

Surveillance Car using ESP32 CAM Module

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Abstract: *Traditional security setups are often held back by their fixed positions and high price tags. To solve this, we developed a budget-friendly, mobile surveillance car powered by the ESP32-CAM module. This system brings together live video streaming and remote-controlled movement, allowing users to keep an eye on things and navigate through different environments in real-time. By using a simple Wi-Fi connection, you can see exactly what the car sees and steers it from a distance through a user-friendly interface.*

What makes this project stand out is how much it packs into such a small, affordable package. Unlike static cameras that have blind spots, this car is designed to be agile—getting into tight or hazardous spaces where a person or a fixed camera can't easily go. Since the ESP32-CAM handles both the high-speed video processing and the motor controls, we were able to keep the hardware simple and the costs low without sacrificing performance.

We also designed the platform with the future in mind. It's modular, meaning you can easily add sensors to detect obstacles or monitor environmental data. Whether it's being used for security patrols in restricted areas, scouting during a disaster response, or even as a hands-on learning tool for robotics students, the system is incredibly versatile. Our tests showed that the video stays stable and the controls remain snappy, proving that effective mobile surveillance doesn't have to be complicated or expensive..

Keywords: *ESP32-CAM, Motor Driver, IoT, Mobile Robotics*

I. INTRODUCTION

Traditional security setups are often held back by their own design. Because they rely on cameras fixed in a single spot, they are expensive to install and leave behind blind spots that are easy to exploit. These systems also struggle in unpredictable or dangerous environments where a static camera simply can't capture the full picture. To bridge this gap, mobile surveillance has become a major focus, offering a way to combine movement with live monitoring for much better flexibility on the ground.

The real game-changer in this field has been the rapid progress of embedded systems and wireless tech. We now have access to tiny, budget-friendly hardware that can handle complex tasks like controlling motors while streaming data at the same time. At the heart of our project is the ESP32-CAM. This clever little module packs a camera, a microcontroller, and Wi-Fi capabilities into one small footprint. It's an ideal brain for a mobile robot because it eliminates the need for extra, bulky hardware, keeping the system lightweight, energy-efficient, and affordable.

The surveillance car we've developed uses this technology to provide a live eye on the ground that can be steered remotely. While a standard camera just sits there, this platform can navigate through disaster zones, industrial sites, or restricted areas that might be too risky for a person to enter. It's designed to be modular, meaning you can easily plug in extra sensors for things like obstacle avoidance or environmental tracking. This makes it more than just a camera on wheels; it's a scalable tool that can be adapted for security patrols, research, or even as an educational kit for students.

Ultimately, this work is about proving that high-tech surveillance doesn't have to be expensive or overly complicated. By focusing on a design that is portable and easy to put together, we've created a system that holds its own in real-world conditions. Our testing shows that the video remains stable and the steering is responsive, demonstrating that



compact embedded systems are more than capable of handling the demands of modern, mobile security. It's a practical step forward in making advanced monitoring accessible to everyone

II. PROBLEM STATEMENT

The problem with most security systems today is that they are stuck in one place. Because they rely on static cameras, they are limited to fixed angles and specific spots, which creates blind spots and makes it hard to track anything moving through a large or unpredictable area. On top of that, setting up and maintaining this kind of traditional infrastructure is often expensive and complicated, putting it out of reach for smaller projects or those on a tight budget.

Even though mobile security options do exist, they often come with their own set of headaches. Many are too bulky, way too expensive, or require specialized hardware that is hard to get a hold of. There is a clear gap for a solution that is small, affordable, and easy to get up and running—something that can stream live video while moving exactly where you need it to go. The real challenge is finding that sweet spot: building a system that is budget-friendly and portable, but still tough enough to be reliable when it counts.

III. LITERATURE SURVEY

Buvana et al. (2019)

Showed that you don't need a huge budget for high-tech security; they successfully combined the ESP32-CAM with motion sensors to create a robot that can patrol and stream video entirely on its own.

Deshpande et al. (2020)

Highlighted how much more flexible these little modules are compared to old-school CCTV, using Wi-Fi and Bluetooth to keep the system affordable and easy to move around.

Barad et al. (2024)

Took the control side of things to the next level by building a smartphone-controlled car that lets users tilt, pan, and zoom their view for much more detailed monitoring.

Kumar et al. (2021) and Rao et al. (2020)

Both proved that these cars can handle tricky environments; they integrated ultrasonic sensors to help the robots dodge obstacles while keeping the video feed steady.

Sharma et al. (2022) and Mehta and Joshi (2021)

Looked at the bigger picture by linking these cars to the cloud, proving that you can store footage and check in on your stream from basically anywhere.

Ali et al. (2022)

Focused on making the technology "user-friendly," designing a simple smartphone interface that makes it easy for anyone—not just engineers—to pick up and use.

Patel et al. (2023)

Added a layer of "smart" tracking by including GPS, so users can see exactly where their surveillance car is on a map while watching the live feed.

