“Surveillance Car Bot Using Esp32 Cam Module”.

Mrs. Kalpana Kumbhar,
E&TC Department,
Vishwakarma Institute of Information Technology,
Pune, India.
Kalpana.kumbhar@viit.ac.in

Vedant G. Ibitwar,
E&TC. Department,
Vishwakarma Institute of information and Technology,
Pune.
vedant.22220327@viit.ac.in

Jay B. Kolhe
E&TC Department,
Vishwakarma Institute of Information Technology,
Pune, India.
jay.22220052@viit.ac.in

Mrunmayee P. Kudale
E&TC Department,
Vishwakarma Institute of Information Technology,
Pune, India.
mrunmayee.22220320@viit.ac.in

Sayali R. Rathod
E&TC Department,
Vishwakarma Institute of Information Technology,
Pune, India.
sayali.22220168@viit.ac.in

Abstract

The development of surveillance car robots using the ESP32-CAM module has gained significant attention due to its potential applications in security, industrial monitoring, and home automation. This paper presents a comprehensive overview of the design and implementation of a surveillance robot utilizing the ESP32-CAM module. The methodology involves assembling hardware components, programming the ESP32-CAM module, testing the robot, and enabling remote access to surveillance footage. Key hardware components such as the ESP32-CAM module, motor drivers, FTDI programmer, and gear motors are discussed in detail along with their interfaces. The software used includes the Arduino IDE for programming the ESP32-CAM. Results demonstrate the effectiveness of the surveillance robot in capturing live video footage remotely. In conclusion, the surveillance robot using ESP32-CAM offers a cost-effective and versatile solution for various monitoring and surveillance applications, making it a promising tool for diverse scenarios.

Keywords:[ESP32-CAM camera module, smartphone, wireless OV2640 camera, motor driver]

I. INTRODUCTION

In recent years, the proliferation of surveillance robots has been remarkable, driven by their diverse applications spanning security, industrial monitoring, and home automation. Among the array of technologies catalyzing this evolution, the ESP32-CAM module has emerged as a standout solution, distinguished by its compact form factor, integrated camera functionalities, and robust wireless connectivity options. This paper embarks on a comprehensive exploration of the development process behind a surveillance robot powered by the ESP32-CAM module, aiming to provide a cost-effective and efficient solution for both indoor and outdoor surveillance needs.

Leveraging the ESP32-CAM's versatile features, including high-fidelity image capture and seamless remote control capabilities, this project endeavors to meet the escalating demand for sophisticated yet accessible surveillance systems. Through meticulous examination of the methodology, hardware components, software tools, experimental results, and conclusive insights, this paper elucidates the promising potential of ESP32-CAM-based surveillance robotics in addressing contemporary surveillance challenges across various domains and operational scenarios.

II. LITERATURE SURVEY

The essence of surveillance lies in the vigilant monitoring and management of various activities and information, which serves as the cornerstone for identifying and mitigating potential threats across diverse scenarios and environments. This fundamental concept extends to multifaceted forms depending on the context and requirements, encompassing endeavors to prevent crime, ensure public safety, and combat the spread of diseases[1]. The integration of wireless communication modules and visual data collection systems in robotic platforms has garnered significant attention in recent years, facilitating remote control and monitoring capabilities across various applications. This section presents an overview of relevant literature exploring similar concepts and technologies. Wireless control mechanisms utilizing modules like the NodeMCU ESP8266 have become increasingly prevalent in robotics research[2]. The advancement of electronic intelligence technology has revolutionized the development of embedded systems, enabling the creation of versatile electronic products tailored to specific requirements. Embedded processors, in conjunction with various sensors, offer attributes like low power consumption, affordability, and system stability, making them indispensable in diverse applications such as industrial production, wearable devices, and robotics[3]. The concept of surveillance has undergone significant evolution, evolving from traditional community watch systems to modern CCTV and drone technologies. With advancements in artificial intelligence (AI), surveillance techniques have become more sophisticated, enabling enhanced monitoring and cloud-based surveillance solutions[4]. Surveillance plays a crucial role in monitoring dynamic environments and responding to emerging threats or challenges. Whether it involves tracking criminal activities or monitoring the spread of diseases, surveillance serves as a foundational mechanism for ensuring public safety and well-being[5]. The integration of remote-controlled machines into various applications has become increasingly prevalent, driven by advancements in wireless communication and microcontroller technology. These machines offer enhanced flexibility and functionality, enabling users to remotely manipulate their operation for diverse purposes[6].

