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ExploroBot: A Versatile Robotic Explorer

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Abstract

"ExploroBot: A versatile robotic explorer is a cutting-edge robotic platform designed for exploration and surveillance applications. Equipped with six battery-operated motors for mobility and an Arduino UNO microcontroller as its brain, the rover integrates ultrasonic sensors and two ESP32 CAM modules for obstacle avoidance and live footage streaming. With precise control mechanisms and advanced sensor technologies, ExploroBot: A versatile robotic explorer offers a versatile solution for navigating complex environments while capturing real-time data for analysis and monitoring. Using 6 battery operated motors for each BO wheel, the Arduino UNO as its brain and an ultrasonic sensor will provide it with the data around the Rover as the ultrasonic sensor is fitted on a Servo Motor for 180-degree movement, and it will help the microcontroller make decisions to avoid collisions with the obstacles, The Rover also has two ESP32 CAM modules, one for pan and tilt movement supported using more than two Servo Motors and another ESP32 CAM module for LIVE footage of the Rover surrounding us using a web server on our mobile phone or laptop. The ultrasonic sensor does send and receive the signal rays to understand the obstacle distance from the rover and help the rover take decisions and avoid obstacles. The one ESP32 CAM module used for object detection uses Coco library for object detection, and the other is used for LIVE streaming of the footage around the rover when it is in action."

Keywords: Remote monitoring, object detection, advanced vision capabilities, AVC, robotics. robotic platform, exploration, surveillance, Arduino UNO, ultrasonic sensor, ESP32 CAM modules, obstacle avoidance, live footage streaming.

INTRODUCTION

Our project named "Vision Rover" is a 6-wheeled Rover using 6 battery-operated motors for each BO wheel, Arduino UNO as its' brain, and an ultrasonic sensor that will provide the data around the Rover as the ultrasonic sensor is fitted on a Servo Motor for 180-degree movement, which will help the microcontroller make decisions to avoid the collision with the obstacles. The Rover is also, having Two ESP32 CAM modules, One for pan and tilt movement supported using more two Servo Motors and another ESP32 CAM module for LIVE footage of the Rover surrounding using web server on our mobile phone or laptop.

In an era where technological advancements continue to redefine the boundaries of exploration and surveillance, the Vision Rover emerges as a groundbreaking project aimed at revolutionizing the capabilities of robotic systems in navigating and understanding complex environments. With a comprehensive array of hardware and software components meticulously integrated, the Vision Rover embodies the pinnacle of innovation, offering unparalleled mobility, perception, and real-time data

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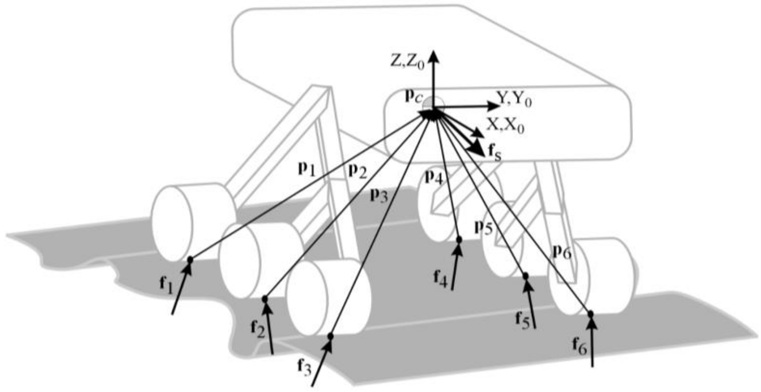

Figure 1. 6-Wheels rover model.

transmission capabilities. At its core, the Vision Rover boasts a six-wheeled configuration, with each wheel driven by a battery-operated motor. This design not only ensures robust locomotion but also endows the rover with the agility needed to traverse a wide range of terrains, from rugged landscapes to urban environments. Serving as the neural center of this sophisticated machinery is the Arduino UNO microcontroller, which orchestrates the seamless coordination of motor functions and sensory data processing, laying the foundation for autonomous operation (Figure 1).

