Journal of Artificial Intelligence and Engineering Applications

Website: https://ioinformatic.org/

June 2026. Vol. 5. No. 3; e-ISSN: 2808-4519

Design of Physical Security System for Server Room Using Esp32-Cam and Ultrasonic Sensor with Automatic Alarm when Motion Detection is Detected (Case Study: Diskominfo Langkat District)

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Abstract

The increasing implementation of Electronic-Based Government Systems (SPBE) requires reliable physical security for server rooms as the center of data storage and processing. However, server room security at the Department of Communication and Informatics (DISKOMINFO) of Langkat Regency is still manually monitored and lacks an automatic detection system. This study aims to design and develop a physical server room security system using ESP32-CAM, an HC-SR04 ultrasonic sensor, a DHT11 temperature sensor, and an automatic buzzer alarm. The research method used is Research and Development (R&D), including system design, hardware and software implementation, and system testing. The developed system is capable of detecting object movement within a range of 5–200 cm, activating an alarm automatically, displaying real-time visual monitoring through ESP32-CAM, and monitoring server room temperature. Testing results indicate that the ultrasonic sensor successfully detects objects within the specified range, the buzzer functions properly as an alarm, the ESP32-CAM provides real-time monitoring through a web browser, and the DHT11 sensor effectively monitors room temperature. Therefore, the system can support physical server room security and improve monitoring effectiveness at DISKOMINFO Langkat Regency.

Keywords: *ESP32-CAM, Ultrasonic Sensor, DHT11, Physical Security System, Server Room, Automatic Alarm*

1. Background

The development of the Electronic-Based Government System (SPBE) requires reliable information technology infrastructure, including the physical security of server rooms as the central facilities for data storage and processing. At the Department of Communication and Informatics (DISKOMINFO) of Langkat Regency, server room monitoring is still conducted manually and is not yet supported by automatic detection systems or real-time visual monitoring, creating potential security and operational risks. Previous studies have utilized ESP32-CAM and ultrasonic sensors for security applications; however, most of them focused solely on object detection or visual monitoring separately. Therefore, this study proposes the design and implementation of a server room physical security system based on ESP32-CAM and an HC-SR04 ultrasonic sensor, equipped with an automatic alarm and temperature monitoring using a DHT11 sensor. The developed system integrates visual monitoring, object detection, alarm notifications, and real-time temperature monitoring into a single platform to enhance the physical security of the server room environment at DISKOMINFO Langkat Regency.

2. Literatur Review

2.1. Design Build

Design and development is the initial stage of system development, beginning with the creation of designs or sketches that represent the functions to be implemented. The design process involves translating system concepts into program code so that they can be technically realized. System development itself refers to the process of creating a new system or improving an existing one to achieve better performance and functionality. Overall, design and development is an integrated process that combines system planning and implementation (Aji Tyo Syahputra et al, 2024).

2.2. Physical Security System

Physical security is an effort to protect information technology infrastructure from unauthorized access, environmental disturbances, and potential equipment failures that may disrupt service continuity. In the context of a server room, physical security includes access control and environmental monitoring, such as the early detection of unauthorized individuals. Poorly managed physical security can lead to system downtime, equipment damage, and the loss of critical data and assets, all of which may directly affect an organization's operational activities (Kautsar et al, 2025).

2.3. Server Room

A server room is one of the essential facilities within an institution that functions as a central hub for data storage and processing, operating continuously 24 hours a day. The server room serves as the backbone of various information system services, including administrative, academic, and other digital services. As the demand for data management and information access continues to increase, the physical condition of the server room must be regularly monitored to ensure that the hardware operates optimally and remains free from disruptions that could lead to operational losses (Maulana et al, 2023).

