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SMART SPY ROVER USING RASPBERRY PI FOR SURVEILLANCE AND THREAT DETECTION

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Abstract: This paper presents the development of a multifunctional spy rover using a Raspberry Pi, designed for real-time surveillance and threat detection in restricted environments. The rover supports live video streaming, video and voice recording, person detection using computer vision, and metal detection for security operations. A laser pointer module is also integrated for threat pinpointing. The system is remotely operable over a network and aims to provide a cost-effective solution for indoor and outdoor security monitoring.

Keywords: Spy Rover, Raspberry Pi, Surveillance, Video Streaming, Metal Detector, Laser Pointer, Person Detection.

I. INTRODUCTION

Surveillance and threat detection in high-risk areas are crucial for both civilian and military applications. Traditional monitoring systems lack mobility and real-time response. This paper proposes a mobile rover platform capable of providing visual, audio, and environmental data using low-cost components. The primary goal is to build a flexible and remotely operated vehicle that can navigate unknown areas while transmitting key security data to the user.

The demand for autonomous and remotely controlled robotic systems has grown significantly, especially within military, security, and disaster management applications. Unmanned Ground Vehicles (UGVs) are increasingly being deployed in environments considered too dangerous or inaccessible for human personnel, such as conflict zones, border patrol areas, and hazardous terrains. Surveillance robots, equipped with modern sensing and communication technologies, offer the capability to gather critical visual and audio information in real time, detect potential threats, and navigate autonomously or under remote guidance. This research focuses on the design and implementation of a multi-functional Military Spy Rover equipped with real-time video and audio surveillance, human detection, and metal detection functionalities.

The system is built around the Raspberry Pi 4 single-board computer, integrating a USB webcam with an inbuilt microphone, a metal detection module, motor control mechanisms, and wireless communication interfaces for remote operation. The project aims to develop a reliable, low-cost surveillance rover capable of providing real-time situational awareness, reducing risks to human soldiers, and enhancing reconnaissance capabilities in tactical environments.

Through the use of open-source technologies such as OpenCV for image processing, PyAudio for audio management, and Wi-Fi-based communication, this system demonstrates the potential of affordable, modular robotic platforms in modern defense operations. The proposed solution addresses limitations observed in conventional surveillance systems, such as limited operational range, lack of integrated detection functionalities, and dependence on manual control alone, by offering a multi-layered, smart surveillance platform adaptable to various military scenarios.

II. RELATED WORK

Over the past decade, various surveillance and reconnaissance robotic systems have been proposed and developed by researchers and engineers, particularly aimed at addressing security challenges in high-risk military zones and inaccessible environments. Early designs primarily focused on basic video surveillance robots equipped with RF or Bluetooth-controlled systems and simple webcams for visual monitoring.

Several studies introduced Arduino-based remote-controlled vehicles capable of capturing live video footage, yet these systems often suffered from limited communication range and lacked integrated detection capabilities. Subsequent works incorporated Raspberry Pi-based models with Wi-Fi connectivity, enabling real-time video streaming and manual control through mobile applications. Some researchers enhanced these designs by adding basic metal detection circuits for landmine detection and obstacle avoidance systems using ultrasonic or infrared sensors. Notably, projects integrating computer vision libraries like OpenCV enabled functionalities such as motion detection and basic face recognition. However, most existing solutions remained constrained to single-task operations, with limited focus on combining multiple critical surveillance features such as simultaneous video and audio recording, human detection, and environmental hazard detection into a unified platform.

Furthermore, previously proposed systems either lacked a reliable mobile control interface or used web interfaces that restricted operational mobility and ease of use. While these works laid essential groundwork in surveillance robot research, there remained a gap in developing a low-cost, multifunctional, Wi-Fi-controlled military spy rover capable of real-time video, audio, human, and metal detection with mobile control integration, addressing the tactical and operational demands of modern military applications.

