Performance of fire hotspot detection system with sensor based on angle width and voltage difference monitoring for forest security

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Abstract. Fires that occur naturally in the forest can cause uncontrolled fires due to the rapid spread of heat. This research is focused on the observation land in the Puncak Besar area of Pacet in Pengalengan District, Indonesia, where the area of land burned is approximately 100 hectares. The early warning system that was built in this study uses a range widening method. This method consists of 1 sector that functions to detect heat and initial gas that occurs in the remote area. The initial area of the hotspot is usually not detected by the forest operator. After testing the sensor performance on this device, the fire sensor can detect hotspots with an average range of 440 cm. The width of the detection angle using a shield can reach a range of -45° to 45° and the wide angle of detection of a fire without a shield can reach a range of -90° to 90°. While the communication system on this device uses the GPRS/GSM module to send data to the Android application as a monitoring system. By using this early forest fire detection system, forest operators can monitor the starting point of a fire in remote areas around the forest and minimize the spread of fire points as one solution to overcome the wider spread of forest fires.

Keywords: Android, Microcontroller, GSM/GPRS, Sensor, Fire, Gas

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1. Introduction

The wide and rapid spread of forest fires in Indonesia is caused by the lack of detection of fire starting points in remote areas around the forest. The reason why the starting point of the fire in the remote area is not detected is due to the limited range of the monitoring system owned by the forest operator. Early detection systems for starting fires can accelerate the handling of larger forest fires with a wider area. Handling early detection of a rapid starting point for fire can slow the damage that occurs in the forest. The recovery of natural ecosystems from the effects of fires can also be minimized. Delay in the entry of information when a forest fire occurs makes the area that experienced fire can only be detected after the fire has become large and wide area coverage. Currently, monitoring technology in forest hotspots...
still relies on satellite technology [1-3]. The delay in the information provided by the satellite makes the area of forest fire spread rapidly. The factors causing these natural disasters are not only human negligence but several factors that can affect forest fires, including lightning strikes in dry forests, underground fires in peatland areas and prolonged drought. Usually, the first detected area is the occurrence of a hotspot in an area far from the range of observation. If this happens for a long time and the terrain of forest fires is difficult to reach, then large forest fires are very difficult to avoid. As a solution to the problem, we need a system that is able to analyze and monitor the indications that cause forest and land fires. Previous research has made a device to monitor the situation in the forest but the tool is still using satellites as a monitoring medium [4], it is considered inefficient because it requires a very long time for the information to get back to earth. Then from the existing reference journals, similar tools were also made but without the use of satellites. The tool only uses 2 sensors namely fire sensor and gas sensor and uses computer media as monitoring media, but for computer reliability, it is considered to be less reliable because it cannot be carried anywhere and is not practical [5]. From the existing literature and reference journals, we need to make a tool that can detect the emergence of hotspots early by utilizing a faster and more practical system, which is an Android-based system. The early detection system for forest fires is designed to detect hotspots early on forest land. This system works by using three Detection Sensors which are gas sensors as CO, NO and Hydrocarbon gas detectors then fire sensors as fire detectors, and temperature and humidity sensors to detect humidity and temperature in the air. The three sensors will then be processed by a microcontroller and will send data wirelessly via radio waves to the data transmission center and then will be processed using another microcontroller. Furthermore, the data that has been processed is sent by the Global Packet Radio Service (GPRS) Module to the Web Server and then the data will be sent to the Android application so the Admin can monitor it. This tool is supported by Wireless Technology which is capable of sending data without the need to use cables is expected to be one of the applicative technological developments that can support forest sustainability programs. This website-based monitoring system is able to present data in the form of indications of the condition of hot spots that have the potential for forest fires.

### 2. Early Detection Method of Forest Fire

The method used in this study uses a method of widening the range of hotspot detection. This method works based on certain settings of the three sensors DHT11, MQ-9 and UVtron R2868. The design of this system consists of three parts. The first system is a detection system, this system is placed in the forest. The second system is a processing system, this system is placed in a forest monitoring post and the third system is a monitoring system, this system is an application contained in a mobile phone.