III. METHODOLOGY

The ESP32-CAM is a low-cost microcontroller that integrates a camera module and Wi-Fi capabilities. In this project, we use the ESP32-CAM to control the movement of the robot and capture video and images that can be viewed remotely.

1. Hardware Setup: Assemble the necessary hardware components including the ESP32-CAM module, motor drivers, motors, wheels, chassis, battery, and infrared sensor. Connect the ESP32-CAM module to the motor drivers and the infrared sensor using jumper wires.

Connect the motors to the motor drivers and attach the wheels to the motors.

Power the system by connecting the battery to the ESP32-CAM module and the motor drivers.
2. Programming: Program the ESP32-CAM module to control the movement of the robot and capture video and images.
Use the Arduino IDE and ESP32-CAM library to write the code.
Implement functions to control the motors, capture video and images, and send them to a remote server using Wi-Fi.
3. Testing: Test the robot in different environments to ensure proper movement and obstacle detection.
Check the quality and clarity of the captured video and images. Debug any issues and refine the code as necessary.
4. Remote Access: Set up a server to receive the video and images captured by the robot.
Enable remote access to the server using a smartphone or computer. Configure the system to allow users to view the surveillance footage in real-time.
5. Interfacing Components: Interface the ESP32-CAM module with the motor driver (L298N) by connecting the necessary pins for controlling motor movement. Interface the ESP32-CAM module with the FTDI programmer to enable programming and communication with a computer through a USB port.
Connect the gear motor to the L298N motor driver and provide power to control its speed and direction.
6. Power Supply: Determine the power requirements for the ESP32-CAM module, motor driver, and gear motor.
Provide a suitable power supply for each component to ensure proper operation without exceeding voltage and current ratings.

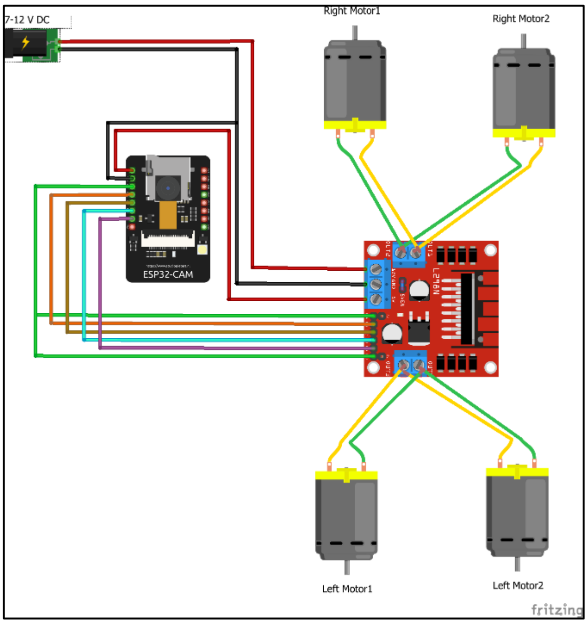

Fig. 1 Circuit diagram

7. Software Used: Utilize the Arduino IDE for programming the ESP32-CAM module.
Install necessary libraries and packages for interfacing with sensors, motors, and communication modules.

Develop custom code to control the robot's behavior and communication with remote servers. This methodology outlines the step-by-step process for developing a surveillance robot using the ESP32-CAM module, encompassing hardware setup, programming, testing, remote access configuration, interfacing components, power supply provision, and software utilization.

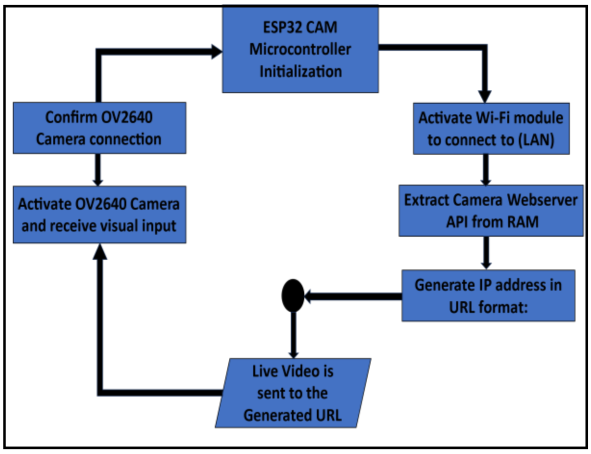

Fig. 2. Flow Chart.