IV. PROJECT DESCRIPTION

The goal of this project is to build a smart, mobile surveillance car that uses the ESP32-CAM to bring together video, wireless control, and robotics into one compact package. By using this module as the primary "eyes" of the system, the car can stream live footage over Wi-Fi, allowing it to navigate through changing environments or reach hazardous areas that are otherwise off-limits to people. Because the ESP32-CAM handles both the imaging and the processing, the hardware remains lightweight and efficient.

The car is designed to be steered remotely from a smartphone or a computer, giving the user the ability to manoeuvre the vehicle while watching a live video feed at the same time. We specifically chose the ESP32-CAM because it is small, consumes very little power, and has built-in camera support, making it perfect for a mobile platform. Under the



hood, the system is powered by rechargeable batteries and syncs up motor drivers with a microcontroller to ensure that navigation is smooth and responsive during extended field use.

To keep the design organized and reliable, the system is broken down into four main parts: vision, control, communication, and power. The vision side focuses on capturing and transmitting the footage, while the control side manages the motors to make sure the car moves exactly when you tell it to. Meanwhile, the communication system maintains the wireless "handshake" between the car and the operator, and the power system ensures the whole unit stays portable and ready for action.

What really makes this project stand out is how it offers a high-tech solution without the massive price tag. Unlike old-school security cameras that are bolted to a wall and limited by fixed angles, this car can go wherever it is needed—whether that is scouting a disaster zone, inspecting an industrial site, or acting as a mobile guard for restricted areas. It is built to be affordable and easy to recreate, making it a practical choice for everything from university research to real-world security needs.

V. OBJECTIVE OF SYSTEM

The primary objective of the surveillance car using the ESP32-CAM module is to develop a mobile, low-cost, and efficient platform capable of providing real-time video monitoring in environments where static surveillance systems are inadequate. The system seeks to combine robotic mobility with embedded vision to extend coverage into areas that are inaccessible, hazardous, or require dynamic observation. By leveraging the ESP32-CAM's integrated camera and Wi-Fi capabilities, the project aims to deliver continuous video streaming and remote control through a user-friendly interface, ensuring situational awareness and responsive navigation.

Another key objective is to demonstrate the feasibility of integrating multiple subsystems—vision, control, communication, and power—into a compact and modular design that can be easily replicated and scaled. The system is intended to serve as a practical solution for applications such as perimeter security, disaster response, industrial inspection, and academic research in robotics and IoT. Beyond surveillance, the project emphasizes adaptability, allowing for the incorporation of additional sensors to enable autonomous navigation and obstacle detection. Ultimately, the system is designed to highlight how affordable embedded hardware can be harnessed to create intelligent, mobile surveillance solutions that bridge the gap between conventional CCTV systems and advanced robotic monitoring platforms.

The objective of this system is to create a mobile surveillance platform that leverages embedded vision and wireless connectivity to deliver real-time monitoring in environments where flexibility and mobility are essential. The design focuses on integrating the ESP32-CAM module with a robotic vehicle to enable live video transmission while maintaining remote manoeuvrability. This ensures that users can observe and interact with the monitored space dynamically, rather than relying on static camera installations.

A central goal is to demonstrate how compact, low-cost hardware can be engineered into a scalable solution that balances efficiency, portability, and ease of deployment. The system is intended to provide reliable surveillance in scenarios such as security patrols, emergency response, and industrial inspection, where conventional fixed systems fall short. By emphasizing modularity, the project also seeks to establish a foundation for future enhancements, including autonomous navigation, sensor fusion, and intelligent decision-making. Ultimately, the system aims to showcase the potential of ESP32-CAM-based mobile platforms as practical tools for advancing modern surveillance technology and supporting research in robotics and IoT.

The objective of the surveillance car using the ESP32-CAM module is to design a mobile monitoring platform that combines embedded vision, wireless communication, and robotic mobility to achieve efficient real-time surveillance. The system seeks to overcome the limitations of fixed camera installations by enabling dynamic coverage of areas that require flexible observation, such as restricted zones, industrial sites, or disaster-affected regions. By integrating the ESP32-CAM for continuous video streaming and a microcontroller-based control unit for navigation, the project aims to provide a cost-effective solution that ensures portability, scalability, and ease of deployment.



Another important objective is to establish a modular framework that can be extended with additional sensors for autonomous navigation and obstacle detection, thereby enhancing adaptability for diverse applications. Ultimately, the system is intended to demonstrate how affordable embedded hardware can be harnessed to create intelligent surveillance solutions that support both academic research and practical field operations, while highlighting the potential of mobile robotic platforms in advancing modern security and monitoring technologies.

VI. ADVANTAGES & APPLICATION

Advantages:

Low-Cost Implementation – Uses affordable components, making the system accessible for academic and practical deployment.

Compact and Portable – Lightweight design allows easy transportation and rapid deployment in diverse environments.

Real-Time Video Streaming – Provides continuous monitoring with minimal latency through Wi-Fi connectivity.

Remote Operability – Enables control and observation from smartphones or computers, ensuring user convenience.

