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Surveillance Robotic Vehicle

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Abstract: This paper introduces an advanced robotic surveillance system that enhances monitoring across sensitive, restricted public areas.The robot is integrated with a wireless camera capable of capturing live video during both daytime and nighttime conditions. It can be remotely operated through a mobile application using an ESP Wi-Fi module, ensuring smooth communication between the robot and an Android device.

The system utilizes the Blynk application to control the robot's movements based on commands sent from the Android phone. By minimizing direct human involvement, this approach ensures continuous observation and security in dangerous environments.The main objective of the project is to develop a smart spy robotic vehicle capable of providing continuous surveillance in challenging locations while transmitting live video feeds in real time.

Additionally, the robot is designed to recognize and monitor different human activities through live video streaming. The Android application enables users to control the robot remotely over a significant distance using Wi-Fi connectivity, offering flexibility and ease of operation.

The project also has strong potential for future development in sectors such as defines , military surveillance, and mining industries. With further improvements, the robotic system could play an important role in enhancing security operations, monitoring hazardous areas, and reducing risks to human personnel.

I. INTRODUCTION

The integration of wireless communication technology with camera-based systems has significantly improved the capabilities of modern robotics and surveillance applications. To enable remote navigation and intelligent surveillance, this research develops a robotic vehicle integrated with an ESP8266 Wi-Fi module, an embedded camera, and a dedicated Android applicationand real-time video streaming. The system is also designed to identify different human activities, including walking, conversing, and falling.

The primary objective of this project is to monitor human presence and activities in areas where direct human supervision is difficult or unsafe. A major feature of the system is the ESP8266 module, which provides reliable Wi-Fi connectivity and enables uninterrupted communication between the robotic vehicle, the operator, and the monitored environment. This wireless connection ensures efficient remote operation and live data transmission.

Several modern systems have been introduced to address limitations in activity monitoring, particularly those that rely on wearable sensors. Although sensor-based methods can accurately detect human activities, they often involve expensive equipment and require users to wear sensors continuously, which may reduce convenience and practicality.

To address these challenges, the proposed approach applies machine learning algorithms along with cross-validation techniques to recognize activities such as walking, chatting, and eating without the use of wearable devices or additional hardware attachments. By relying on video-based analysis instead of physical sensors, the system offers a cost-effective and user-friendly solution. The main aim of this work is to develop an accurate and efficient model for human activity recognition in surveillance environments.

II. METHODOLOGY

The block diagram (Fig.1) of the proposed system illustrates the major hardware and software components along with their functional connections. Movement and system coordination of the robotic vehicle are handled by the ESP8266 module, which serves as the primary controller.The Blynk mobile application serves as a control platform, allowing users to remotely interact with the robot and regulate its speed and direction..

Vehicle movement is achieved using DC motors connected to an L293D motor driver. The motor driver ensures efficient and accurate control of the motors, allowing the robotic vehicle to move smoothly in different directions. These motors function similarly to wheels in an automobile, enabling navigation across various environments.

A camera module is incorporated as the key sensing component of the system. It captures real-time video footage from the surroundings and sends the data to a Raspberry Pi for further processing.

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The Raspberry Pi performs image preprocessing and feature extraction techniques, which are essential for recognizing and analysing human activities.To enable visual observation of detected activities, the system displays the final processed results on a computer screen.

To maintain stable system performance, the Raspberry Pi and ESP8266 module are powered using a regulated 5V power supply. At the same time, the four DC motors operate with support from a 12V battery source, providing sufficient energy for continuous vehicle motion. Overall, the proposed design effectively combines multiple hardware and software technologies to create a reliable surveillance and real-time human activity recognition system suitable for practical applications.

