Smart Wardrobe System Based on Weather Prediction for Visually Impaired Users Using the Sugeno Fuzzy Method

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***Abstract* — Visually impaired individuals face difficulties in selecting appropriate clothing according to daily weather conditions, often relying on the help of others. This dependency can reduce their independence in daily activities. This research aims to design and build a "Smart Wardrobe System" that can provide automatic clothing recommendations based on weather predictions to enhance the independence of visually impaired users. The system is developed based on the Internet of Things (IoT) using an ESP32 microcontroller to retrieve real-time weather data from the BMKG API, including parameters of temperature, humidity, wind speed, and rainfall. The Fuzzy Sugeno method is implemented to process this data and generate a decision for clothing recommendations. To ensure accessibility, the system provides output in the form of voice instructions through a DFPlayer Mini module as well as physical action by automatically opening the relevant clothing drawer using a solenoid lock. The test results show that the Fuzzy Sugeno method successfully provided logical recommendations with an accuracy rate of 94.74% based on test scenarios. This prototype proved effective in providing accessible and actionable recommendations, thereby having the potential to increase the daily independence of visually impaired users.**

Keywords: BMKG API, Fuzzy Sugeno, Internet of Things (IoT), Smart Wardrobe, Visually Impaired

I. INTRODUCTION

Clothing is a primary need that not only functions to protect the body but also supports thermal comfort in various daily activities. Studies show that thermal comfort is influenced by a combination of clothing type (insulation value/"clo"), air temperature, and environmental humidity. Differences in clothing insulation values affect comfort levels, especially at high temperatures such as those in Indonesia, which can reach up to 34°C outdoors [1]. Choosing clothing that does not match weather conditions can cause significant discomfort and even increase the risk of health problems due to heat or cold stress.

In daily life, most people can determine the right clothing based on visual information, smartphone applications, or weather forecasts from mass media. However, for visually impaired individuals, this process becomes far more complex. Limitations in accessing visual information and the lack of specialized assistive systems make them dependent on others to choose appropriate clothing according to environmental conditions [2][3].

Moreover, automated and predictive systems that can independently provide clothing recommendations for visually impaired users are still rare. Several studies have developed IoT-based navigation or object detection aids using ultrasonic sensors and voice output, but they have not been specifically directed toward clothing selection based on weather prediction [4][5]. This highlights the importance of developing an intelligent system capable of accessing real-time weather data and providing clothing suggestions with automatic actuators and an accessible voice interface for visually impaired users.

Several studies related to smart wardrobe development and IoT-based technology have been conducted to improve comfort and efficiency in daily life. The first study, by Andy Lukman Affandy and colleagues, successfully implemented an IoT-based smart wardrobe system using an ESP32 and solenoid for security purposes [6]. However, its focus was purely on security with a visual interface and lacked an intelligent recommendation feature based on external data such as weather.

The second study, by Ihsanul Fadillah Amin and Dewi Laksmiati, demonstrated the effectiveness of using weather APIs in IoT systems for automatic clotheslines [7]. This system could act proactively based on accurate weather predictions via an API. However, its functionality was limited to a single mechanical action (closing the roof) and did not provide specific recommendations or an accessible interface for users with special needs.

The third study, conducted by Shania and colleagues, proved that the Fuzzy Sugeno method is effective for

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recommending clothing colors based on temperature and humidity [8]. Although the methodology is relevant, its implementation was limited to a visual Android application that only recommended colors (not clothing thickness) and was not integrated with physical hardware.

Meanwhile, the fourth study, by Sahrul Ramdani and colleagues, demonstrated that the combination of ultrasonic sensors and DFPlayer sound modules is highly effective for building non-visual interfaces for visually impaired users in navigation aids [9]. However, the device functioned independently, was limited to navigation purposes, and lacked IoT connectivity for intelligent decision-making based on external data.

To overcome the limitations of previous studies, this research aims to design and develop a "Smart Wardrobe System Based on Weather Prediction for Visually Impaired Users." This system is designed as an integrated solution [10] that not only retrieves real-time weather data [11] from the BMKG API [12] but also processes it [13] to provide clear [14] and actionable recommendations [15] for assistive daily living [16].