2.4. ESP32-CAM

ESP32-CAM is a microcontroller module integrated with a camera and Wi-Fi connectivity, allowing it to be used in network-based monitoring systems without requiring complex additional hardware. This module is based on the ESP32 chip, which has data processing capabilities, wireless communication, and image processing integrated into a single board. With its built-in Wi-Fi feature, the ESP32-CAM can directly connect to a local network to display captured images or videos through the TCP/IP protocol. It operates at a voltage of approximately 3.3V and can be programmed using the Arduino IDE, making it easier to develop visual-based security systems (Arrahma & Mukhaiyar, 2023).
The ESP32-CAM Microcontroller specifications are as follows:
1. ESP32 microcontroller.
2. 3.3V operating voltage.
3. Wi-Fi connection.
4. OV2640 camera.
5. Supports programming through the Arduino IDE.
6. GPIO for integration with additional sensors or actuators.
7. Supports TCP/IP communication protocol.
8. Supports web-based video streaming.

2.5. Ultrasonic Sensor

The HC-SR04 ultrasonic sensor is an electronic sensor used to measure the distance of an object by utilizing ultrasonic waves. This sensor works by emitting high-frequency sound waves through the trigger pin and then receiving the reflected waves through the echo pin. Research results show that the ultrasonic sensor is capable of detecting objects quickly and operates stably within a certain distance range according to system requirements (Sudrajat et al, 2025).

2.6. DHT11 Temperature Sensor

The DHT11 temperature sensor is an electronic component used to measure air temperature and humidity in an environment. This sensor is connected to a microcontroller to transmit environmental data in real time via an internet network. The system is capable of continuously monitoring environmental conditions and providing automatic alerts when temperature or humidity exceeds the specified limits. Research results show that the DHT11 sensor is able to provide stable data and helps maintain room conditions within safe operational limits for electronic devices (Wivanius et al, 2025).

2.7. Alarm (Buzzer)

The buzzer (alarm) is an output component that produces a warning sound when the system detects a certain condition. In a server room security system, it functions as an early alarm to provide direct notification when suspicious activity occurs. Based on research published in JITET, the buzzer in an IoT system based on the NodeMCU ESP8266 has been proven to operate automatically and responsively, where it is activated when sensors detect dangerous conditions, simultaneously with the delivery of digital notifications to users (Zulkifli et al, 2024).

3. Design and Analysis

3.1. Research Methodology

Metode yang digunakan dalam penelitian ini adalah metode rancang bangun. Metode ini mencakup beberapa tahapan utama, yaitu:

Figure 1: Research Workflow

3.2. Control System Flowchart

The design of this tool begins with the creation of a flowchart to facilitate the planning and development of the program on the microcontroller. Creating a flowchart is useful for simplifying the understanding of the tool's working process. The program flowchart from this research includes the tool's operational control system, which can be seen in Figure III.2:

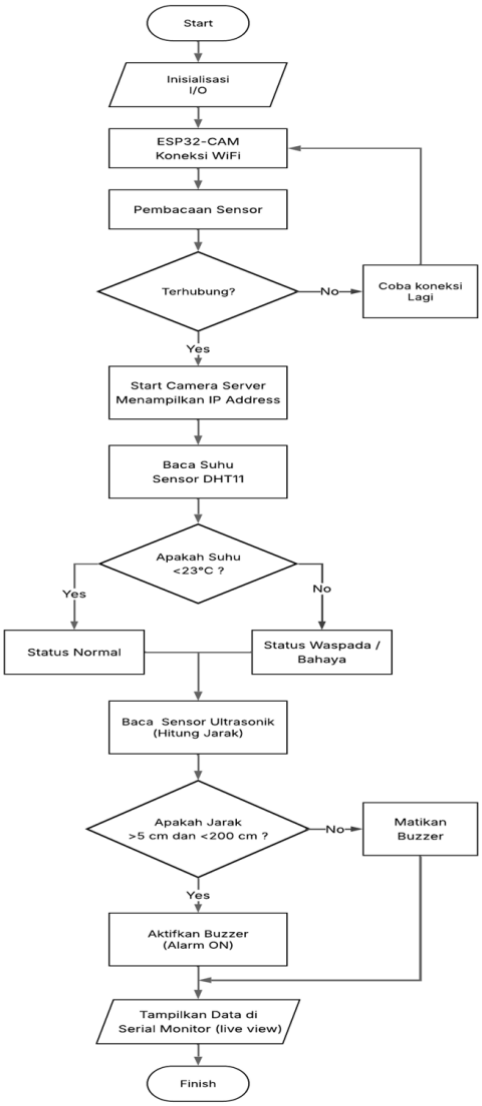

Figure 2: Flowchart Monitoring System

The following is an explanation of the flowchart of this system:

