Monitoring System for Early Detection of Fire in Wetlands based Internet of Things (IoT) using Fuzzy Methods

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Monitoring System for Early Detection of Fire in Wetlands based Internet of Things (IoT) using Fuzzy Methods

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Abstract. In Indonesia, especially the province of South Kalimantan is a province with a high frequency of forest and wetland fires. These fires seem to be a routine annual natural disaster. BNPB (National Disaster Management Agency) and BPBD (Regional Disaster Management Agency) Central Kalimantan recorded that during 2014 to early 2019, the largest area of forest and wetlands fires in Central Kalimantan occurred in 2015 with a total burned area of 583,833.44 ha. The fire early detection monitoring system that will be made based on Arduino Uno uses the MQ-2, DHT-22 sensor, and flame detector sensor and is integrated with the Thingspeak IoT, which functions to receive data sent from the Arduino Uno microcontroller using the ESP8266 module, then Thingspeak will send the data to an Android smartphone in the form of a real-time display and also a pop-up notification when a potential fire is detected. Finally, the fuzzy method is also added so that later the reading data from the MQ-2, DHT-22, and flame detector sensors will be more accurate before being sent to Thingspeak. The level of accuracy obtained from the readings of the three sensors against the tests that have been carried out is 90%.

Keywords: Fire Monitoring System, Arduino Uno, Fuzzy Method, Monitoring System

1. Introduction

The impacts of forest and wetland fires range from decreased environmental conditions, material loss to human health, which can lead to respiratory infections, eye pain, and coughing from fire smoke. Based on data from BNPB (National Disaster Management Agency) and BPBD (Regional Disaster Management Agency) Central Kalimantan, from 2014 to early 2019, the largest area of forest and wetlands fires in Central Kalimantan occurred in 2015 with a total burned area of 583,833,44 ha. Then from 12 districts/cities in Central Kalimantan, from early January to August 2018, Palangkaraya City was the city with the most incidents of forest and wetlands fires with 76 incidents, followed by East Kotawaringin with 53 incidents.

Because the impact of the fires caused is so significant, there must be severe handling of this forest and wetlands fire disaster. The solution that will be made is to implement a monitoring system for forest and wetlands fires so that it can provide quick action before and when fires occur and minimize the impact of losses caused by fires [1]-[2].

Based on these conditions, a similar monitoring system will be built by adding Thingspeak. Thingspeak is a web-based on open API IoT (source platform) information which is reliable in storing sensor data from various IoT applications. Thingspeak functions to retrieve, store, analyze, observe, and work on data sent from sensors connected to a microcontroller. The resulting output data is in the form of graphs and conclusions and can be accessed via the web desktop and Android-based mobile applications [3]-[6].

Research on fire monitoring systems has been carried out in ref [7]. In his research entitled "Building Fire Management Systems Using Fuzzy Methods". The study used an MQ-2 smoke sensor, a DHT-22 temperature sensor and a flame detector sensor. This study applies the Fuzzy Logic method to the Uno Atmega328P microcontroller.

Another research was also carried out in ref [8], entitled "Prototype of Land Fire Fire Spot Detection Based on Arduino Uno R3 with Early Warning through the Website". This research concluded that the MQ-2, DHT-11 sensors and flame detector sensors were able to detect fire light very quickly and make it easier for users to access information, especially in forest prone to fires.

Similar research was also carried out in ref [9], entitled "Monitoring and Early Warning System for Forest and Peatland Fires Based on Arduino with Website Interface and Short Message Service (SMS)". This research was designed to monitor forest and peatland fires by measuring the level of temperature, humidity, and smoke. The tool used to measure the high temperature and humidity of the air is the DHT-11 sensor, while to measure the level of smoke density using the MQ-7 sensor. Tool testing is done by measuring temperature, humidity, and smoke, the results of which will be displayed on the website interface and SMS.

In addition, a fuzzy method is also added, which will later function to process input data into output data so that the data sent is more accurate. Referring to the above discussion, a "Monitoring System for Early Detection of Fires on Wetlands. Based on the Arduino Uno Microcontroller and the Internet of Things using the Fuzzy method" was created.

2. Research Methods

The research procedure used in this study can be seen in Figure 1.