The system implements the Fuzzy Sugeno method to model the decision-making process. Fuzzy logic is chosen for its ability to handle uncertain or imprecise variables, such as "hot," "cool," or "humid," which are highly relevant to human perception of weather. With inputs in the form of temperature, humidity, wind speed, and rainfall, the Fuzzy Sugeno model produces clear output recommendations, such as "Thin Clothes," "Thick Clothes," or "Use a Raincoat."

To maximize accessibility, the system is equipped with voice output via a DFPlayer Mini module and speaker that will clearly read out the recommendation. Furthermore, the system automatically opens the drawer or compartment containing the recommended type of clothing using relays and solenoid locks. Thus, users not only receive information but also physical assistance in finding the appropriate clothing significantly enhancing their independence and comfort in daily activities.

II. METHOD

A. System Block Diagram

The block diagram in Fig. 1 illustrates the overall architecture and workflow of the Smart Wardrobe System. The system is divided into three main parts: Input, Process, and Output. In the Input section, the system utilizes several components to collect data from external sources and receive user commands. The main data source is the BMKG API, accessed through an internet connection to provide real-time weather forecast information, including temperature, humidity, wind speed, and rainfall. In addition, an HC-SR04 Ultrasonic Sensor is used to detect the presence of users in front of the wardrobe, which serves as a trigger for system interaction. The system is also equipped with Push Buttons, allowing users to issue manual commands, such as requesting clothing recommendations or opening drawers directly.

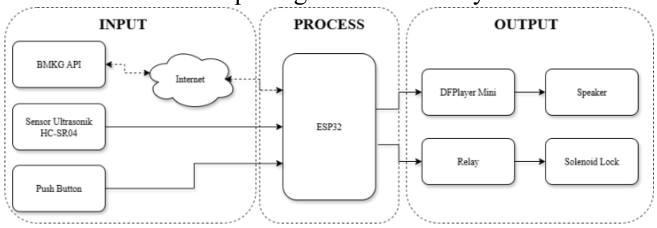

Figure 1. Block Diagram

In the Process section, all data received from the input components are processed by the main control unit, the ESP32 microcontroller. The ESP32 is responsible for retrieving and parsing weather data from the API, reading signals from the ultrasonic sensor, and receiving inputs from the buttons. The microcontroller then executes the Fuzzy Sugeno algorithm to analyze weather conditions and determine the most suitable clothing recommendation. Once the recommendation decision is generated, the ESP32 sends the corresponding commands to the components in the output section.

Finally, in the Output section, the processing results are presented to the user through both audio and physical actuator interfaces. For the accessible audio interface for visually impaired users, the system employs a DFPlayer Mini module connected to a speaker to deliver the recommendation results and other instructions in spoken form. Meanwhile, for physical action, the ESP32 sends signals to a Relay module, which acts as an electronic switch. The relay then activates the Solenoid Lock, allowing the drawer containing the recommended clothing to open automatically.

B. System Flowchart

The flowchart depicts the workflow of the Smart Wardrobe System starting from initialization until it delivers output to the user. The process begins with the initialization of the main components, namely the BMKG API for retrieving weather data and the Ultrasonic Sensor for detecting user presence. Next, the system attempts to connect the device to a Wi-Fi network and will keep trying until a successful connection is established.

Once the internet connection is stable, the system automatically retrieves weather data from the BMKG API. The raw data is then processed using the Fuzzy Sugeno method to generate suitable clothing recommendations based on the current weather conditions. The recommendation result is temporarily stored in the system's memory.

Afterward, the system enters standby mode and waits for user interaction. The HC-SR04 Ultrasonic Sensor continuously measures the distance in front of it. If the sensor detects a user within a distance of less than 50 cm, the DFPlayer module plays a greeting audio to initiate interaction. Then, the system waits for user input via the push buttons.

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C. Circuit Design

As shown in Fig. 3, the circuit is designed with the ESP32 as the main control unit, mounted on a PCB to simplify wiring and improve system organization. The system's primary power source is a 12V 5A adapter. The voltage from this adapter is regulated by an LM2596 step-down converter module, which reduces it to 5V. A 1000µF capacitor is added to the LM2596 output line to serve as a filter that smooths and stabilizes the voltage. This ensures that the 5V power supplied to the ESP32 and other components remains clean and free from electrical ripple interference.