1. Start.
2. Initialize input and output.
3. Connect the ESP32-CAM to the preconfigured WiFi network using the SSID and password specified in the program.
4. Read the ultrasonic sensor and DHT11 sensor.
5. Check the WiFi and sensor connection status. If the device is not successfully connected (NO), the system will continue to reconnect until it is successfully connected. If the connection is successful (YES), the system will proceed to the next process.
6. The system activates the camera server and displays the IP address for accessing the camera through a web browser on the same network.
7. Read the temperature from the DHT11 sensor. If the temperature is <23°C → Normal Status and if the temperature is >23°C → Alert/Danger Status.
8. Read the ultrasonic sensor status to detect object movement in the server room.
9. Object movement detection by the ultrasonic sensor: If the distance is not within the 5 cm – 200 cm range, the sensor does not detect any movement (NO), the buzzer will remain off and the sensor will continue the detection process. Conversely, if the sensor detects movement within the 5 cm – 200 cm range (YES), the system will activate the buzzer as a warning alarm.
10. Activate the buzzer: When the ultrasonic sensor detects object movement, the buzzer will automatically activate as an alarm to provide an immediate warning on the spot.
11. Display the ESP32-CAM live view and room temperature values on the Serial Monitor.
12. Finish.

3.3. Block Diagram Series

Circuit block diagram design is the design of electronic components to achieve the desired function. In general, the design planning for this device is as follows:

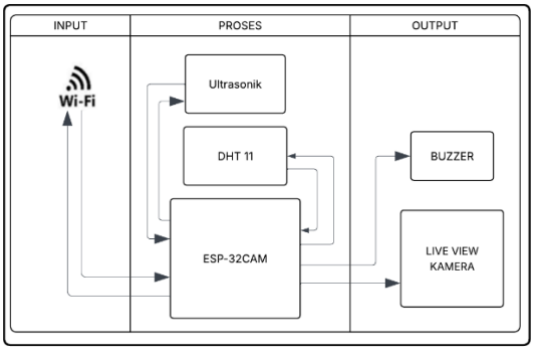

Figure 3: Blok Diagram Series

The block diagram in Figure III.3 illustrates that the first process is connecting the ESP32-CAM to a local WiFi network. Next, the ultrasonic sensor is used to detect objects, while the DHT11 sensor is used to measure the temperature of the server room. The data from both sensors are then transmitted to the ESP32-CAM for processing. The processed data are used to activate the buzzer as an automatic alarm when an object is detected, while the ESP32-CAM camera provides real-time monitoring of the room through a web browser on devices connected to the same network.

3.4. Electronic Circuit Scheme

The electronic circuit schematic uses ESP32-CAM as the main controller that receives data from the HC-SR04 ultrasonic sensor and DHT11 temperature sensor. The ESP32-CAM is connected to a local WiFi network and functions as a web server for real-time monitoring through a browser. The ultrasonic sensor detects object presence, the DHT11 sensor measures room temperature, and the buzzer acts as an alarm output. The following figure illustrates the electronic circuit schematic of the server room physical security system.

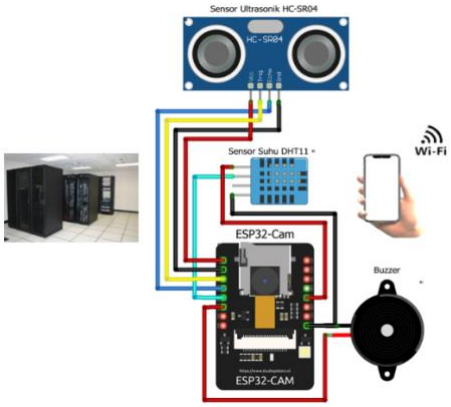

Figure 4: Electronic Circuit Scheme

4. Results and Discussion

In this chapter, the author outlines and explains the research results by conducting tests. The tests to be conducted are software and hardware tests. Here is the explanation

4.1. Software Testing

To conduct the program test, the initial steps in this experiment are as follows:

```
void setup() {
  // put your setup code here, to run once:

}

void loop() {
  // put your main code here, to run repeatedly:

}
```

Figure 5: Initial Display of Arduino IDE

4.2. Hardware Testing

After all the programs are typed, design the hardware as shown in Figure IV.2.

