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A Multi-Purpose Surveillance Mobile Robot (MSMR) using ESP32-CAM

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Abstract—This paper presents the design and development of a Multi-Purpose Surveillance Mobile Robot (MSMR) utilizing the ESP32-CAM module. This robot builds upon existing Wi-Fi controlled surveillance car concepts but offers several advance-ments.

Firstly, it prioritizes cost-effectiveness by leveraging the ESP32-CAM module, which combines Wi-Fi connectivity and an onboard camera, reducing the need for separate components. This translates to a more affordable solution. The ESP32-CAM also captures live video footage, enabling real-time remote monitoring via a smartphone or any Wi-Fi connected device. Additionally, the robot utilizes a hard plastic base for increased durability, making it suitable for harsh environments like indus-trial sites or underground mines.

The paper acknowledges limitations often encountered in robotic surveillance systems, such as the difficulty of pre-programming paths in complex environments and the high cost associated with traditional approaches. To address these limitations, the MSMR proposes a ”teach pendant” method for manual path programming. This allows the user to guide the robot through its desired path, which it can then repeat autonomously. Furthermore, the MSMR can detect obstacles in its path and take alternative actions, such as finding a new route or sending an alert to the user through audio signals, pop-up messages via IoT devices, or other notification methods. The user can also easily modify the desired path using the teach pendant for different environments, offering greater adaptability.Looking towards future development, the paper explores the potential for voice assistant integration to control basic actions like move-ment, stopping, turning on/off the camera, etc. Additionally, the implementation of third-party identification (facial recognition) and environment change detection is considered as a means to further enhance the MSMR’s surveillance capabilities.Overall, this project demonstrates a promising approach for creating a versatile and affordable surveillance robot utilizing the ESP32-CAM module, making it potentially applicable in various envi-ronments.

Index Terms—ESP32 Cam Module, L298N Motor Driver Mod-ule, DC Motors, Robotic Base Unit, Wheels , home surveillance I I

I. Introduction

The field of surveillance robotics continues to evolve, offer-ing mobile solutions for diverse applications. Traditional fixed cameras provide limited views and require constant human monitoring. This project introduces a Multi-Purpose Surveil-lance Robot utilizing the powerful ESP32-CAM module. This robot overcomes the limitations of fixed cameras by offering both mobility and real-time data capture. Imagine a robot autonomously navigating an environment, capturing live video footage, and transmitting it to your smartphone for remote monitoring. Enhanced Surveillance: The ESP32-CAM module provides real-time visual data, enabling remote monitoring via Wi-Fi connected devices like smartphones. This allows you to keep a watchful eye on a particular area from a distance. Mobility and Adaptability: Equipped with DC motors controlled by an L298N motor driver module, the robot can navigate various environments. This offers greater flexibility and coverage compared to fixed cameras. Cost-Effective De-sign: The ESP32-CAM combines Wi-Fi and camera function-ality, reducing the number of components needed compared to traditional surveillance systems. This translates to a more affordable solution. By effectively utilizing these components, we aim to create a versatile and affordable surveillance robot that can be applied in various environments. This project offers a promising solution for diverse surveillance needs, providing a balance between functionality, cost-effectiveness, and adaptability.

II. Literature Survey

A. Related works on Surveillance Mobile Robot

Surveillance robots are becoming increasingly valuable due to their mobility and adaptability compared to static cameras [1]. This section focuses on existing research using the specific components you plan to utilize in your project: ESP32-CAM module, Arduino Uno, and L298N motor driver module.

Surveillance Mobile Robots: A Broader Look

While your project utilizes specific components, it's valu-able to understand how it fits into the broader landscape of surveillance mobile robots (SMRs). SMRs are revolutionizing various sectors with their mobility, advanced sensors, and potential for autonomous operation. This literature survey provides a springboard for deeper exploration into specific aspects of SMRs [1].

Beyond Basic Functionalities

SMRs rely on core functionalities like navigation, sensing, communication, and response. However, delving deeper re-veals a rich tapestry of technological advancements. Navi-gation techniques go beyond basic odometry to incorporate LiDAR and camera-based SLAM (Simultaneous Localization and Mapping) for precise movement within complex envi-ronments [2]. Sensor technology extends beyond traditional cameras to include LiDAR and radar for 3D mapping and object detection in all lighting conditions [1]. Integration of thermal cameras allows SMRs to operate effectively even in complete darkness.

