	V	-
5	Request for temperature info current server via telegram BOT	V	-
6	Enabling Server Room Temperature	V	-
7	Receive the current server room temperature message	V	-
8	Receive hot temperature messages	V	-
9	Receive cold temperature messages	V	-
	Quantity	9	0

Table 9. UAT Usability test.

User Acceptance Test			
System Name	IoT-based server room security system uses microcontrollers and fuzzy logic methods		
Testing topics	Usability test		
Test Date	15/07/2023		
Tester Name	Mr. Adi		
No	Module	Description	Results (V)(X)
1	NodeMCU8266	As the brains of all Processes that take place in the system	V
2	DHT11	As an input for temperature and humidity	V
3	LCD I2C	Displays temperature and humidity	V
4	Buzzer	Alarms to notify if the temperature is too cold and hot	V
5	Relay	As *On//Off fan*	V

Following the completion of the system design and coding stages, a comprehensive evaluation was conducted to assess the performance and functionality of the implemented server room monitoring system. The testing process was performed at two levels: system-level testing, which focused on performance evaluation, and user-level testing, which focused on functionality and usability. Functional testing was carried out using the User Acceptance Test (UAT) approach, where the evaluation criteria were derived from the primary operational requirements of server administrators. The testing activities were conducted within the Data Center Duren Tiga environment to ensure that the developed system met the actual needs of users. In addition, the Fuzzy Logic Mamdani method was evaluated through both computational and performance testing. Computational testing compared the results generated by the system with manual fuzzy calculations to determine the accuracy and error level of the implemented algorithm. Performance testing examined the behavior of the fuzzy system under various temperature and humidity conditions, including both normal and abnormal scenarios. Input values for temperature and humidity were manually introduced into the system, and the resulting fan speed outputs were compared with manually calculated results. This evaluation process was intended to verify the accuracy, consistency, and reliability of the Mamdani fuzzy inference mechanism in controlling environmental conditions within the server room.

5. Conclusion

This study successfully designed and implemented an IoT-based server room monitoring system utilizing a NodeMCU ESP8266 microcontroller, DHT11 temperature and humidity sensor, PIR motion sensor, Telegram-based notification service, and the *Fuzzy Logic Mamdani* method. The developed system was capable of continuously monitoring environmental conditions within the server room and maintaining temperature stability according to predefined operational thresholds. The integration of hardware components, including the DHT11 sensor, cooling fan, buzzer, and communication modules, functioned effectively to support real-time monitoring and automated environmental control. Testing results demonstrated that the system achieved a functional suitability level of approximately 90%, indicating that most system functions operated according to the specified requirements. The DHT11 sensor was able to detect temperature and humidity conditions reliably, while the PIR sensor successfully identified movement within the server room and triggered notification mechanisms when necessary. Furthermore, the implementation of the *Fuzzy Logic Mamdani* algorithm effectively processed temperature and humidity data to determine appropriate control actions and fan speed adjustments. The integration with Telegram enabled administrators to receive environmental information and warning notifications remotely and in real time, thereby improving monitoring efficiency and reducing the need for continuous on-site supervision. Overall, the proposed system provides a practical and cost-effective solution for enhancing server room environmental monitoring and security management.

Future work may focus on improving system performance by utilizing more advanced processing platforms such as Raspberry Pi, implementing backup power systems to ensure continuous operation during power outages, employing more stable internet communication infrastructures, and comparing the performance of alternative fuzzy inference approaches such as Sugeno or trapezoidal membership-based fuzzy models to further improve decision-making accuracy and environmental control effectiveness.

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