As the main actuators, the system employs five solenoid locks to automatically lock and unlock each wardrobe compartment. To control them, an 8-channel relay module is used as an electronic switch. The relay's input pins are connected to the digital pins of the ESP32, enabling the microcontroller to activate the corresponding 12V solenoid. Each solenoid circuit is also equipped with a 1N4007 diode that functions as a flyback diode to protect the relay components from voltage spikes generated when the solenoid is turned off.

To provide instructions and feedback for visually impaired users, the system is equipped with an audio interface. A 5W 8Ω speaker is connected to the DFPlayer Mini module, an MP3 audio playback device. The DFPlayer module communicates with the ESP32 through the UART TX/RX pins, allowing the system to play pre-recorded voice messages containing clothing recommendations based on the weather prediction results.

User interaction is handled by six push buttons. Each button is connected to a digital input pin on the ESP32 and serves as an interface for users to request clothing recommendations based on the weather or to manually open drawers without relying on system recommendations.

To detect user presence, an HC-SR04 ultrasonic sensor is installed. The sensor's Trigger and Echo pins are connected to the ESP32's digital pins to measure distance. This data is used to automatically activate the system when a user approaches the wardrobe. Finally, an I2C OLED display is connected to the I2C pins (SDA & SCL) of the ESP32 to display system status information, which is useful during system development and testing.

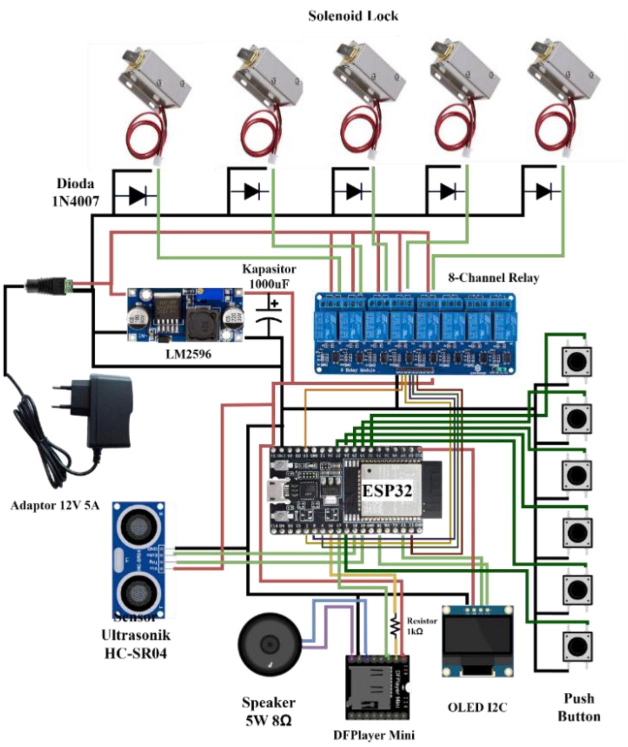

Figure 3. System Circuit Design

D. Device Design

As illustrated in Fig. 4, the device design in this study is generally divided into three main sections, namely the Overall View, ESP32 Control Box, Button Box, and Drawer Section.

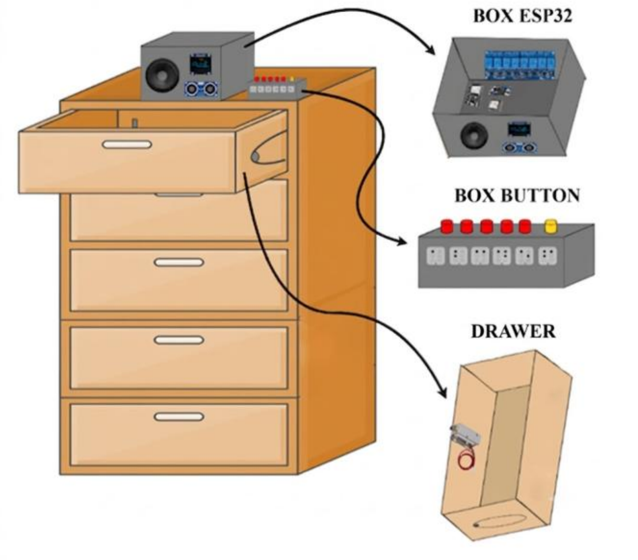

Figure 4. 3D Design of the Device

The Overall View represents the prototype of a wardrobe with dimensions of 80 cm × 40 cm × 120 cm, consisting of five drawers used to store different categories of clothing. At the top of the wardrobe are placed the ESP32 Control Box and the Button Box, which serve as the main interface and processing modules of the system.