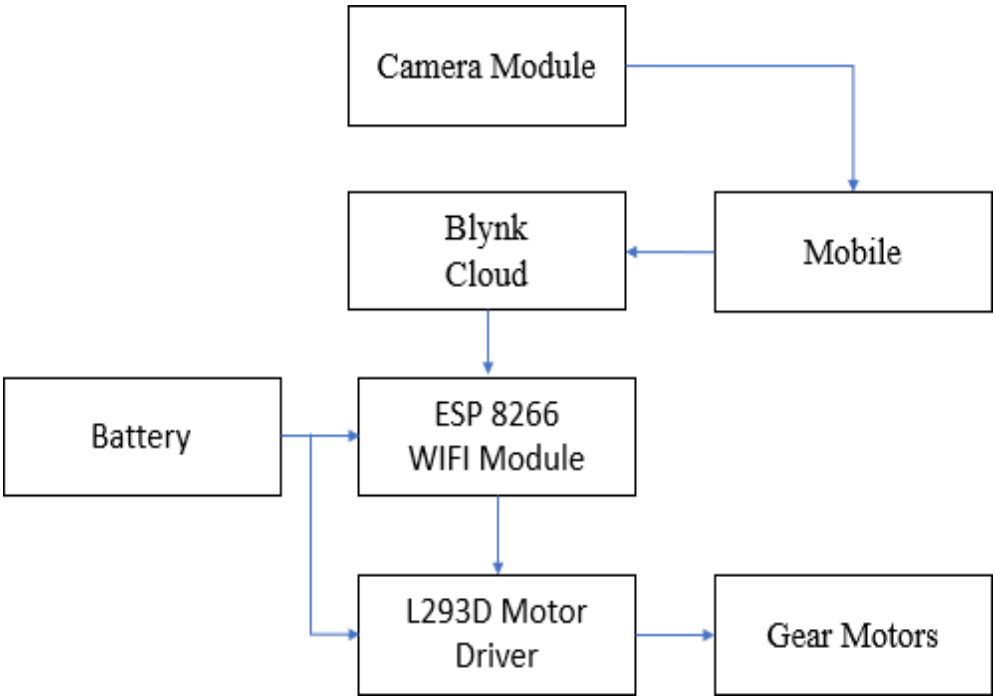


Fig.1 System block diagrams.

III. LITERATURE SURVEY

The project holds promise for future advancements; specifically, the robot's ability to distinguish between different human activities could extend its applications to the defense and mining sectors.

1) The study by T. Akilan presents an IoT-driven spying robot managed by an Arduino UNO and controlled via PC and smartphone [1]

2) Patoliya, Jignesh, Haard Mehta, and Hitesh Patel introduces objective behind developing this robot is for the surveillance of human activities in the war field or border regions in order to reduce infiltrations from the enemy side [2]

3) Shah, Mohammad Shoeb, and P. B. Borole: Presents the four-wheeled robot is designed to be driven both manually and autonomously [3]

4) R. Bhardwaj, S. Kumar, and S. C. Gupta, Human activity recognition in real world: To accurately classify daily human movements in real-world environments to support healthcare monitoring, fitness tracking, and ambient assisted living [4]

IV. RESULT

The final outcomes of the project demonstrate that the proposed system successfully achieved its intended objectives. The implementation of computer vision techniques and machine learning algorithms enabled the system to accurately identify and classify various human activities. The model effectively distinguishes between actions such as walking, talking, and falling, highlighting the reliability and efficiency of the technologies used in the project.

The high level of activity recognition accuracy improves the system's capability to differentiate among multiple human behaviours in real-time environments.

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In addition, the smooth integration of hardware components including the ESP8266 module, high-resolution camera, and motor mechanisms shows that the overall system operates efficiently as a unified platform.

The results also indicate that the developed system has strong potential for real-world applications, especially in surveillance and monitoring environments where precise human activity detection is important. The successful coordination between software and hardware components confirms the practicality and effectiveness of the proposed surveillance robotic system.