Central to the rover's ability to navigate autonomously and avoid collisions with obstacles is the integration of an ultrasonic sensor mounted on a Servo Motor. This sensor, with its 180-degree field of view, acts as the rover's vigilant eye, continuously scanning the surrounding environment for potential hazards. Through precise servo-controlled movements, the ultrasonic sensor provides the rover with critical spatial awareness, enabling it to make informed decisions in real-time and safely navigate its path.

Beyond its mobility and collision avoidance capabilities, the Vision Rover excels in environmental perception and surveillance, thanks to the incorporation of two ESP32 CAM modules. One of these modules is dedicated to pan and tilt movements, facilitated by additional Servo Motors, allowing the rover to dynamically adjust its field of view and focus on specific points of interest. This feature enhances the rover's ability to gather detailed visual information, making it well-suited for tasks such as reconnaissance and remote sensing.

Moreover, the Vision Rover integrates another ESP32 CAM module specifically for live streaming of footage via a web server, enabling real-time monitoring and control from any Internet-enabled device, including mobile phones and laptops. This functionality not only enhances situational awareness but also facilitates remote operation and collaboration, making the rover an invaluable tool for a wide range of applications, from disaster response to environmental monitoring.

In summary, the Vision Rover represents a transformative leap in the realm of robotic exploration and surveillance, embodying a harmonious fusion of cutting-edge technologies aimed at pushing the boundaries of what is possible. Through its unparalleled mobility, perception, and data transmission capabilities, the rover holds the promise of revolutionizing how we interact with and understand our surrounding environments. In this research article, we delve deep into the design, implementation, and evaluation of the Vision Rover, shedding light on its technical specifications, operational capabilities, and potential impact on various fields of exploration and research. By documenting our journey and insights gained through this project, we aim to contribute to the ongoing discourse surrounding robotic systems and pave the way for future advancements in autonomous exploration and surveillance [1].

RELATED WORKS

Mars exploration rover mission, it represent the first extended exploration of the surface of another planet with a mobile robotic science laboratory, and it will lay the groundwork for the next generation of surface science missions. Each rover is equipped with a set of tools that will enable it to carry out a field geology investigation of each landing site and to address a set of science objectives aimed at understanding the role of water in the past environment on Mars [2].

Peiyuan Jiang [3] in their article "An Overview of Yolo Algorithm Progression" suggests advancements in the You Only Look Once (YOLO) algorithm and its subsequent iterations. Through their analysis, several noteworthy observations and insightful findings emerge, highlighting both disparities and similarities among various YOLO versions as well as comparisons between YOLO and Convolutional Neural Networks. The primary takeaway is the ongoing enhancement of the YOLO algorithm. The article succinctly outlines the evolution of the YOLO algorithm, summarizes techniques for target recognition and feature selection, and provides scholarly support for its application in targeted image analysis and feature extraction, particularly in financial and related domains. Additionally, this article significantly contributes to the body of literature on YOLO and other object detection methodologies.

Wei Fang in 2022 [4] presents a real-time object detection approach tailored for constrained environments. Tinier-YOLO is devised by integrating the fire module from SqueezeNet into Tiny-YOLO-V3 initially to shrink the model size. Subsequently, the quantity and placement of fire modules within the network architecture are investigated. Tinier-YOLO employs dense connections inspired by DenseNet to establish connectivity between fire modules. These dense connections contribute to enhancing detection accuracy and real-time performance by fortifying feature propagation and ensuring maximal information flow throughout the network.

In their 2023 article, Tausif Diwan et al. [5] highlight object detection as a predominant and formidable challenge within computer vision. With the rapid advancement of deep learning over the past decade, researchers have extensively explored and contributed to enhancing the performance of object detection, as well as associated tasks like object classification, localization, and segmentation, leveraging underlying deep learning models. Object detectors are broadly categorized into two types: two-stage and single-stage detectors. Two-stage detectors primarily employ a selective region proposal approach through intricate architectures, while single-stage detectors aim to detect objects across all spatial regions using comparatively simpler architectures in a single pass.