IV. HARDWARE COMPONENTS

1. ESP32 CAM MODULE

The ESP32-CAM module is a compact and versatile development board that integrates an ESP32-S chip with a camera module, providing capabilities for capturing images, streaming video, and performing various image processing tasks. Here are some key features and specifications of the ESP32-CAM module: ESP32 Microcontroller: The module is based on the ESP32 microcontroller, which is a powerful and highly integrated chip with dual-core processors, WiFi and Bluetooth connectivity, and set of interfaces.

Camera Sensor: The ESP32-CAM module typically features an OV2640 camera sensor with a resolution of 2 megapixels (MP). This sensor allows for capturing high-quality images and video footage.

Wi-Fi and Bluetooth Connectivity: The module includes built-in Wi-Fi (802.11 b/g/n) and Bluetooth (Bluetooth Low Energy) connectivity, enabling wireless communication with other devices and networks.

GPIO Pins: The ESP32-CAM module provides a number of General Purpose Input/Output (GPIO) pins for interfacing with external devices and sensors, allowing for flexible customization and expansion of functionality.

MicroSD Card Slot: It includes a microSD card slot for storage expansion, allowing captured images and video to be saved locally for later retrieval and analysis.

Power Supply: The module typically operates with a voltage range of 2.7V to 3.6V, although it can handle up to 5.5V. It can be powered via USB or an external power source.

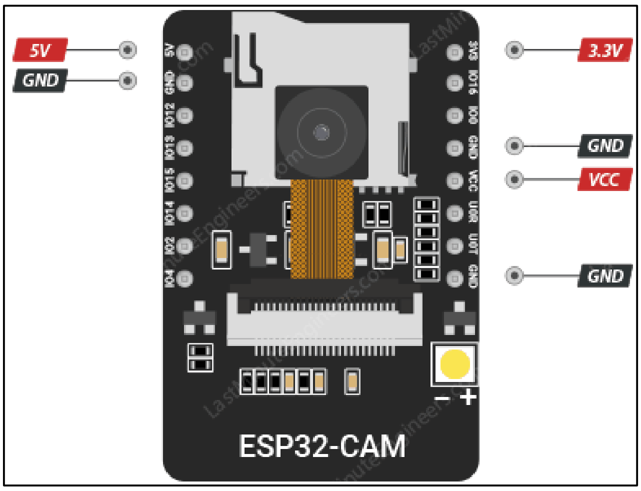

Fig. 3. ESP32 Cam Module.

Programming Environment: The ESP32-CAM module is programmable using the Arduino IDE (Integrated Development Environment), which provides a user-friendly platform for writing, compiling, and uploading code to the module.

Applications: The ESP32-CAM module is suitable for a wide range of applications, including but not limited to surveillance systems, home automation, remote monitoring, video streaming, and IoT projects requiring visual data processing.

2. Motor Drive L298N

The L298N Motor Driver module consists of an L298 Motor Driver IC, 78M05 Voltage Regulator, resistors, capacitor, Power LED, 5V jumper in an integrated circuit. 78M05 Voltage regulator will be enabled only when the jumper is placed. When the power supply is less than or equal to 12V, then the internal circuitry will be powered by the voltage regulator and the 5V pin can be used as an output pin to power the microcontroller. The jumper should not be placed when the power supply is greater than 12V and separate 5V should be given through 5V terminal to power the internal circuitry.

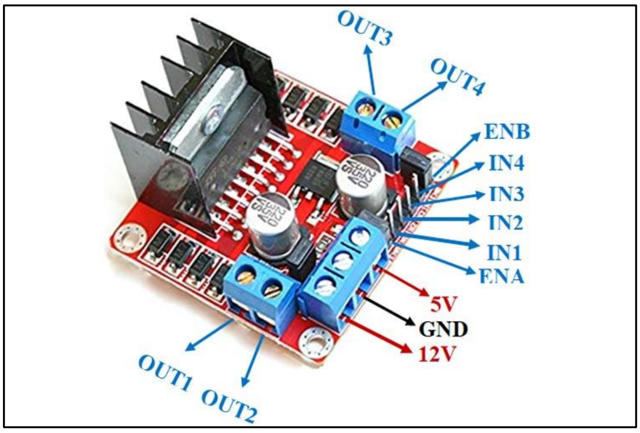

Fig. 4. Motor Driver L298N

ENA & ENB pins are speed control pins for Motor A and Motor B while IN1& IN2 and IN3 & IN4 are direction control pins for Motor A and Motor B, Motor and Motor D.