Figure 1. Research Process Flow

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2.1 System planning

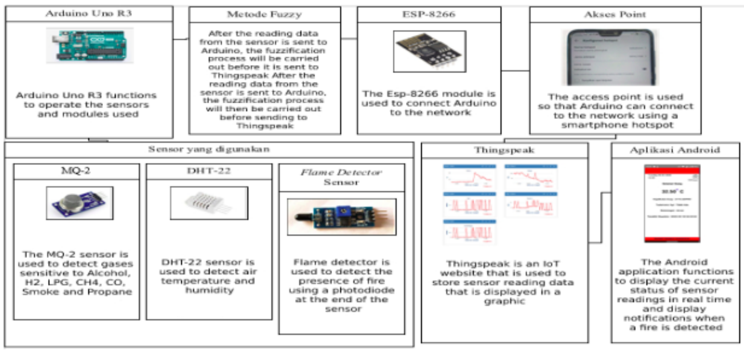

Figure 2. General Description of the System

The flow of the system in this study can be seen in Figure 2:

1. The Arduino is turned on, and then the MQ-2, DHT-22 sensors, and flame detector sensors will detect the state of temperature, smoke, and fire around the sensor.
2. Data that has been seen by the sensor will be forwarded to Arduino for processing
3. Arduino processes the data that has been received by the sensor using the fuzzy method
4. After the fuzzification process is complete, Arduino then sends the data to the Thingspeak website via ESP8266
5. Thingspeak receives, after the data, and this data will be sent and also displayed in an Android-based application that has a pop-up notification as a monitoring medium.

2.2 Trial Scenarios

At this stage, tests will be carried out on the system that has been created. Prototype testing aims to ensure that the sensors used are functioning correctly and can be connected to the system so that monitoring can be done via the Thingspeak website and the Android application. The test was carried out in a place that resembled the original position, namely forest and wetlands but on a smaller scale.

2.3 Implementation

At this stage, fuzzy logic will be incorporated into the system that has been built. There are two types of input data entered, namely, data on smoke levels and temperature. The data is sent from a sensor that is connected to the Arduino IDE software, and then it will be stored and then processed using the fuzzy method to find out which value of the sensor readings is more likely to be a member. After going through the fuzzy process, it will produce output in the form of data that is ready to send the sensor to the user. The input smoke level uses variable part per million (ppm) value data [10]-[12]. So, the membership list for the smoke variable is [0 10000]. Smoke uses 2 fuzzy sets, namely smokeless and smoky. Fires that occur are usually identified by the increase in smoke from smoke in normal air, which changes the conditions to the air above normal, which is greater than the value of 4500 ppm. With smokeless [0 4000] and smoky [4500 10000] domains [13]. List of smoke levels membership can be seen in Figure 3.

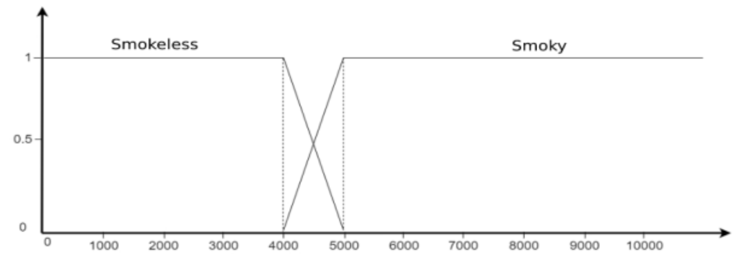

Figure 3. Membership List of Smoke Density

As for the temperature using three fuzzy sets, namely normal, warm, and hot, fires occur usually known by an increase in temperature from normal air which rises above normal temperatures, which is greater than 30 ° C. Thus, in this study, the membership list for temperature variables was [20 40]. With normal [20 30], warm [25 35] and hot [30 40]. The list of temperature membership can be seen in Figure 4.

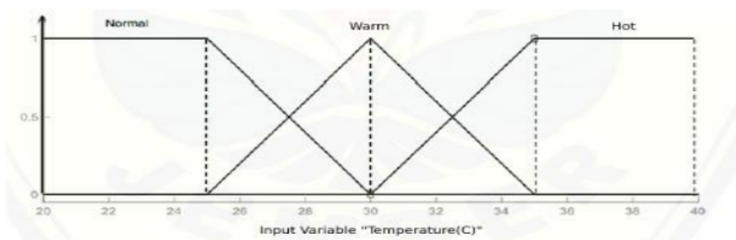

Figure 4. List of Temperature Membership

Fuzzy logic has several stages starting with the process of fuzzification (formation of fuzzy sets), rules, the composition of rules, and defuzzification (affirmation) . The steps of the fuzzy logic process can be seen in the Figure 5.