R. Vairavan et al.'s project outlines an obstacle avoidance robot vehicle controlled by an ultrasonic sensor [6]. The robot, constructed with an Arduino microcontroller, integrates an ultrasonic sensor positioned at its front. This sensor collects surrounding data and detects obstacles, prompting the robot to adjust its path to navigate around obstructions [7–10]. The sensor transmits data to the controller, which analyzes it to determine the robot's wheel movement. Additionally, wheel encoders contribute to the robot's movement and direction based on input from the ultrasonic sensor. Ultimately, this vehicle serves the purpose of detecting obstacles and preventing collisions [11–14].

TECHNIQUES USED

1. *Web server:* Live streaming of the surrounding of the Rover is transmitted to the user via the web server over the Internet.
2. *Arduino programming language:* Used to give instructions to the microcontroller Arduino UNO in the form of code to perform the obstacle avoidance.
3. *ESP32 CAM modules:* It does grasps the environment of the Rover and transmit it to the user for decision making.
4. *Ultrasonic sensor:* Senses the obstacles around the Rover and alert the microcontroller Arduino UNO to avoid collision.
5. *Servo Motors:* Help in movement of the ESP32 CAM modules and ultrasonic sensor for surrounding analysis.
6. *Battery operated motors:* Help in movement of the Rover around the environment.

7. *Microcontroller:* Works as the brain of the Rover helps explore the environment of the Rover and help the user in decision making.
8. *Computer vision:* Detects the objects surrounding the Rover and recognizes those objects known as object detection.

PROPOSED METHODOLOGY

Degrees to capture distance data from the surrounding environment.

Check for obstacle: The program compares the captured distance data with a pre-defined threshold distance (safe distance from obstacles).

Obstacle detected (yes): If an obstacle is within the threshold distance:

The program initiates obstacle avoidance maneuvers.

Depending on the obstacle location based on the servo position, the rover might turn left, right, or back up to avoid collision.

No obstacle detected (no): If no obstacle is detected:

The program proceeds with the "Continue Movement" step.

Continue movement: The program sends control signals to the motors for desired movement options (forward, backward, and turn). This allows the rover to navigate the environment while avoiding obstacles.

Optional functionalities (After Loop): This flowchart outlines the overall logic for your Vision Rover project, incorporating obstacle avoidance, optional camera control, and live streaming functionalities.

Initialization (Start): The program begins by initializing the essential components:

1. Arduino UNO or equivalent microcontroller board.
2. ESP32 CAM module for image/video capture and potential live streaming.
3. Ultrasonic sensor for obstacle detection.
4. Servo Motors for Pan and Tilt camera movement (optional).
5. Motors for rover movement (forward, backward, and turn).

Main loop: The program enters a continuous loop that repeats the core functionalities for navigation and obstacle avoidance [15]. Start Ultrasonic Sensor Sweep: The Servo Motor rotates the ultrasonic sensor through a designated range (Figure 2; e.g., 180).

(Optional) Pan and tilt camera control: This optional step allows for controlling the camera view using Pan and Tilt Servo Motors. The user (potentially through a mobile app) can adjust the camera direction to capture specific areas of interest [16].

(Optional) Capture live stream data: This optional step enables capturing image or video frames from the ESP32 CAM for live streaming functionality. Here, the program captures visual data from the environment [17].

(Optional) Transmit live stream data: Depending on your implementation, this optional step might:

1. *Option 1: Continuous transmission:* Continuously transmit the captured live stream data throughout the loop. As long as live streaming is enabled, data is transmitted after capture.
2. *Option 2: One-time transmission:* Transmit the captured live stream data only once, after the capture process is complete. The program then continues with obstacle avoidance within the loop.

