

IO T Based Surveillance Robot with Video Streaming and Safety Automation

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Abstract— The Smart IoT Based Surveillance Robot has been developed as a prototype for the monitoring of dangerous areas in an IoT context, which allows remote observation of hazardous places through wireless technology. The system uses the ESP32-CAM, ESP32 Development Board, fire detection sensor, human detection mechanism, DHT11 temperature and humidity sensor, extinguishing mechanism, L298 motor controller, motors, and a low-power laser. The device is controlled by a smartphone connected to the Wi-Fi network of the robot. The ESP32-CAM controls the robot via a web-based interface where the user directs the robot to move in all four directions, activates the laser, and watches the video from the robot. The second ESP32 unit provides the user with the necessary data about the fire situation, presence of people, temperature, and humidity information. When the fire sensor detects some conditions which resemble a fire incident, the monitoring unit can automatically turn on the gas extinguishing device such as a pump with the corresponding extinguishing agent, while simultaneously updating the displayed state. The proposed system integrates robotic technology, embedded systems, wireless technology, video transmission and environmental monitoring features. It is an educational prototype and practical effectiveness depends on calibration, reliability of communication, power control and safety checking.

Index Terms— Automatic Fire Response, DHT11, ESP32-CAM, ESP32, Fire Detection, Human Detection, IoT, L298 Motor Driver, Smart IoT Based Surveillance Robot, Wi-Fi Surveillance.

I. INTRODUCTION

In relation to various industrial sites such as warehouses, laboratories, tunnels, and dangerous areas, when occupied by inspectors, workers are

subjected to hazards like flames, smoke, heat, and the like. Remote surveillance and automating monitoring processes help minimize the need for personnel entering such environment. The Smart Spy Robot is made to be a mobile platform that can be controlled via a smartphone. The ESP32-CAM is utilized to send real-time video streaming, as well as to serve as the web interface for steering the robot and its laser module. The L298 motor controller is responsible for the operation of the robot's four drive wheels due to motor wiring. The separate ESP32 monitoring unit gathers data from the fire detector and DHT11 sensors, as well as from the human detection sensor, and these calculations can be viewed on the monitoring webpage. In case the fire algorithm activates a relevant fire condition, the control unit enables the extinguishing system, but it is conditional on the safety systems being functional.

II. LITERATURE REVIEW

2.1 IoT-Based Monitoring Systems

IoT systems connect sensors, microcontrollers, and user interfaces for remote monitoring. The ESP32 provides Wi-Fi connectivity and GPIO interfaces, making it suitable for low-cost sensing and web-based control applications.

2.2 Mobile Robotic Surveillance

Mobile robots equipped with DC motors and cameras can inspect locations that are difficult or unsafe for people to access directly. A motor driver such as the L298 allows a microcontroller to control DC motor direction. Two bridge channels can control paired

motor groups when electrical and thermal limits are respected.

2.3 Camera-Based Remote Surveillance

Camera-enabled embedded systems can stream images to a remote user through a web interface. The ESP32-CAM offers a compact platform for image capture and wireless video applications, allowing an operator to observe surroundings while controlling the vehicle.

2.4 Fire Detection and Automatic Response

Flame sensors detect optical characteristics associated with flames, depending on sensor type. When a calibrated detection rule is satisfied, a microcontroller can activate a relay-driven pump or another response mechanism. Sunlight, reflections, obstructions, smoke, and sensor orientation can affect detection. Calibration, repeated-sample validation, fault monitoring, and manual override are recommended.

2.5 Temperature and Humidity Monitoring

The DHT11 is a low-cost digital temperature and relative-humidity sensor. Its readings can provide environmental context, but it is not a certified fire detector and should not replace a dedicated fire alarm.

2.6 Research Gap and Motivation

Basic student projects often demonstrate wireless movement, live video, or environmental monitoring separately. This project integrates these functions into one mobile platform using two ESP32 modules, separating camera/vehicle control from environmental monitoring and automatic response

III. PROPOSED SYSTEM

3.1 Robot Control and Video Surveillance

The ESP32-CAM hosts the robot control web page, streams live video, processes movement commands, and switches the laser demonstration output through an appropriate driver circuit. The L298 motor driver controls four DC motors connected in suitable pairs.