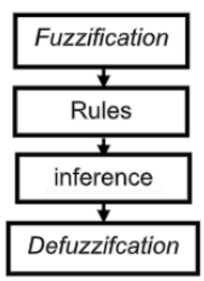

Figure 5. Fuzzy Logic Process Structure

Figure 5 is the structure of the Fuzzy logic process. Where according to the flow of the image, the process starts from fuzzification, inference, rules, and defuzzification as the final result [14]. From the above process flow, it can be described as follows:

1. Fuzzification
   In the first process, where the fuzzification process is the process of changing the input/output system through fuzzy. A range of input variable values are grouped into fuzzy sets; each fuzzy has a membership list that shows the mapping of data input points into its membership value in the form of a membership list and has an interval between 0 to 1. The fuzzy membership list is calculated based on the membership formula fuzzification triangles that match the parameter results. The form of fuzzification determines the membership list in an input/output range [15].
2. Rules
   If the system consists of several rules, then the inference is obtained from the collection and correlation between the rules. There are three input variables and one output variable that have been determined by the formation of rules by analyzing the boundaries in a fuzzy set. The output consists of 12 fuzzy rules, which can be seen
3. Inference
   The inference stage part is looking for the MIN function first.
4. Defuzzification
   The input of the defuzzification process is a fuzzy set obtained from the fuzzy rules' composition so that the resulting output is in the form of a number in the fuzzy set. If given a fuzzy set within a certain range, a certain (crisp) value must be taken as output.

3. Results and Discussion

At this stage of processing or processing the data, it becomes a conclusion in the form of information conveyed by the system to its users (Users). At this stage, data processing is carried out using a fuzzy inference system in the form of a computational framework and is based on IF-THEN fuzzy rules, fuzzy reasoning, and fuzzy set theory [16].

In the system that has been created, there are two interfaces, namely the system interface on the web/desktop and the system interface on an Android smartphone. Both have different functions. Display on the web/desktop using the Thingspeak platform. The data presented is in the form of graphical data, the results of data processing sent from each sensor.

1. Temperature Graph Display

Figure 6. Temperature Graph

Figure 6 show the displays real-time temperature monitoring with a time range that is every 5 minutes.

2. Smoke Graph Display

Figure 7. Smoke Graph

Figure 7 displays the smoke monitoring in real-time with a time range every 5 minutes.

3. Fire Graph Display

Figure 8. Fire Graph

Figure 8 show the real-time fire monitoring with a time range, which is every 5 minutes.

4. Status Graph Display

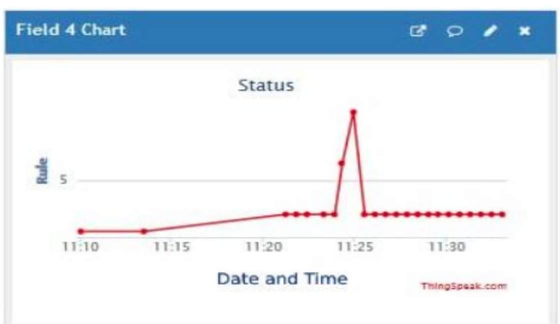

Figure 9. Status Graph Display

Figure 9 show the real-time monitoring of fuzzy conclusions with a time range that is every 5 minutes. The data displayed is the result of processing data sent by each sensor in the form of a status. The status is divided into 4 conclusions, namely normal status, alert status 1, alert status 2 and danger status.
Meanwhile, the interface on an Android smartphone is in the form of today's time and date, temperature conditions, smoke and fire, current status, last update, and notification page which contains unread data and read data.

5. Android Interface Page
Figure 10 is an implementation of an Android mobile device to display the details of the read data. Pieces of the data include time, gas value, temperature value, fire, and the condition's status.

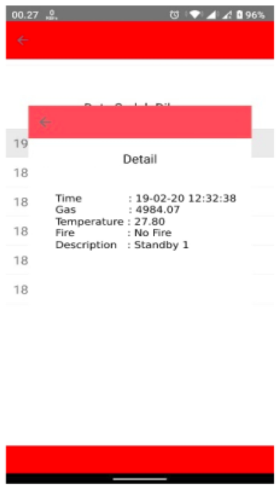

Figure 10. Android Interface Page

6. Notification Interface Page

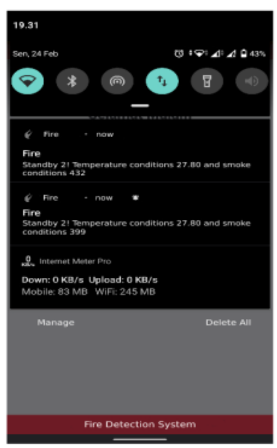

Figure 11. Notification Interface Page

Figure 11 is a display of the user (user) getting information in the form of the latest status of a state or condition detected by the system and stored in Thingspeak.