![Overall system design diagram.](image-url)
The system placed in the forest has a role to provide information such as providing data on temperature, humidity, and indications of a fire in the forest. And the second system has a role to receive data from the forest and then tasked to send data to the server to be distributed to the third system, the Android application. The following is picture 1 illustration of the overall system design. The methodology and working pattern of the application of hotspot detection in this study can be seen more clearly in the block diagram as shown in figure.2 below:

![Diagram of the object system hardware block.](image)

The block diagram in this study consists of a series of sensors. The sensor circuit will detect the presence of smoke or flammable gas, fire, temperature and humidity around the data system that will come out of this circuit is in the form of AO or Analog Output data. The analog data is in the form of voltage 0-5 V which represents how much the intensity of combustible gas, fire, temperature and humidity is detected by the sensor. Then the data will be entered into the microcontroller in the form of analog data and will be chopped by the Analog to Digital Converter (ADC) to 1024 the amount of data (0 Th to 1023 data). Then the data from the microcontroller in the form of digital data will be sent into the transmitter module. Radio transmitters utilize radio frequencies in digital data transmission which will then be received by the receiver module and still in digital data. Data from the receiver will enter the microcontroller. The digital data will be sent by the GPRS module to the web server as a data center before being sent to the user.

3. Result and Analysis

Testing in this study was carried out on the method of widening the range carried out by the three sensors. Tests carried out to see the performance between sensors in the detection of hot spots by setting the desired widening range. So that the detection of initial hotspots can be known with a rate of 5 seconds as the aim of this study. The temperature of 45 °C is the setpoint temperature set in the program in the design of this system. If the temperature is detected above the setpoint value, the sensor will send a notification to the user application. Temperature and humidity sensors work according to a
predetermined plan where the higher the temperature the humidity will be lower. In the fire sensor testing, there are two types of testing, namely testing the distance of fire detection without the use of a protector and the use of a protector on this sensor. This test aims to determine the distance of fire detection by the UVTron sensor when it is unshielded. The test is done by placing the fire source in front of the UVTron sensor with different distances between 25 cm-450 cm, taking data based on the indicators on the serial monitor (detected or undetected). The test results are shown in Table 1.

Table 1. Testing of fire detection without protection.

| Testing | Distance (cm) | Voltage (volt) | Testing | Distance (cm) | Voltage (volt) |
|---------|---------------|----------------|---------|---------------|----------------|
| 1       | 25            | 4.93           | 12      | 300           | 3.92           |
| 2       | 50            | 4.81           | 13      | 325           | 3.60           |
| 3       | 75            | 4.70           | 14      | 350           | 3.50           |
| 4       | 100           | 4.69           | 15      | 375           | 3.39           |
| 5       | 125           | 4.63           | 16      | 400           | 3.39           |
| 6       | 150           | 4.57           | 17      | 425           | 3.31           |
| 7       | 175           | 4.48           | 18      | 430           | 3.30           |
| 8       | 200           | 4.42           | 19      | 435           | 3.28           |
| 9       | 225           | 4.39           | 20      | 440           | 3.27           |
| 10      | 250           | 4.04           | 21      | 425           | 0              |
| 11      | 275           | 3.98           | 22      | 450           | 0              |

Analysis of the testing distance fire detection using a shield which is done vertically includes the range of distances from 25 cm to 450 cm. In Table 1 it can be seen that the performance of the fire sensor without a protector can work at a distance of 440 cm. While the sensor using a protective has a performance like Table 2 below:

Table 2. Fire detection testing distance with protectors.