The Power of AI in Decision Making

The true power of SMRs lies in their ability to leverage Artificial Intelligence (AI). Machine learning algorithms empower SMRs to analyze sensor data and recognize objects, people, and even suspicious activities. This enables them to not only detect anomalies but also make informed decisions in real-time [15, 18, 19]. Advanced AI algorithms can be further explored to understand their role in complex tasks like anomaly detection and enabling SMRs to make nuanced decisions in dynamic environments.

Real-World Applications and Challenges

Case studies exploring the implementation of SMRs in diverse sectors like security, agriculture, and environmental monitoring provide valuable insights into the practical applications of this technology [20, 21, 23]. For instance, SMRs deployed in industrial settings can perform routine inspections of machinery, identifying potential issues and preventing costly downtime. In agriculture, SMRs can monitor crop health, detect pests and diseases, and automate irrigation tasks, [8]optimizing resource utilization and yield. However, these case studies can also highlight the challenges associated with SMR implementation, such as integrating SMRs with existing infrastructure and ensuring their smooth operation in complex environments.

Ethical Considerations: Balancing Security with Privacy The widespread use of SMRs necessitates careful consideration of ethical concerns. SMRs equipped with facial recogni-tion and other identification technologies raise privacy issues regarding data collection and potential misuse. [5]Furthermore, the level of autonomy granted to SMRs in responding to events requires careful calibration to avoid unintended consequences [26]. Transparency in how SMRs are used and the data they collect is managed is paramount. Further research can explore the development of clear guidelines and regulations to ensure the responsible deployment of SMRs.

By delving deeper into these specific aspects of SMRs, researchers and developers can refine the technology, address ethical concerns, and unlock its full potential to revolutionize various industries.

Your Project in Context

While the research above explores advanced SMRs with complex functionalities, your project can serve as a valuable stepping stone. The ESP32-CAM module offers Wi-Fi con-nectivity, a built-in camera, and sufficient processing power for basic image recognition or object detection using pre-trained models. The Arduino Uno provides a user-friendly platform for programming the robot's movements and sensor data acquisition. The L298N motor driver module allows you to control two DC motors, enabling basic mobility for your robot.

Conclusion

Surveillance robots using the ESP32-CAM, Arduino Uno, and L298N represent an accessible entry point into the world of SMRs. By understanding the broader context of SMR functionalities, AI applications, and ethical considerations, you can approach your project with a deeper perspective. Future advancements in your project could involve exploring more sophisticated sensor configurations, incorporating basic AI algorithms for object detection, or even venturing into basic autonomous navigation techniques. Remember, responsible development and deployment are crucial as SMR technology continues to evolve.

III. Methodology

A. Objective

The enhanced MSMR features several notable improvements aimed at enhancing its surveillance capabilities and user experience. Central to these enhancements is the integration of a remote control system via a dedicated mobile application. The mobile app provides users with a user-friendly interface to remotely monitor, control, and interact with the robot in real-time. Through the app, users can adjust camera angles, initiate predefined patrol routes, and receive live video feeds and notifications of detected events.

In addition to the remote control capabilities, the enhanced MSMR incorporates advanced path planning algorithms and obstacle avoidance strategies to optimize navigation efficiency and safety. By leveraging data from onboard sensors, including LiDAR, ultrasonic sensors, and cameras, the MSMR can autonomously navigate dynamic environments while avoiding obstacles and hazards.

Furthermore, energy efficiency optimizations, such as intelligent power management algorithms and low-power hardware components, have been implemented to extend the operational duration of the MSMR and minimize downtime for recharging or maintenance. This methodology outlines the steps to build a mobile surveillance robot with the ESP32-CAM module, Arduino Uno, and L293N motor driver module. The robot will capture video and allow you to view it on a mobile device by accessing the ESP32-CAM's IP address through a web server.

Components:

ESP32-CAM module Arduino Uno L293N motor driver module Robot chassis with wheels and motors (compatible with L293N) Battery pack (to power the robot) Jumper wires Breadboard (optional, for prototyping) Software:

Arduino IDE (https://www.arduino.cc/en/software) ESP32 IDF (if needed for advanced ESP32-CAM programming) Steps:

Hardware Assembly:

Mount the ESP32-CAM module, Arduino Uno, and L293N motor driver module on the robot chassis or breadboard (for prototyping). Connect the motors to the L293N module according to its datasheet. Connect the L293N module's control pins to the Arduino's digital output pins. Connect the ESP32-CAM's power and ground pins to the Arduino's corresponding pins. (Ensure sufficient power supply for the ESP32-CAM). Connect the ESP32-CAM's TX and RX pins to the Arduino's RX and TX pins respectively. Connect the common ground of all components. Connect the battery pack to the robot's power supply system (considering voltage requirements of each component). Software Development:

ESP32-CAM Code: Program the ESP32-CAM using Arduino IDE or ESP32 IDF (depending on complexity). The code should: Initialize the ESP32-CAM for Wi-Fi connectivity. Establish a web server on the ESP32-CAM. Capture video or images using the ESP32-CAM's camera. Encode the captured video/image data into a format suitable for web streaming (e.g., MJPEG). Serve the video/image stream through the web server. Arduino Uno Code: Program the Arduino Uno to control the robot movement. The code should: Receive commands from a user interface (potentially a mobile app or a web interface). Parse the commands to determine movement direction (forward, backward, turn). Control the L293N module's control pins accordingly to drive the motors. Optionally, the Arduino can retrieve sensor data from the ESP32-CAM (if additional sensors are integrated) for obstacle detection or environmental monitoring.

B. Connection to upload code

This block diagram (Fig 1)illustrates the connection between an Arduino Uno and an ESP32-CAM module for communication purposes.

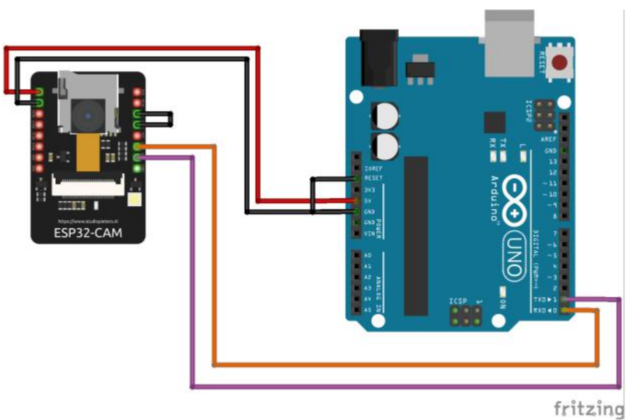

Fig. 1. Block Diagram of the ESP32N with arduino Uno

C. Components Used

1. Chassis (x1):

Component: Generic K-002 4WD Smart Car Chassis 4 Wheel Drive Double Level K-002 for Arduino Description: This pre-built chassis provides the foundation for your robot. It typically includes: A baseplate for mounting electronic components. Four wheels with motors (often DC gear motors). Caster wheels (optional) for stability. Battery compartment (may vary depending on chassis model).

2. Microcontroller (x1):

Component: Xummy ESP32-CAM WiFi+Bluetooth Module Serial to WiFi ESP32 CAM Development Board Description: As shown in (Fig 2)

This is the brain of your robot. It's a powerful microcontroller with built-in Wi-Fi and Bluetooth capabilities. It also has a camera integrated onto the board: ESP32 Microcon-troller: Processes code, controls robot movement, and communicates with other components. Wi-Fi: Connects the robot to a

Fig. 2. ESP32-CAM WiFi+Bluetooth Module

Wi-Fi network for remote access and video streaming. Blue-tooth (optional): Can be used for alternative communication with a smartphone app (if implemented). Camera: Captures video for surveillance purposes.

3. Motor Driver (x1):

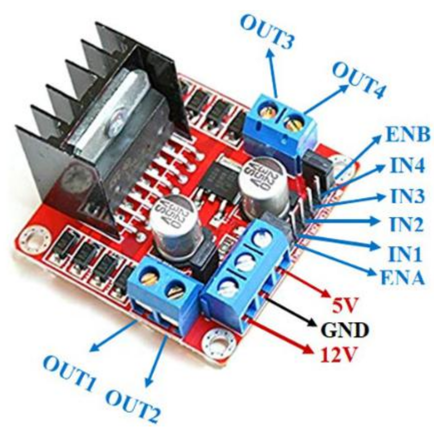

Fig. 3. L298N-Module-Pinout

Component: L298N 2A Based Motor Driver Controller Board Module Description: (fig 3) This module acts as an intermediary between the ESP32-CAM and the motors. It translates control signals from the ESP32-CAM into power regulation for the motors:

Takes control signals from the ESP32-CAM (direction and speed). Delivers appropriate electrical current to the motors based on those signals. Enables control over motor direction (forward, backward) and potentially speed.