III. SYSTEM OVERVIEW

The proposed rover includes the following key modules:

A. Raspberry Pi Controller: Acts as the core processor to handle video, audio, detection models, and sensor interfacing.
B. Live Video Streaming: Uses Camera Module with a VNC server to transmit video to the browser in real time.
C. Video and Voice Recording: Captured media is stored locally using Python scripts with OpenCV (video) and PyAudio (audio).
D. Person Detection: Implemented using Haar Cascades for real-time human detection.
E. Metal Detection Module: Connected via GPIO pins, the sensor triggers an alert when metallic objects are detected in close range.
F. Laser Pointer: Used for indicating objects of interest, controlled via Raspberry Pi GPIO.
G. Remote Access & Control: A web dashboard (Flask) allows users to stream video, control rover motion, and monitor sensor outputs.

IV. HARDWARE USED

• Raspberry Pi 4 Model B – 4GB RAM

• Camera – 1080p, 30fps

• USB Microphone – Omni-directional

• Metal Sensor – Inductive Proximity

• Laser Module – 5V Class III

• Battery Pack – 12V, 2A

• Motor Driver – L298N Dual H-Bridge

V. SOFTWARE AND ALGORITHM

• Language: Python 3.9

• Libraries: OpenCV, Flask, GPIOZero, PyAudio

• Detection Algorithm: Haar Cascade for real-time detection

• Storage: Local SD card logging for media files

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VI. PROPOSED WORK

The proposed research project aims to design, develop, and implement a comprehensive Military Spy Rover system that addresses the operational limitations of conventional surveillance robots by integrating real-time video surveillance, audio recording, human detection, metal detection, and wireless manual control functionalities into a single, compact, and portable platform. This system is intended for use in sensitive military and security environments such as border patrol, conflict zones, disaster-struck areas, and other inaccessible locations where sending human personnel poses significant risks. By leveraging affordable, open-source hardware and software tools, the proposed work envisions a multifunctional reconnaissance robot that can gather critical environmental data, detect threats, and transmit real-time information to an operator from a safe distance. The system is designed around a Raspberry Pi 4 single-board computer as the central control and processing unit, chosen for its versatility, processing power, and rich GPIO interfacing options, enabling seamless communication with various sensors and peripheral modules.

At the heart of the proposed spy rover lies its video capturing and surveillance module, which utilizes a USB webcam with an inbuilt microphone for continuous visual and auditory data acquisition. This module plays a crucial role in providing real-time situational awareness by capturing video footage of the environment and streaming it to a remote operator via Wi-Fi. The captured video stream is processed using the OpenCV computer vision library in Python, enabling frame-by-frame analysis for subsequent tasks such as human detection. The audio data captured simultaneously enhances environmental awareness, allowing the operator to perceive conversations, mechanical sounds, or other critical cues that might indicate human presence or potential threats. The project further integrates an audio processing module through the PyAudio library, enabling real-time sound recording, with the option of either storing it locally or transmitting it alongside the video stream to the remote monitoring station. This dual-mode surveillance approach ensures a holistic assessment of the operational area, which is especially valuable in military and rescue missions where unseen auditory signals can provide vital tactical information.

A key innovation in the proposed work is the inclusion of a real-time human detection system implemented through OpenCV's Haar Cascade classifier algorithm, applied to the live video stream acquired by the rover's webcam. This system continuously scans each video frame for patterns resembling human facial or body features and highlights detected subjects within the video feed. When a human figure is identified, an immediate alert is generated and transmitted to the operator's control application, ensuring quick decision-making in threat detection scenarios. This automated detection feature reduces the need for constant manual video monitoring and ensures that potential intrusions or enemy presence are promptly recognized, even when the operator is multitasking or supervising multiple surveillance devices simultaneously. Unlike previous works that either relied solely on manual observation or employed basic motion detection algorithms prone to false triggers, this proposed solution offers a more intelligent, reliable, and context-aware surveillance capability suitable for military field operations.

Another significant feature integrated into the proposed spy rover is its metal detection module, designed to identify the presence of concealed metallic objects, including landmines, hidden weapons, or improvised explosive devices (IEDs), which are common threats in military environments. The metal detector operates by generating a magnetic field through an inductive coil and monitoring changes in inductance caused by nearby metallic objects. The detection circuit is interfaced with the Raspberry Pi's GPIO pins, allowing it to continuously transmit detection signals to the central controller. Upon the detection of a metallic object within its proximity, the system triggers an alert mechanism, which can involve real-time notification on the operator's application. This feature significantly enhances the safety of reconnaissance missions by enabling the identification of hidden explosive threats from a remote and secure location, preventing casualties and damage to military personnel and equipment.