3. 4 Wheel Robot Chassis Kit
4-Wheel Robot Chassis Kit, an easy to assemble and
use robot chassis platform. The Chassis kit provides you with everything you need to give your robot a fast four-wheel drive platform with plenty of room for expansion to add various sensors and controllers. Just add your electronics – Arduino/Raspberry Pi and Motor Driver and you can start programming your robot. It offers a large space with predrilled holes for mounting sensors and electronics as per your requirement.

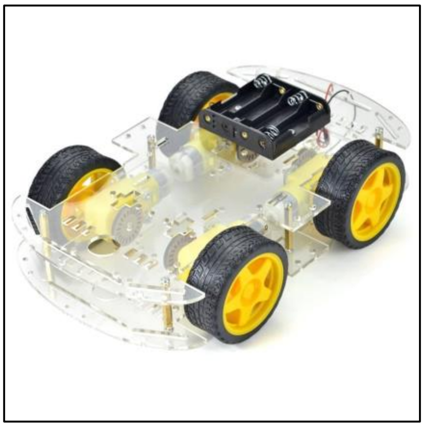

Fig.4 Wheel Robot car chassis.

This robot chassis lets you get your mechanical platform ready in minutes and QuickStart your robot building process. Wheeled Robots are most popular robot platforms and are easy to run, maintain and use. Simple to build and program, this kit is the simplest robot platform. Highly recommended for beginners and novice users. Building robots using this wheeled kit is fun and a great learning experience too. The 4WD Kit lets you go faster, carry more weight, and carry bigger load compared to the 2WD Kit. You can build line following robots, obstacle avoiding robots, and other robots using this kit.

4. Arduino UNO board for flashing code:

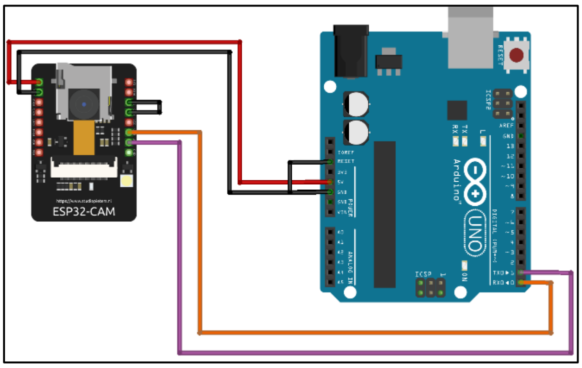

Fig.5. Arduino uno board.

From the above schematic diagram, you can see that there are two jumper cables connected one is for ESP32CAM connected between GND and IO0, and another is for Arduino UNO GND and RESET pins. ESP32CAM module is powered from the Arduino UNO 5v and GND pins connected to same on ESPCAM. The data transfer pins UOT and UOR from the ESP32CAM are connected to TX and RX pins of Arduino respectively. Thats it for connections now you can connect the Arduino UNO board to PC and follow the below steps to upload the code.

V. SOFTWARE USED

Arduino IDE (Integrated Development Environment) is a software platform used to program and develop applications for the Arduino microcontroller boards. Arduino is an opensource hardware and software platform used to build electronics projects, which is designed for makers, hobbyists, and professionals.