Energy Efficiency – Operates on rechargeable batteries, ensuring extended use with minimal power consumption.

Scalable Architecture – Supports integration of additional sensors for enhanced functionality such as obstacle detection.

Ease of Replication – Simple design and readily available components make the system easy to reproduce.

Flexible Coverage – Mobility allows surveillance in areas beyond the reach of static CCTV systems.

User-Friendly Interface – Web-based control ensures intuitive operation without specialized training.

Research Utility – Serves as a practical prototype for studies in robotics, IoT, and embedded vision systems.

Application:

Home Security: It acts like a roving security guard for your house or gated neighbourhood, checking angles that stationary cameras miss.

Schools & Offices: Provides a flexible way to keep campuses and workplaces safe without needing to install dozens of permanent cameras.

Retail & Warehouses: Helps business owners keep an eye on shop floors and large storage areas to prevent theft or track inventory.

Disaster Zones: Can be sent into collapsed buildings or fire-damaged areas to scout for danger or locate survivors when it's too risky for people.

Industrial Checks: Great for inspecting heavy machinery or long pipelines, keeping workers out of potentially hazardous zones.

Traffic Control: An easy way to monitor road conditions and keep traffic flowing smoothly during accidents or construction.

Farming & Agriculture: Allows farmers to check on livestock and crop health across large fields without having to walk the entire perimeter.

Labs & Universities: Serves as a perfect "test-bed" for students and researchers to experiment with new robotics and AI software.

Military Use: Provides a portable, mobile "scout" for reconnaissance, helping teams gather real-time intel in the field.

Big Events: Helps organizers keep track of crowds at concerts or festivals to ensure everyone stays safe and moves efficiently.

VII. RESULT

The implementation of the surveillance car using the ESP32-CAM module produced several notable outcomes that validate the effectiveness of the proposed system.



Smooth Live Video: The ESP32-CAM worked great, sending back a steady, real-time video feed over Wi-Fi with hardly any lag.

Responsive Handling: The car followed every command perfectly through the web dashboard, making it easy to drive and navigate around obstacles.

All-in-One Design: We managed to fit the camera, motors, and battery into one small, lightweight frame without it feeling cluttered or bulky.

Long Battery Life: Because the system doesn't hog power, the rechargeable batteries lasted a long time, so you don't have to keep stopping to charge it.

Easy to Use: You don't need to be a tech expert to run it; the control panel is super intuitive and works right from a web browser.

Solid Connection: The Wi-Fi stayed strong and stable, meaning the car didn't lose touch with the controller even when it drove a fair distance away.

Easy to Upgrade: We proved the design is flexible by adding extra sensors (like ultrasonic ones for obstacle detection) without any issues.

High Value, Low Cost: We built the entire prototype using affordable parts, proving you don't need a massive budget to create a working surveillance tool.

Better Reach: Since the car can move around, it was able to see into corners and hidden spots that a normal wall-mounted camera would miss.

A Great Learning Tool: It really proved its worth as a hands-on project for anyone studying robotics or smart tech, making complex ideas much easier to test.

VIII. FUTURE SCOPE

Looking ahead, there is a world of potential for this ESP32-CAM car to grow from a clever prototype into a high-tech security tool. One of the most exciting next steps is adding "brains" to the system through AI, which would allow the car to recognize specific faces or automatically flag suspicious movement. We could also move toward true independence by adding self-driving features and better obstacle sensors, so the car can scout a building without needing anyone at the steering wheel. To make it even more professional, we could link it to the cloud for remote storage or use "edge computing" to let the car make split-second decisions right on the spot.

Beyond just one car, the future could involve a whole "swarm" of these units working together to cover massive areas from multiple angles at once. We could even plug them into "Smart City" networks so they can share data with other city infrastructure. To keep them running longer, we could look into solar charging or more advanced battery setups, and adding night vision or thermal sensors would make them just as effective in the dark as they are during the day. Of course, as the system gets more advanced, we'd also implement heavy-duty encryption to keep the data safe from hackers. Ultimately, all these upgrades would turn this flexible little robot into a powerful, intelligent, and incredibly secure surveillance solution.

IX. CONCLUSION

Building this ESP32-CAM surveillance car really shows how much you can achieve by combining a camera, Wi-Fi, and a mobile robot into one affordable little package. By giving the camera wheels, we've managed to solve the biggest problem with traditional security cameras—the fact that they're stuck in one spot. This system can go exactly where it's needed, reaching those tricky or dangerous areas that a wall-mounted camera just can't see, all while sending back a live video feed. Its flexible design also means it isn't "finished"; it's built to grow, with plenty of room to add things like self-driving capabilities or smarter sensors down the road.

Beyond just being a handy tool for security or checking out disaster zones, this project serves as a great "launchpad" for anyone interested in the future of robotics and the Internet of Things (IoT). It proves that you don't need a massive budget to create a smart, portable, and easy-to-use surveillance solution. At the end of the day, this prototype is more



than just a cool gadget—it's a clear example of how accessible technology can completely change the way we monitor and protect the world around us.

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