3.2 Environmental Monitoring and Fire Response

A separate ESP32 reads the fire sensor, human-detection sensor, and DHT11. It updates the monitoring web page, displays fire and human-presence status, temperature, and humidity, and

activates the extinguishing mechanism when the configured fire condition is confirmed and safety interlocks allow it.

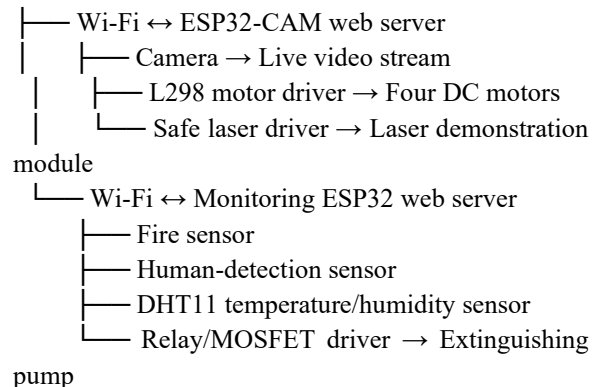
3.3 Major Hardware Components

Component	Function
ESP32-CAM	Robot web server, camera capture and video streaming
ESP32 development board	Sensor acquisition, monitoring server and response logic
L298 motor driver	Controls DC motor direction
Four DC geared motors	Movement of the four-wheel chassis
Fire/flame sensor	Detects a flame-related optical signal
Human-detection sensor	Detects presence according to the chosen sensing method
DHT11	Measures ambient temperature and relative humidity
Relay/MOSFET driver	Switches the pump or suitable actuator
Pump and extinguishing arrangement	Demonstrates extinguishing-agent delivery
Low-power laser module	Controlled laser-pointing demonstration
Battery and regulators	Supply suitable power to controllers, motors and peripherals
Smartphone	Control interface, video display and monitoring

Note: A PIR sensor detects motion from warm bodies but cannot reliably identify a person or detect every stationary person. Vision-based human detection requires suitable image-processing software and computational resources.

3.4 System Architecture

SMARTPHONE / BROWSER



The two web servers may be accessed separately by their respective IP addresses. For a unified dashboard, integrate them using HTTP requests or a lightweight messaging protocol.

3.5 Working Principle

- Power on the robot and monitoring modules and connect them to the designated Wi-Fi network or access points.
- Open the ESP32-CAM web interface on a smartphone.
- Use dedicated controls to move forward, backward, left, right, or stop.
- View live video from the onboard camera.
- Use the separate laser enable/disable control only in a controlled, safe demonstration environment.
- The monitoring ESP32 reads the fire sensor, human-detection sensor, and DHT11.
- The monitoring web page displays fire status, human-presence status, temperature, and humidity.
- When fire logic confirms the configured condition and interlocks allow it, the controller activates the pump.
- The controller updates the status and stops the pump according to the programmed stop condition, timeout, or safe manual override.

IV. METHODOLOGY

4.1. Requirement Analysis

Identify system specifications: wireless mobility, live video feed, environmental sensing, human detection capability, fire detection mechanism, initiation of pump operation automatically, internet operation. Establish hardware connection of the physical components, power consumption specifications, wireless communication area, and general safety requirements.

4.2 Hardware Design

Connect a total of four DC motors to motor controller L298. Connect motor controller outputs to the appropriate GPIOs of ESP32-CAM while paying attention to camera reserve pins and bootstrapping considerations. Connect electrical power supply to the motor controller and motors. Connect the fire sensor, human sensor, and DHT11 to the second ESP32. For

connecting pump, use a proper relay and/or MOSFET driver. Select driver based on specifications of voltage, current, and switching behavior. If high current of the laser is needed, use generator instead of GPIOs.