The ESP32 Control Box functions as the control and data-processing center. Inside this box are housed all core electronic components, including the ESP32 microcontroller, relay module for controlling each drawer, OLED display for showing visual information, ultrasonic sensor for detecting the presence of the user, and the DFPlayer Mini module connected to a speaker that serves as the audio output interface.

The Button Box serves as the control panel used to open drawers manually. It is positioned at the corner of the wardrobe in an easily reachable location for users. This panel contains six push buttons: buttons 1–5 is used to open each drawer manually, while button 6 is designated for activating automatic mode. Each button is equipped with raised Braille labels, as shown in Fig. 5, representing numbers 1 to 6 according to their respective functions. This tactile feature allows visually impaired users to operate the system independently. The design follows the principles of universal design, ensuring usability for all users, including those with visual impairments.

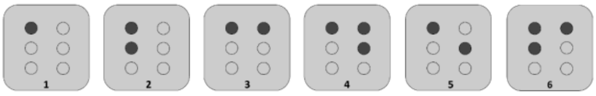

Figure 5. Button Braille Display

E. Fuzzy Sugeno Method Design

The Fuzzy Sugeno method is implemented as the core decision-making mechanism in the Smart Wardrobe system. In this design, three fuzzy input variables are used temperature (°C), humidity (%), and wind speed (km/h) while rainfall (tp) is processed outside the fuzzy logic (if *tp ≥ 1 mm*, the system adds a raincoat recommendation). The inference process uses the AND operator = multiplication, and defuzzification employs a 0-order Sugeno method, calculated using a weighted average to produce an Index value ranging from 0–100. This index is then mapped into a "Thin" or "Thick" clothing decision using a hysteresis threshold of 45/55, preventing repetitive switching decisions under fluctuating input values.

The implementation consists of four main stages: Fuzzification, Inference, Defuzzification, and Rainfall Logic.

1. Fuzzification Process

The fuzzification process converts each numeric input value into its corresponding linguistic representation using trapezoidal membership functions. The trapezoidal function is selected because it provides a flexible representation of transition boundaries between categories. The variable membership functions as shown in Table I.

TABLE I
VARIABLE MEMBERSHIP FUNCTIONS

Variable	Category	Membership Functions
Temperature	Cold	[0, 0, 16, 19]
	Mild	[17, 20, 26, 29.0]
	Hot	[26.0, 29.0, 100, 100]
Humidity	Dry	[0, 0, 40, 55]
	Normal	[45, 55, 65, 75]
	Humid	[60, 75, 100, 100]
Wind speed	Calm	[0, 0, 4, 8]
	Moderate	[6, 9, 14, 20]
	Strong	[16, 22, 60, 60]

2. Fuzzy Rules (Rule Base)

The rules in the fuzzy controller are arranged as if–then statements, e.g., "If X is A then Y is B." In this statement, "X is A" is called the antecedent (premise), while "Y is B" is the consequent (conclusion). The AND operator in the antecedent uses multiplication (product). The rules applied as shown in Table II.

TABLE II
RULE BASE

No.	Rule	C_i → Drawers
1	Hot	20 → Drawers 1, 3
2	Cold	80 → Drawers 2, 4
3	Mild ∧ Strong wind	78 → Drawers 2, 4
4	Mild ∧ Moderate ∧ Humid	35 → Drawers 1, 3
5	Mild ∧ Moderate ∧ Ideal	45 → Drawers 1, 3
6	Mild ∧ Moderate ∧ Dry	68 → Drawers 2, 4
7	Mild ∧ Calm ∧ Humid	22 → Drawers 1, 3
8	Mild ∧ Calm ∧ Ideal	35 → Drawers 1, 3
9	Mild ∧ Calm ∧ Dry	65 → Drawers 2, 4