System testing is carried out aimed at ensuring the system that has been created is in accordance with the results of analysis and design and produces conclusions as expected. Before the system is implemented, what must be done is to ensure the program is free from errors that may occur when the system is created.

The following Figure 12 is a view of the sensor that has been assembled on a breadboard and connected to a laptop.

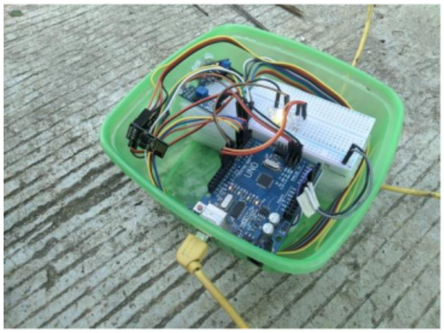

Figure 12. Sensor Circuit Above Breadboard

The first stage is to install the MQ-2 sensor, DHT-22 sensor, and flame detector sensor on top of the breadboard. Next is to connect each sensor to the Arduino Uno Atmega328P using a jumper cable. Then attach the LED light to the breadboard, connect each LED light to the Arduino Uno Atmega 328P so that the program can give the LED light command to turn on based on the setup that has been done in the program. The last step is to connect the Arduino Uno Atmega 328P to the laptop using a USB cable.

At the sensor testing stage, the assembled sensors will be tested with the materials provided, namely dry grassroots, dry twigs, used paper, and leftover cigarette butts. The test is carried out in a place that resembles the original place on a smaller scale. Testing time is carried out from noon (11.00 WITA) to (12.00 WITA). Each test has a time interval of 15 minutes. It aims to condition changes in environmental temperature as the original.

The following is a photo when testing the sensor:

1. Testing prototypes of dry grass
   In the Figure 13, the prototype can detect the presence of fire but has not detected the smoke due to the direction of the smoke away from the prototype. The blue LED for standby status two lights up when the prototype detects a fire from dry grass.

Figure 13. Dried Grass Detection Test

2. Testing prototypes of dry branches
   In the Figure 14, the prototype can detect the presence of fire and also detect smoke due to the direction of the smoke that is approaching the sensor installed on the prototype. The red LED light for hazard status lights up when the prototype detects fire and smoke coming from dry branches.

Figure 14. Dry Twig Detection Test

3. Prototype testing of residual cigarette butts is smoke and fire
   In the Figure 15, the prototype can detect smoke and embers from leftover cigarette butts because the coals from cigarettes can be detected by the sensor installed on the prototype. The red LED light for hazard status lights up when the prototype detects smoke and flames from leftover cigarette butts.

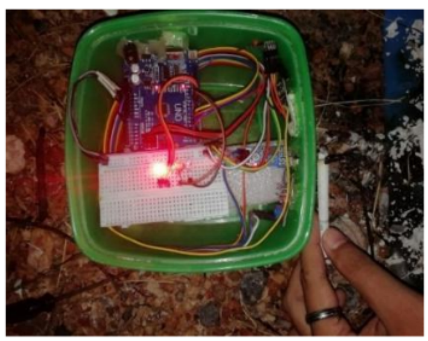

Figure 15. Detection Testing of Remaining Cigarette Butts, There is Smoke and Fire

After the system testing is complete, the next stage is the evaluation stage. The evaluation aims to get the level of accuracy of the system that has been made. Evaluation of the system is done by comparing the suitability of the sensor output with the results displayed by the system. The results of the accuracy of Prototype testing that has been carried out on each test material can be seen in the Table 1.