Figure 6: System Hardware Series

Next, the results of the system hardware circuit:

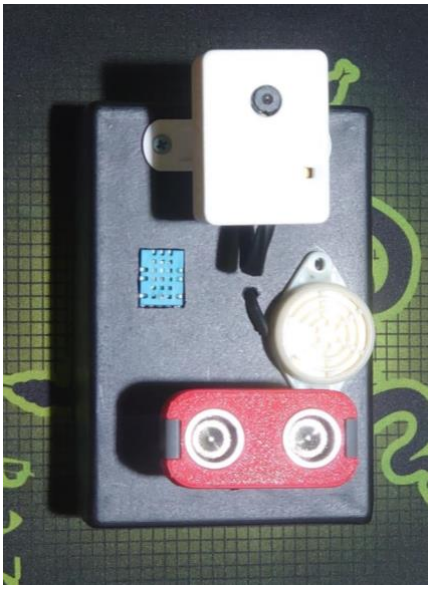

Figure 7: System Hardware Series Results

4.3. Ultrasonic Sensor Testing

Based on test results, the ultrasonic sensor is capable of detecting objects effectively at distances ranging from 5 cm to 200 cm. When an object is within this range, a buzzer automatically activates as a warning alarm.

Table 1: Ultrasonic Sensor Testing

No	Jarak Objek	Status Deteksi	Buzzer
1	3 cm	Tidak Terdeteksi	OFF
2	10 cm	Terdeteksi	ON
3	100 cm	Terdeteksi	ON
4	170 cm	Terdeteksi	ON
5	210 cm	Tidak Terdeteksi	OFF

4.4. DHT11 Sensor Testing

The DHT11 sensor was tested to determine its ability to detect the temperature of the server room. Temperature readings are displayed via the Serial Monitor and a real-time monitoring web page with the results.

Table 2: DHT11 Sensor Testing

No	Suhu (°C)	Status
1	22°C	Normal
2	24°C	Waspada
3	31°C	Bahaya

4.5. System-Wide Testing Implementation

In this whole system test, the notification display and system controls can run and work according to the program design as shown in the image below:

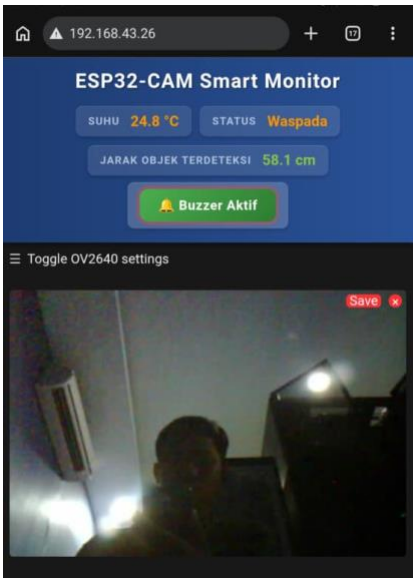

Figure 8: Web Monitoring View

5. Conclusion

Based on the research results, the physical server room security system based on the ESP32-CAM, HC-SR04 ultrasonic sensor, DHT11 sensor, and buzzer was successfully designed and implemented. The system is capable of monitoring server room conditions in real time through a WiFi network by displaying live camera streaming on a web browser. The HC-SR04 ultrasonic sensor can detect object presence within a range of 5–200 cm and automatically activate the buzzer as a warning alarm when an object is detected. In addition, the DHT11 sensor is able to monitor the server room temperature in real time and classify temperature conditions into three categories: Normal (<23°C), Warning (>23°C), and Danger (>30°C). The results indicate that the developed system can enhance the physical security of the server room through integrated visual monitoring, object detection, automatic alarm activation, and temperature monitoring within a single system.

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