3. Fuzzy Sugeno Inference

The inference stage aims to calculate the rule strength (firing strength) based on the fuzzification results and associate it with the fixed consequent of each rule. The firing strength of the i-th rule represents the degree to which the rule is activated according to the input conditions. It is calculated using the AND operator, which in this system is implemented as multiplication (product) of the membership degrees of all antecedents within that rule. The formula is expressed as Equation (1):

$$\alpha_i = \prod_j \mu_{A_{ij}}(xj) \tag{1}$$

4. Defuzzification

A Defuzzification is the stage of converting the combined results of fuzzy rules into a crisp output value that can be directly used by the system. This process transforms the aggregated fuzzy inference results into a single numerical value that represents the system's final decision. The defuzzification process is calculated using Equation (2):

$$z = \frac{\sum_{i=1}^{n}(a_i . C_i)}{\sum_{i=1}^{n} a_i} \tag{2}$$

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5. Rainfall Logic

The rainfall variable from BMKG data is denoted as tp (in millimetres). Unlike the three fuzzy input variables (temperature, humidity, and wind speed), this variable is not fuzzified and does not serve as an antecedent in the fuzzy rule base. Instead, rainfall is handled deterministically after the main decision has been derived from the defuzzified Sugeno 0-order output (z) and the 45/55 hysteresis threshold. If, during the same forecast hour, the rainfall value satisfies $tp \geq 1$ mm, the system adds Drawer 5 (Raincoat) to the output recommendation. This rule can be expressed concisely as Equation (3):

$$tp \geq 1mm \Rightarrow Output := Output \cup \{5\} \quad (3)$$

III. RESULTS AND DISCUSSION

A. System Implementation Result

The hardware prototype of the *Smart Wardrobe* system was successfully designed and assembled according to the proposed specifications. The system consists of two main modules: the wardrobe drawers and the control-monitoring unit.

1. Hardware Implementation

Fig. 6 shown is the wardrobe cabinet constructed using wood and acrylic materials and consists of five drawers, each representing a clothing category: thin shirt, thin pants, thick shirt, thick pants, and raincoat. Each drawer is equipped with a solenoid lock controlled by an 8-channel relay module, enabling automatic opening based on the fuzzy logic weather recommendation.

Figure 6. Wardrobe Drawers

Fig. 7 shown is the control unit, housed in an acrylic box, contains the ESP32 microcontroller as the main controller. The ESP32 retrieves weather data from the BMKG API via a Wi-Fi connection and controls various peripherals, including the OLED I²C 1.3” display, DFPlayer Mini audio module, relay module, and six push buttons, and power management through a 12V 6A external power supply.

Figure 7. Control and Monitoring Box

2. Software Implementation

The software was developed using Arduino IDE and implemented on the ESP32 microcontroller. The program integrates weather data retrieval via the BMKG API, fuzzy Sugeno logic processing, actuator control, audio playback, and OLED display output as shown in the Fig. 8.

Figure 8. OLED Display Preview

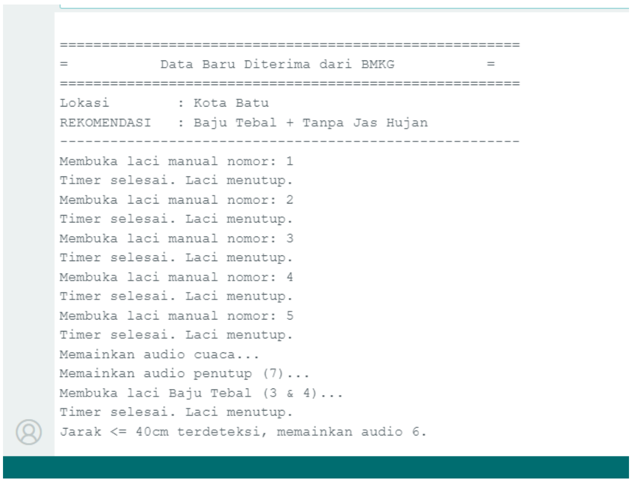


Figure 9. Arduino IDE Serial Monitor Preview

Fig. 9 shown the Arduino IDE’s serial monitor preview that the system also supports manual mode using five push buttons for direct drawer control and one button to reactivate automatic mode. Additionally, an ultrasonic sensor detects user presence and triggers a voice greeting, enhancing accessibility for visually impaired users.