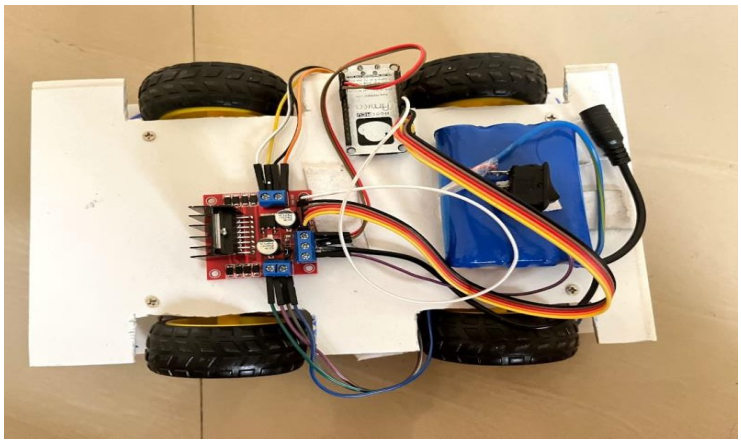


Fig. 2 ActualImplementation

System Accuracy Metric Comparison

System Domain	Component Pipeline	Core Metric Evaluated	Expected/Target Accuracy Range	Factors Influencing Accuracy
Motion Command Execution	Blynk App--> Wi-Fi ESP8266	Command Delivery Rate (Latency & Packet Loss)	98.5% – 99.9% (Highly reliable under local Wi-Fi)	Wi-Fi signal strength, local network congestion, and Blynk Cloud server stability.
Physical Locomotion	L293D Driver --> 360° DC Motors	Positional / Tracking Precision (Slippage error)	85% – 95% (Prone to drifting over long durations)	Motor voltage consistency, surface friction/slippage, and lack of closed-loop feedback (e.g., encoders).
Video Stream	Camera Module	Frame Retention Rate (FPS stability)	95% – 99% (At 24–30 FPS, depending on resolution)	Processing overhead on the bandwidth (CSI vs. USB), and ambient lighting conditions.
Activity Recognition Processing	Image Processing Engine	Classification Accuracy (Precision, Recall, F1-Score)	75% – 92% (Highly dependent on the deployed ML architecture)	Complexity of the computer vision model (e.g., MobileNet-SSD), resolution, and dataset variation.

Accuracy Comparison of DifferentAlgorithms Used:

	Accuracy	Precision	Recall	Score
RandomForest Classifier	71.20	72.5	71.19	71.71
KNeighbors Classifier	68.69	72.16	68.69	69.90
DecisionTree Classifier	71.19	70.39	71.19	70.66

The ReceiverOperatingCharacteristics (ROC) curve, a graph that displays the classifier's performance, is displayed below (Fig.3).

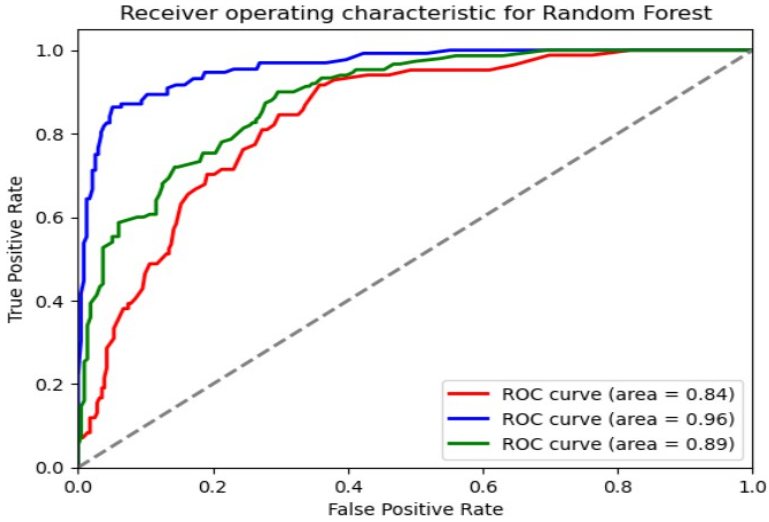


Fig. 3 ReceiverOperatingCharacteristics (ROC)

V. FUTURE SCOPE

The developed prototype effectively showcases the integration of wireless communication technology and computer vision techniques for recognizing human activities. Although the current system performs well, several improvements can be implemented to make it suitable for commercial and industrial applications.

1) At present, the robotic vehicle is controlled manually through a mobile application. In future developments, autonomous functionalities can be introduced to enable automatic environment mapping and intelligent route planning. This enhancement would allow the robot to carry out independent surveillance operations and automatically return to charging stations for battery recharging when required.

2) The system's real-time performance can be significantly improved by incorporating Edge Computing technologies. Upgrading or replacing the ESP8266 module with more advanced Edge AI hardware, such as NVIDIA Jetson devices or dedicated AI accelerators, would enable machine learning models to run directly on the robot itself.

3) Implementing local AI-based processing would reduce dependency on external systems and minimize communication delays. As a result, the surveillance robot would achieve faster response times, improved reliability, and more efficient activity recognition, making it more practical for large-scale monitoring and security applications.

