International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 10 | Oct - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

STM 32 Based Border Surveillance Rover

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Abstract

Border Surveillance is an important application of Embedded Systems, Robotics, Wireless Communication and Remote Monitoring technologies. Traditional Border Surveillance methods often need people to stay in risky, remote hard-to-reach places all the time. To beat these problems I suggest building a four-wheel Mobile Surveillance Rover that can watch from a distance spot obstacles and gather data about the environment.

The design uses two controllers: an STM32 microcontroller and an ESP32 camera module. I find the STM32 acting as the controller very useful because it handles motor control, obstacle detection with an ultrasonic sensor, GPS reading, Environmental Monitoring and battery voltage measurement. The ESP32 camera module sends video wirelessly so the operator can see the Mobile Surveillance Rover from away. The ESP32 also drives a two-axis pan-and-tilt mechanism with servo motors so the camera can turn left-right and up-down for a view.

The Mobile Surveillance Rover includes a motor driver, a distance sensor, a GPS receiver an environmental sensor the ESP32 camera module, servo motors and a stable power supply. The STM32 talks, to the ESP32 so that movement, sensing and camera work in harmony while each controller handles its job. Early tests of an ESP32 motor control prototype showed that simple movement is possible. Next steps will add STM32 control. Bring all parts together.

The main objective is to build an adaptable Mobile Surveillance Rover that can watch and gather data from hard places. I hope future upgrades could add navigation, object detection, real-time data logging and better wireless communication to make the rover more reliable and powerful.

Keywords: Border Surveillance, STM32, ESP32, Mobile Surveillance Rover, Embedded Systems, Wireless Camera, Obstacle Detection, GPS, Environmental Monitoring, Pan-and-Tilt Mechanism.

1 .INTRODUCTION

Border surveillance plays an important role in maintaining national security and protecting sensitive areas from unauthorized entry. In many border regions, continuous monitoring is difficult due to rough terrain, harsh weather conditions, poor visibility, and the risks faced by security personnel. Traditional surveillance methods often require regular human patrols, which can be time-consuming and challenging, especially in remote or dangerous locations. To overcome these challenges, the use of robotic systems for border monitoring has become a promising solution.

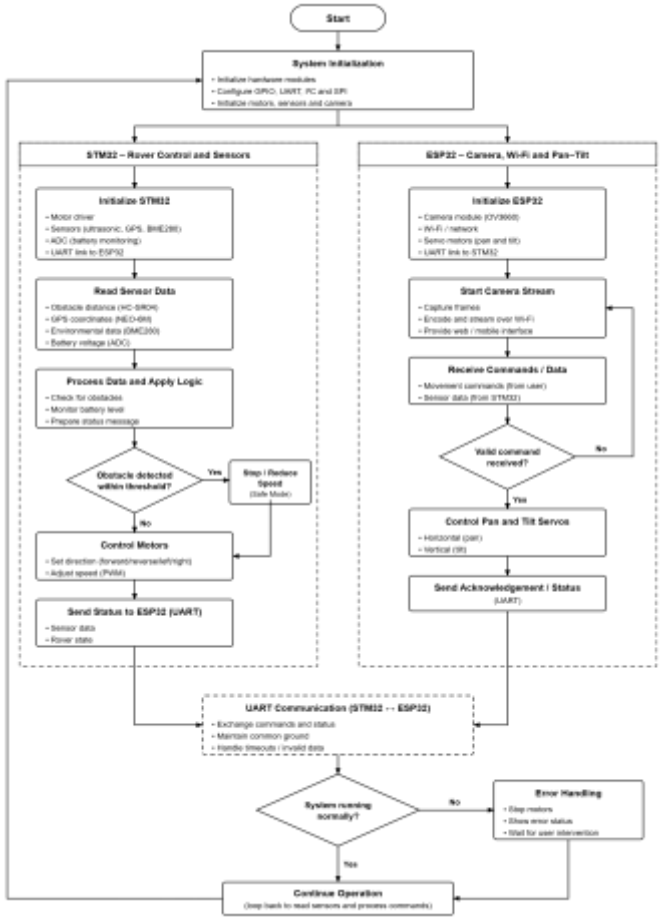
The STM32-based Border Surveillance Rover is designed to provide a smart, efficient, and reliable approach to border monitoring. The system uses an STM32 microcontroller as its main control unit to manage the movement and operation of the rover. The rover can be equipped with sensors and a camera to observe its surroundings, detect nearby obstacles, and assist in identifying unusual activity. Depending on the system configuration, it can be controlled remotely or programmed to perform basic surveillance tasks, reducing the need for continuous human presence in potentially risky areas.