B. System Testing Result

1. Ultrasonic Sensor HC-SR04 Testing

The ultrasonic sensor (HC-SR04) was tested by standing at various distances from the sensor to evaluate its ability to detect the presence of a user. This sensor is responsible for detecting the user's presence in front of the wardrobe, which subsequently triggers the system to greet the user via an audio output. The results of these tests are presented in Table III.

TABLE III
ULTRASONIC SENSOR TESTING RESULTS

Distance (cm)	Detected	Audio Activated	Description
10	Yes	Yes	Subject Detected
30	Yes	Yes	Subject Detected
50	Yes	Yes	Subject Detected
60	Yes	Yes	Subject Detected
70	No	No	Subject Not Detected
90	No	No	Subject Not Detected
100	No	No	Subject Not Detected

2. DFPlayer Mini + 8Ω 5W Speaker Testing

The DFPlayer Mini module serves as the audio playback unit that delivers voice-based feedback according to the fuzzy recommendation results. This test was conducted to verify that each sound file is correctly played and can be clearly heard through the speaker. The testing result shown in Table IV.

TABLE IV
DFPLAYER MINI + SPEAKER TESTING RESULTS

Audio File	Content Description	Audio Output	Sound Quality
0001.mp3	"Opening thin shirt drawer"	Yes	Clear
0002.mp3	"Opening thin pants drawer"	Yes	Clear
0003.mp3	"Opening thick shirt drawer"	Yes	Clear
0004.mp3	"Opening thick pants drawer"	Yes	Clear
0005.mp3	"Opening raincoat drawer"	Yes	Clear
0006.mp3	"Hello, welcome to Smart Wardrobe"	Yes	Clear
0007.mp3	"Have a nice day"	Yes	Clear
0008.mp3	"Today's weather is sunny"	Yes	Clear
0009.mp3	"Today's weather is partly cloudy"	Yes	Clear
0010.mp3	"Today's weather is cloudy"	Yes	Clear
0011.mp3	"Today's weather is overcast"	Yes	Clear
0012.mp3	"Today's weather is hazy"	Yes	Clear
0013.mp3	"Today's weather is light rain"	Yes	Clear
0014.mp3	"Today's weather is moderate rain"	Yes	Clear
0015.mp3	"Today's weather is heavy rain"	Yes	Clear
0016.mp3	"Today's weather is thunderstorm"	Yes	Clear

3. Push Button, Relay, and Solenoid Lock Testing

The system includes a total of six push buttons: five buttons for manual drawer control and one button for automatic operation based on weather-based fuzzy recommendations. This test was conducted to verify that the system correctly activates the relay and solenoid locks, ensuring that the corresponding drawers open accurately according to the input command. The comprehensive test data is presented in Table V, which demonstrates a 100% success rate across all manual and automatic button inputs.

TABLE V
PUSH BUTTON, RELAY, AND SOLENOID LOCK TESTING RESULTS

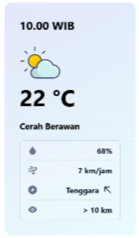
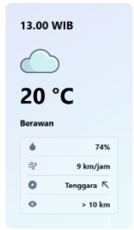
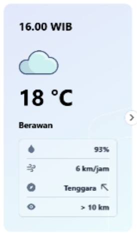
Tested Button	Relay Channel	Solenoid Active	Drawer Opened	Description
1	1	Yes	Yes	Thin shirt drawer opened
2	2	Yes	Yes	Thick shirt drawer opened
3	3	Yes	Yes	Thin pants drawer opened
4	4	Yes	Yes	Thick pants drawer opened
5	5	Yes	Yes	Raincoat drawer opened
6	Combination	Yes	Yes	Drawer opened according to weather-based recommendation

4. BMKG API Data Retrieval Testing

The Smart Wardrobe system utilizes the BMKG public API to obtain real-time weather data such as temperature, humidity, wind speed, and rainfall. This data serves as the input for the Fuzzy Sugeno decision-making process.