VI. CONCLUSION

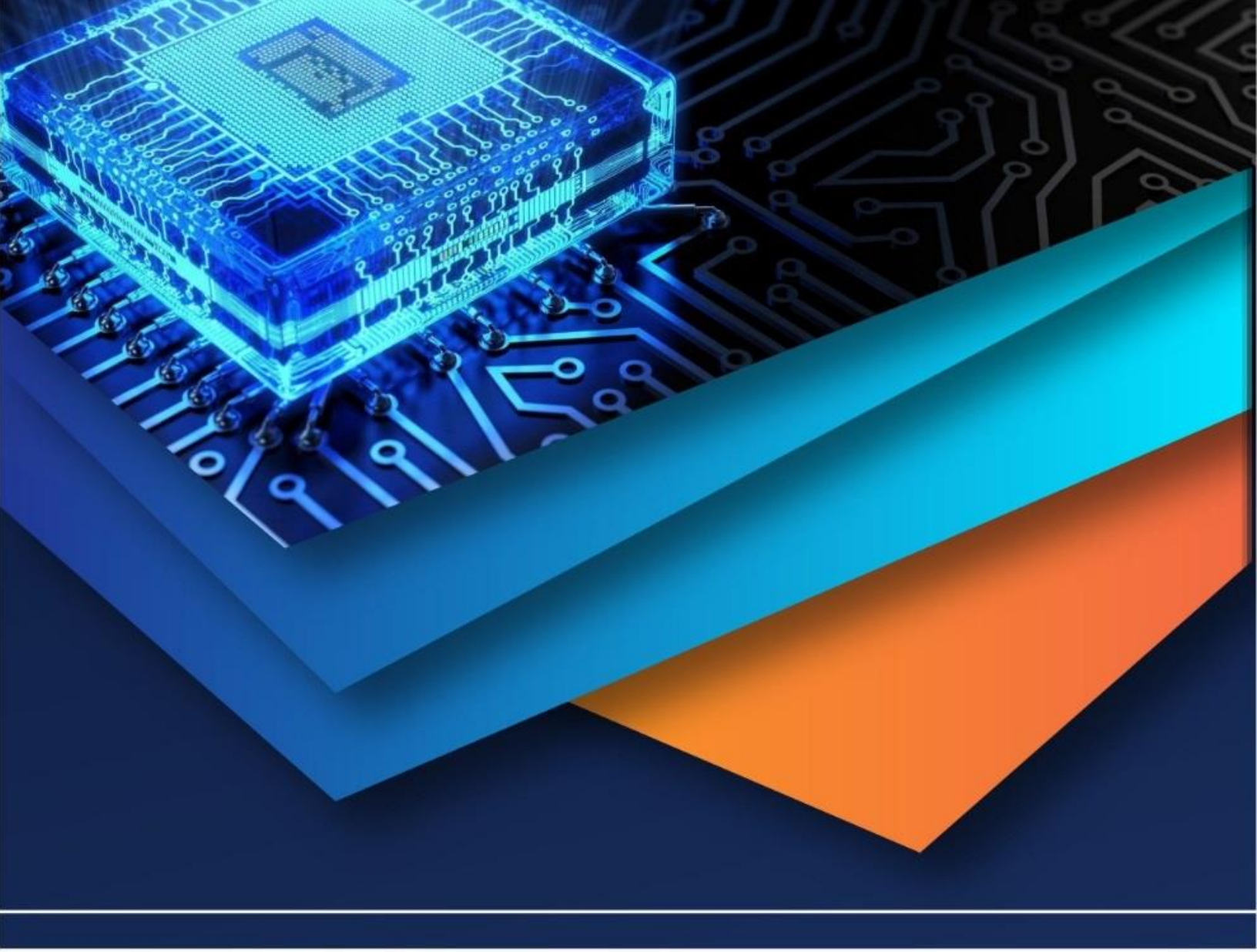
The surveillance robot is developed to provide an efficient and user-friendly monitoring solution with simple operation and reliable performance. The system is capable of supporting surveillance functions such as visual monitoring and motion detection, ensuring effective observation of different environments.

The robot is designed with flexibility in mind, allowing it to adapt easily to locations such as warehouses, underground areas, and multi-story buildings. Its modular structure and scalable architecture make the system highly customizable according to specific user requirements and operational conditions.

In addition, the expandable design allows future integration of advanced control features and technological upgrades. This improves system accessibility, enhances overall functionality, and offers a more efficient alternative to conventional surveillance methods.

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