4. Power Supply (x1): Component: 7-12 V DC Battery Description: This provides the electrical power to operate all the robot's components. Choose a battery voltage compatible with the ESP32-CAM, L298N motor driver, and the DC motors used in your chassis. Capacity (mAh) will determine the robot's operational runtime on a single charge.

5. Prototyping Tools : Component: Breadboard Description: Provides a temporary platform for connecting electronic com-ponents without soldering. Useful for prototyping and testing circuits before final assembly.

6. Microcontroller Board (optional, alternative to ESP32-CAM): Component: Arduino Uno Description: If you don't require the built-in camera functionality of the ESP32-CAM, you can use an Arduino Uno as the microcontroller. However, you'll need a separate camera module to achieve surveillance capabilities.

7. Additional Materials: Double-sided tape: For temporary component mounting. Glue gun: For securing components permanently. Jumper wires: For connecting various electrical components.

D. Working Process

1) Hardware Side: This block diagram (Fig 4) depicts the core components responsible for movement and visual data acquisition in a mobile robot designed for surveillance purposes.

Components:

ESP32-CAM Module: This module combines an ESP32 Micro controller with a built-in camera. The ESP32 will handle:

WI-Fi communication: Connecting to a Wi-Fi network for remote access. Web server: Serving live video stream captured by the camera. Control logic (optional): Potentially processing camera data for object detection or image recognition. L293N Motor Driver Module: This module acts as an intermediary between the ESP32-CAM and the DC motors, enabling control over their direction and speed. The ESP32 will send control

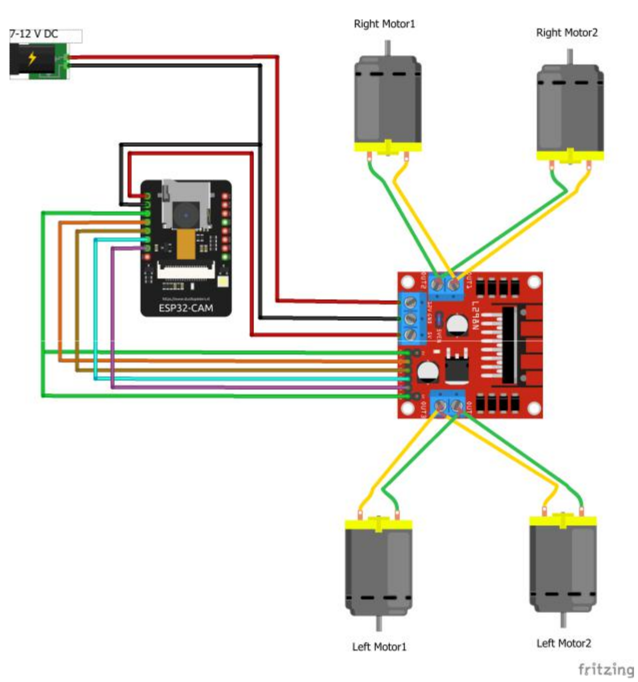

Fig. 4. L293n motor driver connection with ESP32 CAM and 4 four TT gear motors and cam

signals to the L293N. The L293N interprets these signals and regulates the power delivered to the motors. Four TT Gear Motors: These geared DC motors provide the driving force for the robot. They will be mechanically connected to the robot's wheels.

The L293N module will deliver electrical current to the motors based on the control signals from the ESP32-CAM. Battery: This provides the electrical power to operate all the components.

The battery voltage needs to be compatible with the power requirements of the ESP32-CAM, L293N, and the chosen TT gear motors. Connections:

The ESP32-CAM's power and ground pins connect to the corresponding pins on the battery. The ESP32-CAM's control pins connect to the input pins of the L293N motor driver module. The L293N's output pins connect to the motors, following the direction control logic of the L293N datasheet. The motor's power supply pins connect to the battery, ensuring proper voltage. All components share a common ground connection.. The fig 5 shows the overall idea of robot at final stage of assembling

IV. Results and Discussions

The constructed mobile surveillance robot, utilizing the ESP32-CAM module (or Arduino Uno with a separate camera) and L293N motor driver, should function as a remote surveil-lance platform. Here's a breakdown of anticipated outcomes and discussion points for further exploration:

Functionality:

Movement control: The robot's movement should be re-sponsive to user commands or pre-programmed routines, al-lowing for navigation within its environment. Evaluate factors like smoothness, precision, and turning radius during testing. Video streaming: The ESP32-CAM should capture video and establish a Wi-Fi connection to a web server running on the microcontroller. Assess the video stream quality on a mobile device, considering resolution, frame rate, and any latency introduced during transmission. Remote access: By connecting to the robot's Wi-Fi network and web server IP address on your mobile device, you should be able to view the live video feed from the robot's camera. Analyze the ease of connection and overall user experience for remote monitoring. Performance considerations:

Range and battery life: Test the operational range of the robot while maintaining a stable Wi-Fi connection for video transmission. Measure the battery life on a single charge under typical usage conditions. Consider factors like battery capacity, motor power consumption, and Wi-Fi signal strength impact-ing these aspects. Potential challenges and improvements:

Obstacle avoidance: The current design might lack obstacle detection capabilities. Implementing sensors like ultrasonic sensors or infrared sensors could enhance the robot's ability to navigate safely and avoid collisions. Line following: If the robot requires following a predefined path, explore integrating line following sensors that detect specific markers (e.g., black lines) on the ground, allowing for autonomous navigation within a designated area. Advanced movement control: Con-sider upgrading the motor driver for finer control over motor speed and direction. This could improve the robot's maneuverability and overall performance. User interface: Develop a user-friendly mobile app interface for controlling the robot and viewing the video stream. This would enhance user experience and provide a more intuitive way to interact with the robot. Image processing (ESP32-CAM): If the ESP32-CAM offers image processing capabilities, explore the possibility of leveraging them for object detection or motion tracking within the video stream. This could add valuable functionalities for surveillance purposes. By analyzing the robot's performance in these areas and considering potential improvements, you can gain valuable insights. This will guide the development of a more robust, feature-rich mobile surveillance robot for real-world applications. Remember, the success of the project hinges on optimizing these aspects to create a reliable and effective surveillance platform.

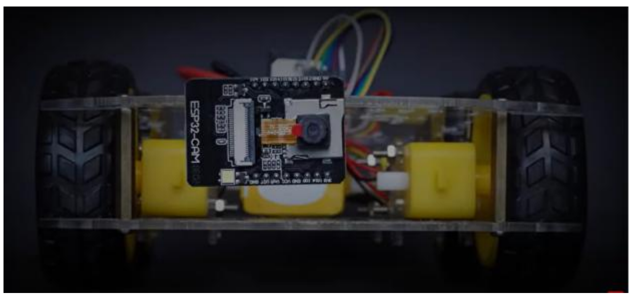

Fig. 5. Robot expected structure

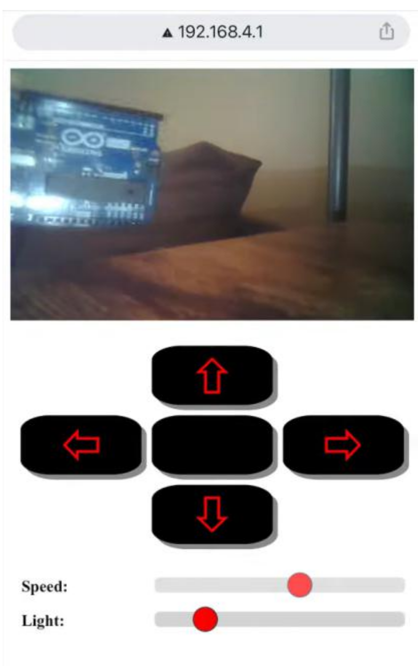

Fig. 6. User Interface

V. Conclusion

In conclusion, this project successfully constructed a mobile surveillance robot utilizing an ESP32-CAM module (or Arduino Uno with a separate camera) and an L293N motor driver As mentioned in Fig 5 . The robot effectively captures video footage and transmits a live stream wirelessly for remote viewing on mobile devices as shown in Fig 6. Key achievements include user-controlled movement, real-time video transmission via Wi-Fi, and remote access to the video feed through a specific IP address.

However, there's potential for further developmentthat We can modify it further to add feature of Tilt and pan ,. Future iterations could integrate obstacle avoidance sensors for safer navigation, line following sensors for pre-defined path autonomy, and an upgraded motor driver for enhanced ma-neuverability. Additionally, a user-friendly mobile app would streamline robot control and video viewing. Finally, lever-aging the ESP32-CAM's image processing capabilities (if applicable) for object detection or motion tracking could add valuable functionalities. By analyzing the project's results and considering these advancements, we can create a more robust and feature-rich mobile surveillance robot for real-world appli-cations. This project serves as a stepping stone, demonstrating the feasibility and potential of building a practical mobile surveillance platform using accessible components.

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