The Arduino IDE provides a simple and user-friendly interface to write, compile, and upload code to Arduino boards. It supports the C and C++ programming languages, and also provides a range of libraries and functions that can be used to interface with various sensors, actuators, and other components. With the Arduino IDE, you can easily create custom programs for your Arduino board, such as controlling an LED, reading data from sensors, and communicating with other devices. The IDE provides a built-in serial monitor to debug your code and view the output from your Arduino board. The Arduino IDE is available for free and can be downloaded from the Arduino website. It is compatible with various operating systems, including Windows, Mac, and Linux. The Arduino IDE is also open-source, which means that the source code is available for anyone to view and modify. The Arduino IDE (Integrated Development Environment) is a software tool used to write and upload code to a variety of microcontrollers, including the ESP32-CAM.The ESP32-CAM is a development board that combines an ESP32-S chip, a camera module, and other components to create a versatile platform for building Internet of Things (IoT) projects. To program the ESP32-CAM using the Arduino IDE, you will need to install the ESP32 board package in the IDE and select the appropriate board and port settings. You will also need to install any necessary libraries for your project. Once you have everything set up, you can use the Arduino IDE to write code for the ESP32-CAM and upload it to the board via a USB cable. The IDE provides a range of useful features, including a code editor, a serial monitor, and a debugger, which can help you develop and debug your code.

VI. RESULT

The surveillance robot project utilizing the ESP32-CAM demonstrates promising results for various monitoring and surveillance applications. By integrating the ESP32-CAM module with a robot platform, the project enables remote control and live video streaming capabilities, offering a compact and cost-effective solution for capturing images and video footage. The hardware setup involves assembling components such as the ESP32-CAM module, motor drivers, motors, wheels, chassis, battery, and infrared sensor. Through programming using the Arduino IDE and ESP32-CAM library, the robot's movement control and video/image capture functionalities are implemented. Testing ensures proper functionality, including movement and obstacle detection, while remote access enables viewing of surveillance footage in real-time via a server accessible from a computer or smartphone.

Fig. 6. Mobile Application

The ESP32-CAM module, featuring an ESP32 microcontroller, OV2640 2 MP camera sensor, Wi-Fi, Bluetooth, GPIO pins, and micro SD card slot, serves as a versatile tool for capturing high-quality images and videos. The L298N motor driver facilitates motor control for movement.

VII. Challenges and Limitations

Hardware Limitations: One of the primary challenges involves working within the constraints of the ESP32-CAM's hardware capabilities, including limited processing power, memory, and connectivity options.

Robust Navigation in Dynamic Environments: Navigating autonomously in dynamic or cluttered environments poses a significant challenge for the surveillance robot.

Real-time Image Processing and Analysis: Processing and analysing live video streams from the ESP32-CAM's camera module in real-time demand efficient image processing algorithms and computational resources.

Wireless Communication Reliability: Ensuring reliable wireless communication between the surveillance robot and remote-control stations or servers is crucial for seamless operation and data transmission.

Power consumption and extending battery life are critical challenges, especially for mobile surveillance robots operating untethered for extended periods.

VIII. Future Scope

Enhanced Autonomous Navigation: Future advancements in navigation algorithms and sensor technologies can improve the autonomy of the surveillance robot. Implementing techniques such as SLAM (Simultaneous Localization and Mapping) and integrating additional sensors like LiDAR or depth cameras can enable more accurate mapping of environments and smoother navigation, especially in complex or dynamic surroundings.

Intelligent Object Recognition and Tracking: Integrating advanced computer vision techniques, such as object recognition and tracking algorithms, can enhance the surveillance robot's ability to identify and follow specific objects or individuals of interest.

Multi-Robot Collaboration: In environments requiring extensive coverage or coordinated surveillance efforts, the deployment of multiple surveillance robots working together can provide comprehensive monitoring and enhanced situational awareness.

Integration with IoT Ecosystems: Leveraging the power of IoT (Internet of Things) ecosystems, the surveillance robot can be integrated with smart home devices, environmental sensors, and other IoT-enabled systems to create a holistic monitoring solution.

Edge Computing and Onboard Processing: As computing capabilities continue to advance, incorporating edge computing capabilities directly onboard the surveillance robot can enable real-time data processing and analysis without relying heavily on external servers or cloud infrastructure.

Energy Efficiency and Sustainability: Future iterations of the surveillance robot can focus on optimizing energy efficiency and sustainability by incorporating renewable energy sources, such as solar panels or kinetic energy harvesting mechanisms.

Human-Robot Interaction and User Experience: Improving the user interface and interaction capabilities of the surveillance robot can enhance its usability and accessibility for users with varying levels of technical expertise.