The manual control system of the proposed spy rover represents a significant improvement over conventional RF and Bluetooth-based systems by utilizing Wi-Fi-based communication for enhanced range, reliability, and multi-device connectivity. A custom mobile application is developed using the MIT App Inventor platform, providing the operator with a user-friendly graphical interface featuring directional control buttons, surveillance activation switches, and real-time status indicators for human and metal detection events. The mobile app connects to the Raspberry Pi via a peer-to-peer Wi-Fi network or a dedicated local hotspot created by the Raspberry Pi itself. This connection allows the transmission of movement commands and the reception of live video, audio, and sensor data. The application ensures responsive control of the rover's movements, including forward, backward, left, right, and stop commands, while also facilitating remote activation or deactivation of individual surveillance modules based on operational requirements. The integration of this mobile app-based control mechanism offers greater operational flexibility, allowing personnel to control and monitor the rover from a safe distance using readily available Android devices, thereby eliminating the need for specialized controllers or base stations.

In addition to these core modules, the proposed spy rover incorporates a motor control and navigation subsystem managed by an L298N motor driver module. This module receives directional signals from the Raspberry Pi's GPIO pins and controls the DC motors attached to the rover's wheels, enabling smooth and precise maneuvering on varied terrains. The motor driver supports bidirectional rotation control, facilitating forward and reverse movement, as well as turning capabilities, essential for navigating through narrow paths, obstacles, and complex field layouts. The physical chassis of the rover is designed to be lightweight yet durable, ensuring stability during movement while accommodating all hardware components securely. The wheel assembly is selected to suit both indoor and outdoor environments, providing adequate grip and stability on uneven, rocky, or sandy surfaces commonly encountered in military operational areas.

A crucial aspect of the proposed system is its wireless communication framework, which handles the bidirectional transfer of data and control commands between the rover and the remote operator's mobile device. The system utilizes the Raspberry Pi's onboard Wi-Fi module to establish a direct peer-to-peer connection or connect to an existing local area network (LAN) for broader operational range. Data transmission is managed using Python's socket programming libraries, ensuring low-latency communication suitable for real-time applications. Video and audio data streams, as well as detection alerts and command signals, are transmitted through this communication channel, maintaining continuous and reliable contact between the spy rover and the operator. This robust wireless communication setup significantly enhances the rover's operational flexibility, allowing it to be deployed in both infrastructure-supported and standalone field environments without additional networking equipment.

Fig 1 : Raspberry pi

The proposed spy rover also integrates a data storage and logging system to maintain records of surveillance operations, including video recordings, audio clips, detection event logs, and operational status reports. Video and audio files are timestamped and stored locally on the Raspberry Pi's storage device, while detection events such as human presence or metallic object identification are recorded in structured text files or lightweight databases like SQLite. This archival capability ensures that critical surveillance data can be reviewed post-mission for intelligence analysis, operational assessment, and evidence documentation. Furthermore, the system's logging mechanism aids in performance monitoring and troubleshooting by maintaining detailed records of system status, error logs, and operational anomalies.

In summary, the proposed Military Spy Rover project envisions a comprehensive, multi-layered surveillance system that consolidates visual and audio monitoring, automated threat detection, metal detection, and reliable remote control into a single, compact platform. By addressing the limitations of conventional surveillance systems, such as limited operational range, lack of integrated detection functionalities, and dependence on manual observation alone, this project offers a smart, adaptable, and cost-effective solution for modern military and security operations. The system's modular design, based on open-source hardware and software tools, allows for easy customization and future scalability, enabling the integration of additional functionalities such as GPS-based navigation, AI-driven object recognition, night vision cameras, and long-range RF communication modules. Through this proposed work, the project aims to contribute to the growing field of unmanned reconnaissance robotics by delivering a practical, deployable, and field-tested surveillance rover that enhances operational safety, situational awareness, and mission success rates in high-risk environments.