4.3 Software Development

Using the Arduino IDE and the ESP32 board support package, develop two firmware programmes. The ESP32-CAM firmware should initialize the camera; establish the Wi-Fi connection; initiate the web server and video stream; react to movement instructions; manage the motor driver; turn the laser on or off; and stop the motors if the connection is lost for a certain amount of time. The monitoring ESP32 firmware should perform the following tasks: set up the sensors and drivers; obtain readings from the DHT11; check the fire sensor using the calibrated measuring instrument; check if humans are present; relay information over the internet; turn the pump on if fire conditions are satisfied; and set the timeouts, and deal with fault tolerance problems and manual control.

4.4 Wi-Fi Communication

Both modules are able to connect to a wireless router or to the access point mode. In the event when both modules create access points independently from each other, there is a chance that it would be necessary for the phone to change the Wi-Fi networks. In this situation, it is better to use a single router or a consolidated website.

4.5 Integration and Testing

Test movement, video streaming, laser control, environmental sensing, human detection, and pump activation separately before integration. Verify that Wi-Fi loss stops movement, the laser defaults to OFF, and the pump cannot operate unexpectedly during maintenance or sensor failure.

V. IMPLEMENTATION

5.1 Hardware Implementation

Mount the ESP32-CAM at a suitable height on the four-wheel chassis. Secure the motors and connect them to the motor driver. Mount the sensor and pump controller separately where practical. Use appropriately rated regulators, separate motor and logic supply paths where necessary, suitable common grounding, and decoupling to reduce motor

interference. Important limitation: The L298 has two H-bridge channels and can control four motors when paired appropriately, but each pair must remain within current and thermal limits. Motor starting or stall current may exceed the safe capability of a typical L298 module.

5.2 Software Modules

Module	Implementation
Wi-Fi initialization	Connect to local network or start an access point
Camera initialization	Configure camera and start video stream
Motor control	Set driver inputs according to web commands
Laser control	Switch a dedicated output through a suitable driver
Sensor acquisition	Read fire sensor, human sensor and DHT11
Fire detection	Evaluate readings against calibrated criteria
Automatic response	Activate pump after the fire condition is confirmed
Web interface	Display controls, video, readings and status
Fault management	Use communication timeouts, safe defaults and fault indicators

5.3 Web-Server Interface

Robot control page: live camera video; Forward, Reverse, Left, Right and Stop buttons; and separate laser enable/disable controls. The laser must default to OFF. Monitoring page: temperature in °C; relative humidity in %; fire status; human-presence status; pump status; sensor-fault indicator; and Wi-Fi/connection status. If sensor updates stop, show a stale-data or connection warning rather than leaving old values unmarked.

5.4 Fire Detection and Automatic Extinguishing Logic Start monitoring and read the fire sensor. Evaluate the sensor against a calibrated detection rule, preferably using repeated samples to reduce false triggers. If no fire condition is confirmed, keep the pump OFF, update status, and continue reading sensors. If a fire condition is confirmed, update the alert and check safety interlocks. If the interlocks permit operation, activate the pump and monitor the timeout and stop conditions. Stop the pump according to the configured stop logic and update the monitoring page. If a sensor fault occurs, report the fault rather than treating it as proof that no fire exists. A basic flame sensor does not detect every possible fire or smoke condition. Use a suitable extinguishing agent, maximum run time, manual emergency stop, and controlled testing. Do not rely on this prototype as the only fire-protection system.

5.5 Safety and Reliability Measures

- Stop motors if a valid movement command is not received within a defined timeout.
- Set motor and laser outputs to safe states during startup and reset.
- Use a low-power laser demonstration module with an enclosed beam or safe target; never aim it at eyes, people, animals, vehicles, aircraft, or reflective surfaces.
- Use a properly rated pump driver and fuse, and keep liquids away from exposed electronics.
- Test automatic response using a safe simulated sensor input before using any extinguishing agent.
- Do not test on a live fire or near flammable materials without professional assessment and appropriate supervision.

VI. RESULTS AND DISCUSSION

The following functional tests were carried out on the assembled prototype. All test cases produced the expected results.