The BMKG API provides weather data at 3-hour intervals, which are parsed and used to update the system's internal parameters. The ESP32 connects to the internet via a Wi-Fi network, accesses the API endpoint, retrieves JSON-formatted weather data, and extracts relevant variables for processing. The performance and success rate of this data extraction process are evaluated and presented in Table VI.

TABLE VI
BMKG API DATA RETRIEVAL TEST RESULTS

Data Displayed on OLED	Data on BMKG Website	Retrieval Status
		Match
		Match
		Match
		Match
		Match
		Match

5. Fuzzy Sugeno Method Testing Results

The Fuzzy Sugeno method testing was conducted to evaluate whether the system could provide appropriate clothing recommendations based on actual weather data retrieved from the BMKG API. By processing combinations of four parameters, the system determines which types of clothing are suitable for visually impaired users. The complete mapping of the input parameters, fuzzy inference outputs, and the resulting recommendations are comprehensively presented in Table VII.

TABLE VII
FUZZY SUGENO METHOD TESTING RESULTS

Date & Time	T (°C)	HU (%)	WS (km/h)	Tp (mm)	Opened Drawers	Manual Calculation
2025-08-12 03:00	17.0	96	0.4	0.1	2, 4 (Thick)	Index = (0.667×80)/(0.667) = 80.00 (Thick)
2025-08-12 06:00	18.0	94	1.4	0.1	2, 4 (Thick)	Index = (0.333×80 + 0.333×22)/(0.666) = 51.89 (Thick)
2025-08-12 09:00	22.0	77	5.7	0.1	1, 3 (Thin)	Index = (0.575×22)/(0.575) = 22.00 (Thin)
2025-08-12 12:00	22.0	75	7.1	0.6	1, 3 (Thin)	Index = (0.367×35 + 0.225×22)/(0.592) = 30.05 (Thin)
2025-08-12 18:00	18.0	95	0.8	1.2	2, 4, 5 (Thick + Raincoat)	Index = (0.900×80)/(0.900) = 80.00 (Thick)
2025-08-13 09:00	23.0	61	4.3	0.0	1, 3 (Thin)	Index = (0.062×22 + 0.925×35)/(0.987) = 34.19 (Thin)

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Date & Time	T (°C)	HU (%)	WS (km/h)	Tp (mm)	Opened Drawers	Manual Calculation
2025-08-13 18:00	17.0	97	1.9	1.1	2, 4, 5 (Thick + Raincoat)	Index = (1.000×80)/(1.000) = 80.00 (Thick)
2025-08-14 03:00	15.0	96	1.0	1.6	2, 4, 5 (Thick + Raincoat)	Index = (1.000×80)/(1.000) = 80.00 (Thick)
2025-08-15 10:00	22.0	68	7.3	0.3	1, 3 (Thin)	Index = (0.462×35 + 0.217×22)/(0.679) = 32.71 (Thin)
2025-08-15 16:00	18.0	93	6.9	0.6	2, 4 (Thick)	Index = (0.333×80 + 0.100×35 + 0.092×22)/(0.525) = 61.30 (Thick)

6. User Testing Results

This testing phase was conducted to evaluate how effectively the Smart Wardrobe System can be independently used by visually impaired users. The evaluation involved five respondents of one visually impaired participant and four non-visually-impaired participants with their eyes covered (to simulate blindness). The test measured ease of use, response time, and accessibility performance. This testing phase was conducted to evaluate how effectively the Smart Wardrobe System can be independently used by visually impaired users. The evaluation involved five respondents of one visually impaired participant and four non-visually-impaired participants with their eyes covered (to simulate blindness). The test measured ease of use, response time, and accessibility performance. The detailed experimental data gathered from each participant across five consecutive trials are presented sequentially from Table VIII to Table XII.

As indicated in Table VIII, the visually impaired participant (Respondent 1) initially experienced minor software lag, with a delayed greeting in the first and third trials. However, a significant learning curve was observed as their usage time steadily decreased from 1 minute 2 seconds in Trial 1 to an efficient 57 seconds by Trial 5, concluding that the system was comfortable to use.

A similar trend of rapid adaptation is reflected in the simulated blindness group (Table IX to Table XII). In the initial trials, some participants faced minor physical orientation challenges. For instance, Respondent 2 and 3 initially struggled with drawer recognition (Table IX and Table X), while Respondent 4 had difficulty locating the physical button in their first attempt (Table XI). Additionally, occasional issues regarding voice clarity were noted in the middle trials of Respondent 3 and 4.