The STM32 microcontroller is a suitable choice for this project because of its fast processing capabilities, low power consumption, and ability to interface with different electronic components. It can coordinate the rover's motors, sensor readings, and other connected modules to ensure smooth and controlled operation. By integrating embedded system technology with a mobile robotic platform, the project aims to develop a practical surveillance solution that can support security personnel in monitoring areas that are difficult to access.

The main objective of this project is to design and develop a cost-effective border surveillance rover that improves monitoring capabilities while reducing the physical effort and risk involved in manual patrolling. The proposed system can serve as a foundation for future improvements, such as wireless video transmission, GPS-based location tracking, night vision, and intelligent motion detection. Overall, the STM32-based Border

Surveillance Rover demonstrates how embedded systems and robotics can be combined to develop a useful security application with the potential to make surveillance safer, more flexible, and more efficient.

2. Flowchart



The system basically begins by booting up its hardware that requires configuring GPIO, UART, I²C and SPI. As soon as that is enabled, the system executes its functions using two processors that run parallel to each other.

The STM32 manages the entire functionality of the rover concerning its movements and its sensing. It sets the distance of obstacles through the HC-SR04, finds position through the NEO-6M GPS and the temperature/humidity through BME280. It also manages the battery charge through ADC. Once it receives the information, it checks if the distance is lesser than its threshold. If yes, then it takes the necessary measures to stop or slow down the motors. Otherwise, it gives a command to its motors to go in the required direction and manage the speed using PWM.

The other processor ESP32 manages camera and wireless. It captures pictures through camera, forwards them using WiFi and makes them visible through web interface. It also receives movement command from the user and the data from STM32. Upon receipt of a valid command, the servos get activated; an acknowledgement is sent back to the STM32. An invalid command is ignored, and the ESP32 resumes streaming. The two controllers exchange information through the UART connection. It has a common ground and deals with erroneous data and timeouts. The last verification of the process has to determine whether the system operation is OK. If so, the cycle starts again from the reading of the sensors; if not, the motors stop, the error message is issued, and the rover awaits the user's response.

3. LITERATURE REVIEW

Robotic surveillance systems have attracted a great deal of attention as a result of the need to effectively monitor remote, restricted, and possibly dangerous areas. Traditional methods of surveillance usually call for a constant human presence and can be limited in both mobility and the area they can cover. An alternative solution is provided by mobile robotic platforms fitted with cameras, sensors, and wireless communication technologies, since they allow operators to keep an eye on the surroundings from a safe distance. There have been a number of studies looking into the use of mobile robots, wireless sensor networks, and embedded systems for surveillance and security applications. Sun and others [1] suggested BorderSense: Border Patrol Through Advanced Wireless Sensor Networks, a hybrid wireless sensor network structure designed for border surveillance. This framework brings together multimedia sensor nodes, ground sensors, underground sensor networks, and mobile sensor nodes in order to enhance border monitoring and the ability to track intrusions. The study points out the limitations of separate surveillance technologies, such as the problem of line-of-sight and the occurrence of false alarms, and stresses the advantages of coordinating multiple sensing technologies. This research forms a basis for appreciating the significance of integrating various monitoring methods in border surveillance applications. A study involving the development of a surveillance robot based on face recognition with the use of a Raspberry Pi and IoT was given in [2]. The system combines a camera, a passive infrared sensor, and IoT-based communication in order to enable remote monitoring and the transmission of images and video. It can be operated via a web interface, which permits an operator to observe the environment under observation from a distance. Even though the system includes intelligent image-processing capabilities, its design also shows the way in which mobile robotic

platforms can be employed for surveillance in industrial and other sensitive environments. The obstacle detection and live video feedback features of a remotely operated mobile robot were studied in [3]. The system is based on an Arduino Mega 2560 microcontroller, an HC-SR04 ultrasonic sensor, and an ESP32-CAM module in order to enable wireless control, proximity sensing, and real-time visual feedback. Their study shows the potential of combining visual monitoring with distance sensing in order to enhance the operator's awareness of the surroundings when operating the robot remotely. Moreover, research into intelligent surveillance robots has investigated the combination of ultrasonic sensors and cameras as means of detecting obstacles and observing the environment [4]. These systems show the value of fusing distance measurements with visual data. Yet the complexity of their implementation, their processing demands, and their performance may differ according to the hardware chosen, the operating environment, and the control method. According to the studies surveyed, combining remote control of movement, live video monitoring, and obstacle detection using sensors is a practical way of developing a mobile surveillance system. Yet a border surveillance application also has to meet the demands of reliable operation, efficient communication, and the capability to monitor areas that are hard for people to reach. For this reason, the paper describes the development of an STM32-based Border Surveillance Rover which incorporates remote movement control, live video monitoring, and ultrasonic obstacle sensing. GPS and temperature and humidity sensors can also be used to aid location tracking and environmental monitoring in cases where these functions are included. The system proposed here is centred on a practical, manually operated prototype designed to help with remote observation and not to replace the current border security facilities.

