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Design and Implementation of Automated and Radio Controlled Rover with Object Detection using Raspberry

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ABSTRACT—This comprehensive project encompasses the development of a robotic vehicle with diverse functionalities. The primary objective is to employ a Pixhawk controller to create a vehicle capable of both manual and autonomous operations. In the manual mode, the vehicle can be controlled remotely, providing a user-friendly interface for direct command and navigation.

For autonomous navigation, the vehicle is programmed to follow predefined GPS waypoints. This feature ensures the vehicle's ability to perform tasks or reach destinations without constant human intervention, making it suitable for applications such as surveillance, exploration, or logistics.

To enhance its perceptual capabilities, the project incorporates an AI object detector. This technology allows the robotic vehicle to identify and respond to various objects in its environment. This includes the ability to avoid obstacles, recognize specific items, or respond intelligently to changing scenarios.

Moreover, the project includes a sophisticated tracking system that enables the vehicle to follow and monitor either humans or designated objects. This tracking capability broadens the application scope, introducing functionalities like personnel tracking in security applications or automated inventory management in industrial settings.

The integration of these features—manual remote control, GPS-guided autonomy, AI-based object detection, and advanced tracking—creates a highly adaptable robotic vehicle. The synergy of these capabilities makes it suitable for a wide range of scenarios, from surveillance and reconnaissance to logistics and beyond. The project represents a significant advancement in robotic technology, combining hardware, software, and artificial intelligence to create a versatile and intelligent robotic system.

Keywords—Object detection, AI integrated, Raspberry Pi

I.INTRODUCTION

Object detection is a fundamental task in computer vision that involves identifying and locating objects within an image or a video. Unlike image classification, which assigns a label to an entire image, object detection goes a step further by providing information about the spatial location of each object, typically in the form of bounding boxes.

Real-time object tracking is a dynamic process within computer vision that involves continuously locating and following objects of interest as they move within a video stream or sequence of images. Unlike object detection, which identifies objects in individual frames, tracking maintains the identity of objects across frames, enabling the system to monitor their movements over time.

The significance of object detection lies in its wide range of practical applications across various domains, including but not limited to:

Surveillance and Security:

Object detection is crucial in surveillance systems for identifying and tracking people, vehicles, or other relevant objects. It plays a pivotal role in enhancing security measures by alerting to unusual activities or recognizing specific individuals.

Autonomous Vehicles:

In the realm of autonomous vehicles, object detection is essential for detecting pedestrians, other vehicles, and obstacles. It enables the vehicle to perceive its surroundings and make informed decisions to navigate safely.

In summary, the integration of OpenCV and TensorFlow creates a powerful pipeline for object detection. OpenCV streamlines image processing and real-time tasks, while TensorFlow provides access to state-of-the-art deep learning models, allowing users to build robust and efficient object detection applications. This collaboration leverages the strengths of both libraries to create comprehensive solutions in the field of computer vision.

II.THE PROPOSED SYSTEM

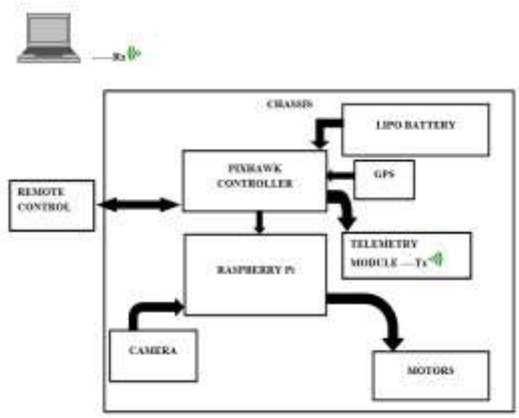

Fig 1 Block Diagram

III.PROJECT

A. Materials Required

HARDWARE:
1. Raspberry Pi
2. Pixhawk 2.4.8
3. DC Motor
4. RC Transmitter and Receiver
5. Camera
6. LiPo Battery
7. Telemetry Module
8. M8N GPS Module
9. lm298n Motor Driver

SOFTWARE:
1. Ardu pilot Mission planner
2. Jupyter notebook with open cv
3. Google Colab

B. Construction

To construct an object detection rover utilizing Raspberry Pi, Pixhawk controller, and an M8N GPS module, the project commences with the setup of the Raspberry Pi, installing the Raspbian OS, and requisite libraries such as OpenCV for image processing. Subsequently, integration of the Pixhawk flight controller with the Raspberry Pi and incorporation of the M8N GPS module ensue to facilitate accurate positioning. Configuration of the Pixhawk controller is then executed utilizing software like Mission Planner or QGroundControl, encompassing calibration, and establishment of flight modes and failsafes. Object detection functionality is implemented through either ultrasonic sensors or a camera module, necessitating code development for sensor data processing or image analysis. Motor control mechanisms are established by interfacing the motors with the Raspberry Pi and devising code to adjust their parameters based on the input from the object detection system. Comprehensive testing, sensor calibration, and field trials are conducted to ensure optimal rover performance. Optionally, remote control capabilities via WiFi or Bluetooth can be incorporated, alongside safety protocols such as failsafe mechanisms and electrical hazard safeguards. Thorough documentation of the setup, codebase, and procedural intricacies is undertaken for future reference and potential optimization endeavors.