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VII. RESULTS

Fig 2: Working model

The proposed Military Spy Rover system was successfully developed, implemented, and tested under controlled as well as semi-realistic environmental conditions to evaluate its performance in real-time surveillance and threat detection applications. The integrated system, combining live video and audio monitoring, human detection, metal detection, and wireless manual control, demonstrated reliable and consistent performance throughout the testing phases. During the trials, the video capturing module achieved stable real-time video streaming at a resolution of 640x480 pixels, maintaining an average frame rate of 20 to 25 frames per second under standard lighting conditions. The video stream was successfully transmitted to the operator's mobile application via Wi-Fi without significant lag or frame loss within a 25–30 meter operational range, making it highly suitable for indoor and outdoor reconnaissance tasks.

Overall, the integrated system operated effectively as a multi-purpose surveillance rover, meeting its primary objectives of real-time monitoring, autonomous detection, and secure, responsive remote control. The experimental results validated the design and functional reliability of the proposed spy rover in surveillance scenarios, confirming its potential as a practical tool for military and security applications. The successful integration of affordable, open-source hardware and software components also highlighted the feasibility of deploying cost-effective, scalable robotic surveillance solutions in real-world defense operations.

VIII. CONCLUSION

In conclusion, the Military Spy Rover project successfully achieved its primary objective of designing and implementing a low-cost, multifunctional surveillance robot capable of operating in high-risk and inaccessible environments. The integrated system effectively combined real-time video and audio surveillance, human detection, metal detection, and remote manual control into a compact, portable platform. Built around the Raspberry Pi 4 single-board computer and controlled through a custom-developed mobile application using MIT App Inventor, the spy rover demonstrated reliable operational performance across all core functionalities. The system achieved consistent video streaming at acceptable frame rates, clear audio capture within effective ranges, and accurate detection of human presence and metallic objects in its vicinity. Through successful testing, the project validated the feasibility of leveraging open-source hardware and software tools to develop a practical, scalable, and customizable robotic surveillance solution suitable for military reconnaissance, border security, disaster management, and sensitive area patrolling. The modular architecture of the system ensures future expandability, allowing for the addition of advanced features such as AI-based object recognition, GPS navigation, night vision, and long-range wireless communication modules. The promising results of this project highlight its potential to enhance operational safety, improve situational awareness, and reduce the exposure of military personnel to hazardous environments, thereby contributing a valuable, deployable tool for modern defense strategies and security systems.

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REFERENCES

[1] S. M. Sali and K. R. Joy, "Intelligent Rover: An IoT Based Smart Surveillance Robotic Car for Military," IEEE, Mar. 2023.
[2] S. E. Roslin, P. Soundar, R. Surendar, and C. Kannan, "Design and Development of Surveillance Rover for Border Security," EPRA International Journal of Research and Development, vol. 8, no. 3, Mar. 2023.
[3] A. S. M. Tesma, "Warfield Spying Rover: The Advancement in Intelligence Gathering," International Journal of Engineering Research & Technology (IJERT), vol. 10, no. 3, Mar. 2021.
[4] J. Suárez-Armas, P. Caballero-Gil, and C. Caballero-Gil, "Video Surveillance Robot Powered by Raspberry Pi," arXiv preprint arXiv:2209.14130, Sep. 2022.
[5] S. S. Sruthy, S. Yamuna, and S. N. George, "An IoT Based Active Building Surveillance System Using Raspberry Pi and NodeMCU," arXiv preprint arXiv:2001.11340, Jan. 2020.
[6] Q. Liu, S. Yuan, and Z. Li, "A Survey on Sensor Technologies for Unmanned Ground Vehicles," arXiv preprint arXiv:2007.01992, Jul. 2020.
[7] K. Janani, S. Gobhinath, K. V. S. Kumar, S. Roshni, and A. Rajesh, "Vision Based Surveillance Robot for Military Applications," in Proc. 8th Int. Conf. on Advanced Computing and Communication Systems, 2022.
[8] M. K. A. Al-Habsia and M. Kalimuthua, "Design and Fabrication of Unmanned Ground Surveillance Vehicle," Journal of Student Research, vol. 6, no. 2, 2017.
[9] A. Shaji, A. K. Das, H. P. S., A. Ashok, and S. H. A., "Review on Surveillance Robot Using Raspberry Pi and IoT," International Research Journal of Engineering and Technology (IRJET), vol. 7, no. 4, Apr. 2020.
[10] S. A. M. Tesma, "Warfield Spying Rover with Defence," International Journal of Engineering and Advanced Scientific Technology (IJEAST), vol. 6, no. 6, Jun. 2021.