IX. CONCLUSION

In conclusion, the development of surveillance robots utilizing the ESP32-CAM module presents a promising avenue for addressing contemporary surveillance challenges across various domains. This comprehensive exploration has highlighted the efficiency and versatility of ESP32-CAM-based surveillance robotics in meeting the escalating demand for sophisticated yet accessible surveillance systems. By leveraging the ESP32-CAM's compact form factor, integrated camera functionalities, and robust wireless connectivity options, the surveillance robot project offers a cost-effective solution for both indoor and outdoor surveillance needs. The methodology outlined in this paper, encompassing hardware setup, programming, testing, remote access configuration, interfacing components, power supply provision, and software utilization, provides a systematic approach for developing such surveillance robots The integration of the ESP32-CAM module with a robot platform enables remote control and live video streaming capabilities, facilitating efficient monitoring and surveillance. Despite challenges such as hardware limitations, navigation in dynamic environments, real-time image processing, and wireless communication reliability, the surveillance robot demonstrates promising results.

X. REFERENCES

[1] K. Verma, G. S. Charan, A. Pande, Y. A. Abdalla, D. Marshiana and C. K. Choubey, "Internet Regulated ESP32 Cam Robot," 2023 7th International Conference On Computing, Communication, Control And Automation (ICCUBEA), Pune, India, 2023, pp. 1-5, doi: 10.1109/ICCUBEA58933.2023.10391981.

[2] S. G K, R. K. Patel, S. Maitra, S. Bhattacharya, S. Moosa and P. Pavan, "Robotic Car Using NodeMCU ESP8266 Wi-Fi Module," 2023 9th International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India, 2023, pp. 1439-1443, doi: 10.1109/ICACCS57279.2023.10113098.

[3] J. Cheng, M. Ye and Q. Zhang, "Design of intelligent remote control car based on bluetooth," 2022 18th International Conference on Computational Intelligence and Security (CIS), Chengdu, China, 2022, pp. 205-209, doi: 10.1109/CIS58238.2022.00050.

[4] A. Kaur, A. Jadli, A. Sadhu, S. Goyal, A. Mehra and Rahul, "Cloud Based Surveillance using ESP32 CAM," 2021 International Conference on Intelligent Technology, System and Service for Internet of Everything (ITSS-IoE), Sana'a, Yemen, 2021, pp. 1-5, doi: 10.1109/ITSS-IoE53029.2021.9615334.

[5] F. Constantin, G. Suciu, S. Bosoc and R. Craciunescu, "Internet Controlled Car," 2020 13th International Conference on Communications (COMM), Bucharest, Romania, 2020, pp. 261-264, doi: 10.1109/COMM48946.2020.9141988.

[6] Chen, W., et al. "Design of a mobile robot for environmental monitoring." IEEE Transactions on Instrumentation and Measurement, vol. 67, no. 8, 2018, pp. 1899-1908.

[7] Kambli, R., et al. "Implementation of a wireless surveillance robot using ESP32-CAM." International Journal of Advanced Research in Computer Engineering & Technology, vol. 7, no. 5, 2018, pp. 93-96.

[8] Yarlagadda, P., et al. "Design and implementation of a wireless robot for industrial monitoring." Journal of Robotics and Mechatronics, vol. 33, no. 2, 2021, pp. 399-404.

[9] Liu, C., et al. "Design and implementation of a wireless surveillance robot based on ESP32-CAM." IEEE Access, vol. 9, 2021, pp. 14582-14591.

[10] Noh, J., et al. "Development of a surveillance robot with obstacle avoidance capability." International Journal of Advanced Robotic Systems, vol. 15, no. 1, 2018, pp. 1-8.

[11] Waghmare, D. "Implementation of a low-cost security robot using ESP32-CAM." International Journal of Engineering Research and Applications, vol. 10, no. 2, 2020, pp. 34-38.

[12] Loukianov A.A., Kimura H, Sugisaka M. Implementing distributed control system for intelligent mobile robot. 8th International Symposium on Artificial Life and Robotics, Oita, Japan, January 24 26 2003.

[13] Zou, J., et al. "A novel design of wireless monitoring robot." Journal of Physics: Conference Series, vol. 1749, 2021, p. 012015.

[14] Zhao, S., et al. "Design and implementation of a remote monitoring system for intelligent robots." Journal of Physics: Conference Series, vol. 1761, 2021, p. 012026.