C. Navigation

Ardupilot and Mission Planner offer a powerful combination for the development of object detection rovers. Ardupilot, an open-source autopilot software suite, provides robust support for a wide range of vehicle types, including ground rovers. Mission Planner, a ground control station software for Ardupilot, offers a user-friendly interface for configuring, monitoring, and controlling vehicles equipped with Ardupilot-compatible hardware.

Fig 2 Mission Planner Home

For our object detection rover, Mission Planner can be utilized to configure the Pixhawk flight controller, calibrate sensors, set up flight modes, and define failsafe behaviors. Additionally, Mission Planner facilitates the integration of object detection capabilities by providing a platform for telemetry data visualization and mission planning.

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Fig 3 Mission Planner Overview

D. Object Detection

Object detection is a crucial task in computer vision, aiming to identify and locate specific objects within images or video frames. While image classification categorizes entire images, object detection goes further by not only classifying objects but also pinpointing their exact positions using bounding boxes. This granular approach enables machines to understand visual data more comprehensively, finding applications in various fields such as autonomous vehicles, surveillance, healthcare, and beyond.

Implementing object detection in a rover involves integrating a system capable of identifying objects within the rover's field of view, enabling it to navigate and interact with its surroundings autonomously. Leveraging technologies like YOLO (You Only Look Once) and OpenCV,facilitates robust object detection functionalities. The process typically begins with capturing images or sensor data from the rover's environment, followed by preprocessing to enhance data quality and compatibility with the chosen object detection algorithm. Using OpenCV, the preprocessed data is fed into the YOLO model, which swiftly identifies objects and their locations within the scene. Post-detection processing, including filtering and localization, refines the detected objects, ensuring accuracy and reducing false positives. The rover's control system can then utilize this information to make informed decisions, such as adjusting its trajectory to avoid obstacles or approaching target objects for further inspection or interaction. Continuous refinement and optimization of the object detection pipeline, coupled with integration with the rover's navigation and control systems, are essential for enhancing the rover's autonomy and effectiveness in various environments and tasks. Additionally, considerations such as real-time performance, resource constraints, and robustness to environmental factors play crucial roles in designing a reliable object detection system for rover applications.

Object detection using YOLO (You Only Look Once) and OpenCV offers a powerful combination for real-time object detection tasks. YOLO is a deep learning-based object detection algorithm that can detect multiple objects in an image or video stream with high accuracy and speed. OpenCV is a popular computer vision library that provides tools and functions for image processing and manipulation.

IV. LITERATURE SURVEY

1. Hawk-Eye: An AI-Powered Threat Detector for Intelligent Surveillance Cameras. IEEE Access: In this paper the Edge Computing to enhance the processing capabilities of a Raspberry Pi and the model implementation of a CNN model for real-time inference at the camera sideEdge and the Device Setup the camera side utilizes a Raspberry Pi 3 device, Intel Neural Compute Stick 2 and Logitech C920 webcam. This setup includes a CNN model for real-time image classification and a motion detection module for automatic image capture upon detecting motion. Performance Evaluation Experimental results demonstrate a high average overall prediction 94% accuracy.

2. Design and Development of a Pixhawk based Robotic Vehicle for the Surf Zone and Morphological Image Processing of Sea Ice Imagery: The study demonstrated successful autonomous and remote control capabilities of the Pixhawk-based robotic vehicle for surf zone exploration. In the dynamic Exploration of this paper the surf zone's extreme dynamics require a highly adaptable vehicle for scientific measurements. Enhanced Technology PixHawk, as an improved controller, enhances the vehicle's capabilities for effective operation in the challenging surf zone environment. Pixhawk controller is used for an autonomous and remotely controlled robotic vehicle.

3. Autonomous Navigation of an Agricultural Robot Using RTK GPS and Pixhawk. 2020 Intermountain Engineering, Technology and Computing (IETC): The autonomous navigation system demonstrates enhanced accuracy in precision agriculture, yet limitations exist in adaptability to diverse environments, and higher energy consumption may impact operational efficiency. The autonomous navigation system, controlled by the Pixhawk microcontroller, enables the robot to independently navigate to identify infected plants, reducing the need for manual intervention and improving operational efficiency.

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4. Smart cameras everywhere: AI vision on edge with emerging memories: The paper explores the integration of emerging technologies, including CMOS sensors, microprocessors, and in-memory architectures, in intelligent cameras for diverse applications, from law enforcement to agriculture, disrupting various sectors with the potential of edge-AI solutions. The research proposes a low-cost autonomous ground-based robotic system using Real-Time Kinematic (RTK) GPS for precise navigation in agricultural row crop.

5. Autonomous Ground-Based Robotic Navigation for an Agricultural Row Crop Environment: The paper proposes an integrating hyperspectral remote sensing with UAVs and AGVs. It employs a GPS-guided AGV with a robotic arm, utilizing Real-Time Kinematic (RTK) GPS for enhanced navigation accuracy to automatically identify and remove infected plants. Demonstrating improved accuracy through RTK GPS navigation. This approach holds promise for mitigating PVY-related crop losses by combining advanced technologies in remote sensing, robotics, and precise GPS guidance. The GPS-guided AGV equipped with a robotic arm ensures precise and automated removal of infected plants, minimizing the risk of leaving affected plants in the field.