Table 1. Test Accuracy Results

Test Time (WITA)	Precondition	MQ-2 Smoke Sensor	Temperature Sensor DHT-22	*Flame Detector Sensor*	LED Indicator Light	Evaluation	Conclusion
11.00	• Burn the dry grass • Burn dry twigs • Burn waste paper • Turn on leftover cigarette butts	33.80 ^{o}C 47.90 ^{o}C 50.90 ^{o}C 42.20 ^{o}C	3685.04 PPM 4794.05 PPM 4083.28 PPM 6814.08 PPM	Flame detected Flame detected Flame detected Turns on but not detected	Standby 2 Danger Standby 2 Standby 1	Each sensor can detect well	Corresponding Corresponding Corresponding Corresponding
11.15	• Burn the dry grass • Burn dry twigs • Burning waste paper • Lit up leftover cigarette butts	36.90 ^{o}C 50.00 ^{o}C 37.20 ^{o}C 43.50 ^{o}C	5628.84 PPM 5107.22 PPM 4064.32 PPM 4453.08 PPM	Flame detected Flame detected Flame detected No flame detected	Standby 2 Danger Standby 2 Secure	The fire sensor experienced a one-time detection read error	Corresponding Corresponding Corresponding It is not in accordance with
11.30	• Burn the dry grass • Burn dry twigs • Burning waste paper	37.20 ^{o}C 51.60 ^{o}C 49.40 ^{o}C	4699.61 PPM 5503.21 PPM 3041.06 PPM	Flame detected Flame detected Flame detected	Standby 2 Danger Standby 2	The smoke sensor made a mistake	Corresponding Corresponding It is not in accordance with
Test Time (WITA)	Precondition	MQ-2 Smoke Sensor	Temperature Sensor DHT-22	*Flame Detector Sensor*	LED Indicator Light	Evaluation	Conclusion
11.45	• Burn the dry grass • Burn dry twigs • Burning waste paper • Lit up leftover	39.60 ^{o}C 50.40 ^{o}C 48.70 ^{o}C	4614.27 PPM 5806.74 PPM 3997.95 PPM 5249.56 PPM	Flame detected Flame detected Flame detected Flame detected	Standby 2 Danger Standby 2	Each sensor can detect well	Corresponding Corresponding Corresponding

	cigarette butts	32.60 ^{o}C			Danger		Corresponding
12.00	• Burn the dry grass	47.90 ^{o}C	4632.50 PPM	Flame detected	Standby 2	Each sensor can detect well	Corresponding
	• Burn dry twigs	49.80 ^{o}C	6023.14 PPM	Flame detected	Danger		Corresponding
	• Burning waste paper	48.50 ^{o}C	4248.13 PPM	Flame detected	Danger		Corresponding
	• Lit up leftover cigarette butts	31.40 ^{o}C	6482.21 PPM	No flame detected	Standby 1		Corresponding

In the Table 1, it can be seen that the comparison of the results of all system tests to measure the level of accuracy of the system can be calculated with the following equation:

$$\textit{Classification Accuracy} = \frac{TP}{TP+FN} \times 100\ \% = \frac{18}{20} \times 100\ \% = 90 \quad (1)$$

Information:
• TP (true positive) = indicates a measurement that is classified as correct
• FN (false negative) = indicates unclassified measurement.

So, from the above calculations, it is known that the level of accuracy of the reading of the system is 90%. This result was caused by an error in sensor readings that occurred twice when the test was carried out. The errors that occur are in the MQ-2 sensor and also the flame detector sensor. The error on the MQ-2 sensor occurs due to the wind blowing the smoke from the combustion away from the sensor so that the sensor cannot read the smoke changes that occur, while for the flame detector sensor the error occurs because the coals of residual cigarette butts are too small so that the sensor cannot read the existing flame. So from the above calculation, it is known that the accuracy of the system reading is 90%. This result was caused by an error in sensor readings that occurred twice when the test was carried out. The errors that occur are in the MQ-2 sensor and also the flame detector sensor. The error on the MQ-2 sensor occurs because the wind blows the smoke from the combustion away from the sensor so that the sensor cannot read the smoke changes that occur, while for the flame detector sensor, the error occurs. Because the coals of residual cigarette butts are too small so that the sensor cannot read the existing flame.

4. Conclusion

Prototypes for early detection of forest and wetlands fires have been successfully created using the MQ-2 Smoke sensor, DHT-22 Temperature Sensor, and Flame Detector Sensor based on Arduino Uno Atmega328P. The prototype successfully applies the fuzzy method in its calculations. The prototype created is able to send sensor readings to the Thingspeak website using the ESP8266 module and is able to display data from Thingspeak to an Android smartphone and is able to display pop-up notifications when 2 alert status and danger is detected. The level of accuracy obtained from the readings of the three sensors against the tests that have been carried out is 90%.

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