Loop continuation:

After the optional functionalities, the program returns to the "Start Ultrasonic Sensor Sweep" step, restarting the loop for continuous obstacle detection and navigation. This ensures the rover constantly monitors its surroundings for safe and efficient movement.

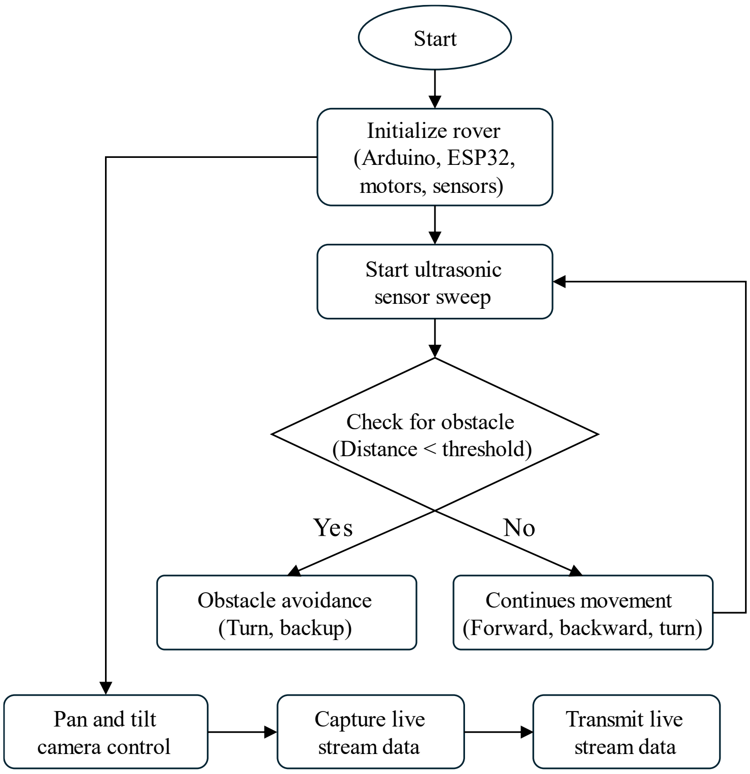

Figure 2. Flow chart of vision rover.

IMPLEMENTATION AND RESULTS

This research section details the implementation using the suggested technique, and the implementation tools and data set are provided below.

Tool Used

In this research, the authors used the ESP32 CAM Modules tool to obtain the results. The ESP32-CAM is a development board with an onboard camera that can perform machine learning tasks like image classification and person detection. It can capture uncompressed images at a resolution of 1600 × 1200, and has a 160°/66°/120° field of view.

Dataset Description

The authors employed YOLO, a real-time object detection library, which is an algorithm capable of identifying particular objects in images, live streams, or videos. Utilizing features acquired through deep convolutional neural networks, YOLO swiftly detects objects present within an image (Figure 3).

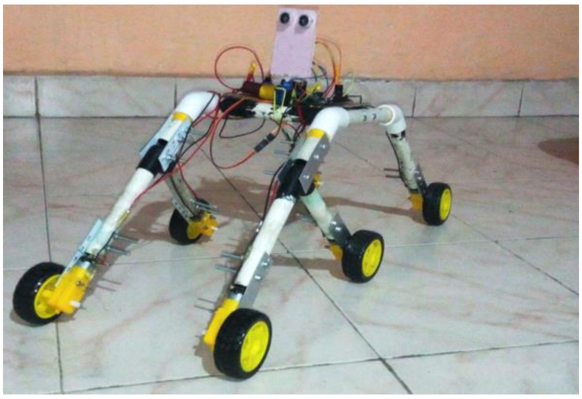

Figure 3. Actual rover.