6.1 Test Case Verification Table

Test ID	Test case	Procedure	Expected result	Actual result	Status
TC01	Wi-Fi initialization	Power on both ESP32 modules	Both connect or start configured access points	Both modules connected to the Wi-Fi network	Pass
TC02	Forward movement	Press Forward	Robot moves forward	Robot moved forward	Pass
TC03	Reverse movement	Press Reverse	Robot moves backward	Robot moved backward	Pass

TC04	Turning operation	Press Left and Right separately	Robot turns as requested	Robot turned left and right as requested	Pass
TC05	Emergency stop	Press Stop during movement	Motors stop promptly	Motors stopped promptly	Pass
TC06	Camera streaming	Open camera page	Live video appears on smartphone	Live video appeared on the smartphone	Pass
TC07	Laser operation	Enable and disable module	Responds to control; defaults OFF	Laser responded to control and stayed OFF by default	Pass
TC08	Temperature	Read DHT11 in stable conditions	Reasonable agreement with reference	Temperature reading agreed with the reference	Pass
TC09	Humidity	Read DHT11	Relative humidity displayed	Relative humidity was displayed	Pass
TC10	Fire detection	Perform safe sensor test	Status changes according to rule	Fire status changed according to the rule	Pass
TC11	Human detection	Test presence and absence	Status follows sensor behavior	Human-presence status followed the sensor	Pass
TC12	Automatic response	Simulate confirmed fire input	Pump activates if interlocks permit	Pump activated when interlocks permitted	Pass
TC13	Pump timeout	Trigger stop condition or timeout	Pump stops as programmed	Pump stopped as programmed	Pass
TC14	Wi-Fi interruption	Interrupt control connection	Movement stops after timeout; loss indicated	Movement stopped after timeout and connection loss was indicated	Pass
TC15	Sensor fault	Disconnect or simulate sensor failure	Fault indicated; unsafe response prevented	Fault was indicated and unsafe response was prevented	Pass
TC16	Integrated operation	Operate robot while monitoring	Functions operate together without unacceptable interference	All functions operated together without interference	Pass

6.2 Discussion

The design demonstrates integration of remote movement, video surveillance, environmental sensing, and automatic actuation. Separating camera/vehicle control from monitoring reduces the workload on each controller but creates two web addresses unless a unified dashboard is implemented. Reliability depends on Wi-Fi range, motor interference, camera frame rate, sensor positioning, lighting, pump power, and the human-detection method.

monitoring page contains DHT11 temperature and humidity data, fire and presence information.

The fire should be put out using the special controller, with the logic having signaled the fire detection once the conditions are fulfilled. Disadvantages of the system include dependence on Wi-Fi, false positives from sensors, limitations in human detection, battery charging and the electric current supplied.

VII. CONCLUSION

The Smart Spy Robot with Fire Detection, Human Detection and IoT-Based Remote Monitoring is a combination of mobile photography and environmental threat detection. The ESP32-CAM is capable of live video streaming and remote control, and a separate ESP32 microcontroller helps collect sensory data and control fire-detection operations. The robot is a four-wheel robot, whose operation can be controlled using the mobile phone. The robot's web page has sections where it is possible to control the robot and the laser demonstration. The

VIII. SCOPE FOR FUTURE WORK

- Detecting human presence based on AI, which is based on appropriately trained computer vision model.
- Creating integrated mobile dashboard that combines the video feed, controls for movement, sensor data, fire notifications and pump operation status.
- Using emails, push notifications or messages to inform users about detection of fire and different communication problems.

- Finding better fire detection solution that makes use of suitable fire, smoke and temperature sensors.
- Changing L298 to another driver according to the motor stall current parameters.
- Monitoring battery charging and informing about the low battery state.
- Autonomous motion using ultrasonic or time-of-flight distance measuring sensors.
- Authenticity of commands, acknowledgements, timeouts and safety of network set up.
- Registration of events taking place, which are characterized by sensor readings and alarms, pump work and connection failures in place.
- Improved flame extinguishing devices in terms of flow measuring devices and safety interlocks.
- Weather-proof box, better antennas and energy management outside.
- Quantitative optimization based on multiple measurements of delays, control response times, sensor errors, battery life and detection efficiency.

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