| Testing | Distance (cm) | Voltage (volt) | Testing | Distance (cm) | Voltage (volt) |
|---------|---------------|----------------|---------|---------------|----------------|
| 1       | 25            | 4.90           | 12      | 300           | 3.50           |
| 2       | 50            | 4.74           | 13      | 325           | 3.39           |
| 3       | 75            | 4.80           | 14      | 350           | 3.39           |
| 4       | 100           | 4.70           | 15      | 375           | 3.31           |
| 5       | 125           | 4.63           | 16      | 400           | 3.31           |
| 6       | 150           | 4.39           | 17      | 425           | 3.31           |
| 7       | 175           | 4.04           | 18      | 430           | 3.30           |
| 8       | 200           | 3.98           | 19      | 435           | 3.29           |
| 9       | 225           | 3.92           | 20      | 440           | 3.29           |
| 10      | 250           | 3.60           | 21      | 445           | 0              |
| 11      | 275           | 3.49           | 22      | 450           | 0              |
By using a shielded obtained a distance of 440 cm until the fire sensor can detect the presence of hotspots. Comparison of the performance of this sensor using a protective and without protective seen in fig. 3 below.

**Figure 3.** Comparison graph of test results for fire detection distance without and with protection.

In figure 3 we can see the comparison of the detection distance of fire without protection and with protection, in Figure 3 the response that is seen by using shielded detection has a lower detection distance compared to not using shielded with the same voltage. But at a voltage of 3.30 volts - 3.29 volts the distance to the detection with a shielded has a longer distance, this is because the voltage tends to be unstable. The voltage with this value is the minimum limit of the sensor's performance. Testing of the Wide Angle of Detection of Fire without shield is carried out to find out the maximum angle width that can be detected by the UVTron sensor without using a shield. Testing is done by placing the fire source at certain angles between -90° to 90° with a distance of 25 cm from the UVTron sensor. Figure 4 shows the results of the angular width response produced by the UVtron sensor in this study.

**Figure 4.** Test result graph of wide angle of fire detection without shield.
The response of the UVtron sensor produces a threshold voltage at 4.998 volts for an angle of 0˚, the sensor range reaches -90˚ at a voltage of 3.91 volts to 90˚ at a voltage of 4.1 volts. The maximum angle width that can be detected by the UVTron sensor using a shield. Testing is done by placing the fire source at certain angles between -90˚ to 90˚ with a distance of 25 cm from the UVTron sensor, taking data based on indicators on the serial monitor (detected or undetected). The results of comparison testing of the wide-angle of fire detection without using a shield and using a shield are shown in Figure 5 below.

![Graph comparison of test results for fire detection angle widths without using a shield and using a shield.](image_url)

**Figure 5.** Graph comparison of test results for fire detection angle widths without using a shield and using a shield.

In figure 5 shows the results of a comparison of detection angle width testing if using a shield and without using a shield that can be detected. The difference in angle width between the two methods is 30˚, in the detection using the width detection angle protector is narrower than the detection using no protection. In the detection using a protector has a width of the detection angle from -90˚ to 90 method while the method of not using a protector has an angle width of -60˚ to 60˚.

Figure 6 shows a comparison of the amount of voltage generated when detecting hotspots using a shield and not using a shield. Comparison of an average of 28.77 Volts. Which indicates the voltage on the sensor will be reduced when using a protector compared to the method of detecting not using a protector.
Figure 6. Comparison of voltage differences in the hotspot detection pattern.

In this study conducted communication systems using the website. Figure 7 is the output from the website for the initial hotspot detection information that will be used by the operator. The site that has been built using a specific site address with a display like figure 7 below.

Figure 7. Web server main page display.

On the website menu, the history sent by the detection system is processed in the data processing system. Admin can see history data Id, Date and Time, Temperature, Humidity, CO, and Flame sent to the monitoring system. Display history on the web server can only be seen by the admin (officer) as shown in fig.8 below.

Figure 8. Display history page on web server.
Based on the web server test results, the testing process that has been carried out provides outputs according to the technical requirements that have been made. Web appearance in accordance with the design so that the admin can clearly see the information stored on the web server.

4. Conclusion
The design and realization of a site-based early forest fire detection device have been successfully carried out. Distance testing on the fire sensor is done by using a protective or cover can only detect fire as far as 440 cm and if not using a protective sensor can detect fire as far as 415 cm. Fire sensor testing based on the width of the detection angle using a shield can reach the range of -60° to 60° and the width of the angle of detection of the fire without a shield can reach the range of -90° to 90°. The web server can store information received by the processing system to be sent back to the website application.

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