4. METHODOLOGY

A. System Overview

The Border Surveillance Rover is developed to support remote monitoring of border areas and other locations that are difficult to access. The system uses an STM32 microcontroller for movement control, Wi-Fi communication for remote operation, and an ESP32-CAM module for live video streaming. An ultrasonic sensor measures the distance to nearby objects, while a GPS module and a temperature and humidity sensor provide location and environmental data.

The system combines remote movement control, visual monitoring, and sensor-based data collection. It allows the operator to observe the surrounding area and control the rover from a remote location. The rover operates under manual control and does not use autonomous navigation.

B. Hardware Implementation

The prototype consists of a mobile chassis, STM32 microcontroller, motor driver, DC motors, ESP32-CAM, ultrasonic sensor, GPS module, and temperature and humidity sensor. The STM32 processes the movement commands and sends control signals to the motor driver, which operates the DC motors.

The ESP32-CAM captures video and transmits it through the configured Wi-Fi connection. The ultrasonic sensor measures the distance between the rover and nearby objects. The GPS module provides geographical coordinates, while the environmental sensor measures the surrounding temperature and relative humidity. The components are interconnected using suitable electrical connections and power supplies.

C. Remote Control and Monitoring

The rover is operated remotely through a Wi-Fi-based control interface. The operator sends commands to move the rover forward, backward, left, or right, or to stop its movement. These commands are processed by the control system to operate the motors.

During operation, the ESP32-CAM provides a live video feed to help the operator observe the surroundings. Distance measurements from the ultrasonic sensor, location information from the GPS module, and environmental readings are used as additional monitoring inputs. The operator uses the available video and sensor information to make movement decisions.

D. Software Implementation

The software is developed to manage rover movement, communication, video streaming, and sensor data collection. The STM32 firmware handles movement commands, motor control, and communication with the connected sensors. The ESP32-CAM operates separately to capture and stream live video.

At startup, the controller and connected modules are initialized. Once communication is established, the rover receives movement commands and responds by operating the motors. Meanwhile, the camera provides the video

stream, and the connected sensors supply distance, location, and environmental readings. This process continues throughout operation, enabling remote monitoring and manual control.

E. Testing and Performance Evaluation

The prototype is tested to verify movement control, Wi-Fi communication, video streaming, ultrasonic distance measurement, GPS functionality, and environmental monitoring. Movement tests are conducted by sending different commands and observing the rover's response.

The ultrasonic sensor readings can be compared with actual measured distances to assess measurement accuracy. GPS coordinates and temperature and humidity readings can also be checked against suitable reference sources. The video subsystem is evaluated based on stream availability and image clarity. The system's performance is documented according to the results obtained during practical testing.

F. Summary

The proposed rover integrates an STM32-based movement controller with Wi-Fi remote operation, ESP32-CAM video streaming, ultrasonic distance measurement, GPS tracking, and environmental monitoring. These features provide the operator with visual and sensor-based information for remote surveillance. The prototype relies on manual operation and is intended to assist monitoring in areas where direct observation is challenging.

5. RESULT

The proposed border surveillance system that is based on the use of the STM32-controlled Border Surveillance Rover makes border monitoring simpler and more convenient. It includes the use of an STM32 microcontroller for controlling the movement of the rover, detection of obstacles and surveillance of the surroundings by means of a camera and other sensors. All data can be transmitted to the control station wirelessly.





6. CONCLUSIONS

This is the draft of the poster regarding the proposed design of a four-wheel rover for remote surveillance and monitoring of environment with an STM32 based control system. The proposed system incorporates motor control, obstacle detector, GPS controller, environmental monitoring, camera movement, communication, and power control. A technology allows us to develop and analyze each component individually.
ESP32-based motor-control prototype works and that becomes our first point of migration. The identification of the board and programming are done correctly, and the implementation of the STM32 is verified and the test results are available.

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