Despite these early operational bottlenecks, all participants demonstrated a noticeable improvement in proficiency. By the fifth trial, every respondent successfully located the buttons, recognized the drawers, and recorded their fastest execution times—most notably Respondent 5, who completed the task in just 29 seconds (Table XII). The consistent transition in user feedback from "confused at first" to "comfortable to use" across all tables strongly validates that the system's interface is highly intuitive and accessible for independent daily operations.

TABLE VIII
RESPONDENT 1 RESULTS (VISUALLY IMPAIRED)

Trial	Usage Time	Voice Clear?	Button Found?	Drawer Recognized?	Comment
1	1 min 2 s	No	Yes	Yes	Greeting delayed
2	1 min	Yes	Yes	Yes	Confused at first
3	1 min 8 s	No	Yes	Yes	Greeting delayed
4	58 s	Yes	Yes	Yes	Started to get smoother
5	57 s	Yes	Yes	Yes	Comfortable to use

TABLE IX
RESPONDENT 2 RESULTS (NON-VISUALLY IMPAIRED)

Trial	Usage Time	Voice Clear?	Button Found?	Drawer Recognized?	Comment
1	1 min 30 s	No	Yes	No	Confused at first
2	1 min 4 s	Yes	Yes	Yes	Greeting delayed
3	52 s	Yes	Yes	Yes	Getting smoother
4	50 s	Yes	Yes	Yes	Already fluent
5	47 s	Yes	Yes	Yes	Comfortable to use

TABLE X
RESPONDENT 3 RESULTS (NON-VISUALLY IMPAIRED)

Trial	Usage Time	Voice Clear?	Button Found?	Drawer Recognized?	Comment
1	35 s	Yes	Yes	No	Confused at first
2	33 s	Yes	Yes	No	Difficulty recognizing drawer
3	35 s	Yes	Yes	Yes	Getting smoother
4	46 s	No	Yes	Yes	Voice unclear
5	37 s	Yes	Yes	Yes	Comfortable to use

TABLE XI
RESPONDENT 4 RESULTS (NON-VISUALLY IMPAIRED)

Trial	Usage Time	Voice Clear?	Button Found?	Drawer Recognized?	Comment
1	39 s	Yes	No	Yes	Difficulty pressing button
2	37 s	Yes	Yes	Yes	Getting smoother
3	50 s	No	Yes	Yes	Voice unclear
4	33 s	Yes	Yes	Yes	Already fluent
5	32 s	Yes	Yes	Yes	Comfortable to use

TABLE XII
RESPONDENT 5 RESULTS (NON-VISUALLY IMPAIRED)

Trial	Usage Time	Voice Clear?	Button Found?	Drawer Recognized?	Comment
1	39 s	Yes	Yes	Yes	Confused at first
2	34 s	Yes	Yes	Yes	Getting smoother
3	34 s	Yes	Yes	Yes	Already fluent
4	33 s	Yes	Yes	Yes	Comfortable to use
5	29 s	Yes	Yes	Yes	Smooth and fast

IV. CONCLUSION

The IoT-based Smart Wardrobe System has been successfully designed and implemented using the ESP32 microcontroller as the main processing unit, which effectively connects to the internet to retrieve real-time weather data from the BMKG API and controls solenoid lock actuators through a relay module to automatically open clothing drawers. To ensure logical and accurate clothing recommendations, the Fuzzy Sugeno method was applied to process four weather input variables—temperature, humidity, wind speed, and rainfall—achieving an outstanding accuracy rate of 94.74% based on testing across 19 different weather scenarios in accordance with predefined fuzzy rules. Furthermore, accessibility evaluations for visually impaired users demonstrated that the system can be operated easily and intuitively without visual assistance, owing to clear and informative audio guidance paired with automated physical control. This is highly evident from the user testing results, which showed a 35.7% improvement in operational efficiency as the average usage time was successfully reduced from 70 seconds down to 45 seconds by the fifth trial, ultimately proving that the system is highly accessible, adaptive, and helpful in supporting visually impaired individuals to independently select weather-appropriate clothing.

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