The “Vision Rover” project came to life through the conscientious integration of various components, culminating in adaptable, flexible, dynamic, and proficient machine. The rover is having six wheels, each propelled by a dedicated battery-operated motor, and an Arduino UNO microcontroller acting as its central nervous system. This microcontroller is work and does control the rover’s movements and decision-making processes in real-time. Furthermore, the “Vision Rover” also, have two ESP32 CAM modules, each fulfilling a distinct role. One module, in collaboration with two Servo Motors, control a pan-and-tilt mechanism, offering a dynamic view. The pan movement controls rotation around the horizontal axis, covering close to 180 degrees. The tilt movement controls rotation on the vertical axis, potentially reaching close to 270 degrees. The other ESP32 CAM module does live streaming, allowing users to get live feedback of the rover’s surroundings from the comfort of their smartphone or laptop through a web server connected to same network.

CONCLUSION

The “Vision Rover” project stands as a testament to the power of combining well-chosen hardware components with software Artificial Intelligence and Machine Learning algorithms. The project successfully developed an obstacle-avoiding and live-streaming rover. The obstacle avoidance system, supported by the ultrasonic sensor, showcases the rover’s remarkable ability to explore its environment. The inclusion of ESP32 CAM modules amplified the rover’s capabilities, granting it the power to capturing live footage and help the user transmit live streams, making it an ideal candidate for remote exploration and surveillance tasks.

The Vision Rover’s success proves its potential to adapt and perform excellently in diverse fields, including search and rescue operations, environmental monitoring, and surveillance. The well-coordinated system of Arduino UNO, ultrasonic sensors, Servo Motors, and ESP32 CAM modules establishes the “Vision Rover” as an all-round machine for easing the human task that might be dangerous to be performed by a human being. This Vision Rover Project serves as a foundation stone for future development in the realm of robotics, proving the critical role of intelligent decision-making, adaptability, and real-time communication in the development of autonomous vehicles. The “Vision Rover” project’s achievements contribute significantly to the ever-expanding knowledge base in robotics and automation.

The “Vision Rover” project excelled at performing many complex tasks. The ultrasonic sensor, the project’s golden eye, proved accurate in detecting and alerting the rover to help avoid obstacles and prevent collision, hence safeguarding the rover. The pan-and-tilt mechanism of one ESP32 CAM module, in perfect coordination with its Servo Motor pair companions, delivered a wide view of the rover’s environment, while the other, the ESP32 CAM, acts like a tiny TV station for your rover. It broadcasts live video in real-time, and you can tune in using any web browser on your devices. The rover smoothly executes instructions from the Arduino UNO microcontroller, exhibiting a spectacular ability to react logically to obstacles and adjust its route accordingly. The live streaming feature emerged as a revolution, offering a precious accessory for remote monitoring and surveillance and a significant advancement to the rover’s practical applications.

Future Scope

The future scope of rover vision is exciting and full of potential. Advancements in technology and our understanding of planetary exploration will shape the evolution of rover vision systems.

Enhanced Imaging Capabilities

1. *Higher resolution cameras:* Future rovers will likely be equipped with even higher resolution cameras, enabling more detailed imaging and finer feature recognition.
2. *Advanced spectrometers:* Spectrometers with improved sensitivity and a wider range of spectral bands will provide richer data for geological and environmental analysis.
3. *Multi-spectral and hyperspectral imaging:* These techniques will enable more comprehensive analysis of the composition and characteristics of planetary surfaces and atmospheres.

Artificial Intelligence and Machine Learning

1. *Advanced computer vision:* AI and machine learning algorithms will play a more significant role in processing and analyzing images. Rovers will become more autonomous in identifying interesting features, hazards, and targets.
2. *Pattern recognition:* AI systems will improve their ability to recognize patterns, which is essential for geological and biological discoveries.

Autonomous Navigation

1. *Improved path planning:* Rovers will become more proficient in autonomously planning routes, avoiding obstacles, and optimizing paths for scientific exploration.
2. *Terrain understanding:* Enhanced vision systems will provide a better understanding of the terrain, helping rovers avoid challenging features like steep slopes or soft sand.

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