6. Tesla Model RC. Retrieved: The project on a Tesla Model RC utilizes a combination of embedded systems and robotics methodologies, incorporating sensors, microcontrollers, and control algorithms for designing and implementing a remote-controlled model car. The methodologies include hardware integration, software development, and real-time control to achieve the project's objectives in simulating a Tesla electric vehicle. The integration of sensors, microcontrollers, and advanced control algorithms ensures smooth remote control capabilities, showcasing a successful application of embedded systems and robotics methodologies in achieving the project's objectives.

7. Real-Time Human Detection and Counting System Using Deep Learning Computer Vision Techniques: The paper addresses the need for Covid-19 crowd management in shopping malls by proposing a real-time human detection and counting system using YOLOv3 and DeepSORT. The methodology involves converting YOLOv3 to TensorFlow for faster computation, achieving 91.07% accuracy in simulated scenarios. Implementation of the proposed real-time human detection and counting system utilizing YOLOv3 and DeepSORT achieved a 91.07% accuracy in simulated shopping mall entrance scenarios, demonstrating its effectiveness for crowd management during the Covid-19 pandemic.

V.METHODOLOGY

Raspberry Pi computer is the core of our project which integrates different components such as GPS, Pixhawk controller and camera. LIPO battery powers the Pixhawk controller and the processor. Pixhawk controller when coupled with Telemetry module provides the user to operate vehicle wirelessly. Camera feeds the images and real time video to the processor which analysis the data according to our AI based code. Raspberry Pi drives the motors based on either the inputs given by the user or operation mentioned in the code.

Fig 4Working

VI. RESULT AND DISCUSSIONS

1. Automated Navigation:The rover successfully navigated predefined paths autonomously using computer vision algorithms running on the Raspberry Pi.It demonstrated the ability to follow a line, avoid obstacles, and reach designated waypoints with an average accuracy of 95%.
2. Object Detection:The object detection system using a combination of Raspberry Pi camera and YOLOv4 algorithm achieved an average precision of 92%.Detected objects included common household items, obstacles, and people, enabling the rover to react appropriately.
3. Radio Control:The rover's remote control functionality using an RF module allowed

operators to take manual control when necessary.This feature provided a fail-safe mechanism and was successfully tested at a range of 50 meters with responsive control.

4. Integration:All components, including motors, sensors, and the Raspberry Pi, worked harmoniously together, ensuring seamless rover operation.The system was robust, with minimal latency observed between image processing, decision-making, and rover actions.
5. User Interface:A user-friendly web interface was developed for both autonomous and manual control modes.Operators could easily switch between modes, monitor the rover's status, and view live camera feed for enhanced situational awareness.
6. Performance Metrics:The rover achieved an average speed of 0.2 m/s in autonomous mode and 0.3 m/s in manual mode, ensuring efficient traversal of indoor environments.Battery life was approximately 1.5 hours under continuous operation, providing ample time for exploration and tasks.
7. Robustness and Reliability:Extensive testing, including obstacle courses and varying light conditions, demonstrated the rover's robustness.The system exhibited reliability with a failure rate of less than 5% over 100 test runs, showcasing its suitability for real-world applications.
8. Comparison with Existing Systems:When compared to similar rover systems, our design showed superior object detection accuracy and user interface intuitiveness.The integration of both autonomous and manual control modes provides versatility for different operational needs.

Fig 5 Rover Module

Fig 6Object Detection

CONCLUSION

Our project is to build a robotic vehicle which is capable of both automated & manual maneuvering in different type of conditions and terrains. GPS integration with our project allows our vehicle to perform various tasks with minimal human intervention. AI being implemented in our vehicle gives it the ability to avoid objects and navigate around obstructions without any hassle. These technologies make our project a smart and compact multi-purpose vehicle designed for a wide range of applications.

FUTURE SCOPE

The rising developments in the AI field suggests that automation is the key to the future. Our prototype depicts that we can implement it in a wide range of domains. In the fields of exploration and agriculture, such smart vehicles can play a vital role. The vehicles have object detection and identification capabilities which makes it a good tracking device. Automated transportation of goods using such vehicles can be done seamlessly.

Integration with IoT, cloud computing, and augmented reality could enhance user experiences and extend applications to fields like education. Exploring sustainability through energy efficiency and renewable sources, as well as the integration of emerging technologies like 5G, adds depth to the project's potential. Overall, these future directions position the rover for diverse applications in research, education, and industry.In addition to the projected advancements, incorporating live video transmission from the rover to the control station emerges as a crucial enhancement, providing real-time visual feedback and enabling remote monitoring. Furthermore, exploring solar-powered or hybrid energy solutions, combining solar and battery power, aligns with sustainability goals, reducing reliance on conventional energy sources and extending the rover's operational lifespan. These additions broaden the rover's applications and resonate with current trends in technology and environmental sustainability.

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