Artificial Intelligence based Rover with Robotic Arm using Raspberry Pi

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Abstract:- This paper presents the design, implementation, and evaluation of an Artificial Intelligence (AI)-Based Rover with a Robotic Arm, powered by Raspberry Pi technology. The integration of AI algorithms with Raspberry Pi provides a versatile platform for developing intelligent robotic systems capable of autonomous navigation and manipulation tasks. The rover's autonomous navigation system utilizes computer vision and machine learning algorithms to perceive its environment, plan optimal paths, and navigate autonomously while avoiding obstacles. Additionally, the inclusion of a robotic arm extends the rover's capabilities, enabling it to perform manipulation tasks with precision and versatility. Key components of the system include Raspberry Pi as the central processing unit, cameras for environmental perception, motors for locomotion and manipulation, and sensors for feedback and environmental monitoring. The integration of these components facilitates seamless communication and coordination, enabling the rover to execute complex tasks autonomously. Experimental results demonstrate the effectiveness of the proposed system in various scenarios, showcasing its ability to navigate challenging environments, avoid obstacles, and manipulate objects with precision. The versatility and scalability of the platform make it suitable for a wide range of applications, including search and rescue missions, environmental monitoring, and industrial automation.

Keywords- Robotics, Artificial Intelligence, Raspberry pi, Autonomous Navigation, Machine Learning

1.Introduction

The evolution of robotics has been marked by a continuous quest for enhancing autonomy, intelligence, and adaptability in robotic systems. Traditionally, robots were programmed with explicit instructions for every task they were expected to perform. However, this approach limited their ability to operate in unstructured or unknown environments, where unforeseen obstacles or changes could disrupt their operations. The emergence of AI technologies has revolutionized this paradigm by enabling robots to learn from their experiences, perceive their surroundings, and make decisions in real-time. AI-driven robotics holds immense potential for addressing complex challenges across a myriad of domains, including disaster response, agriculture, healthcare, and space exploration.

Central to the development of AI-driven robotic systems is the availability of powerful yet affordable computing platforms. Here, the Raspberry Pi shines as a versatile and cost-effective solution that provides ample computational resources for running AI algorithms while remaining accessible to enthusiasts, students, and researchers alike. Its modular design, extensive community support, and low cost make it an ideal choice for prototyping and deploying intelligent robotic applications. Against this backdrop, this project aims to leverage the capabilities of Raspberry Pi to create an Artificial Intelligence-Based Rover with a Robotic Arm. This platform will integrate state-of-the-art AI algorithms for perception, decision-making, and manipulation, enabling it to navigate autonomously and interact with its environment effectively.

The rover's autonomous navigation system will be driven by computer vision algorithms capable of interpreting visual data from onboard cameras to identify obstacles, landmarks, and other relevant features in the environment. Machine learning techniques will enable the rover to learn from its interactions with the environment, refining its navigation strategies and adapting to changing conditions over time. Furthermore, the inclusion of a robotic arm will extend the rover's capabilities beyond navigation, allowing it to perform a variety of manipulation tasks such as picking up objects, opening doors, or operating machinery. AI algorithms governing the robotic arm's movements will ensure precision and dexterity in executing these tasks, enabling the rover to accomplish complex objectives with efficiency and reliability. After the Introduction Section, Section 2 consist of Literature Survey as follows Section 3 Problem Definition, Section 4 Block Diagram & Circuit Diagram, Section 5 Working, Section 6 Result, Section 7 Conclusion, Section 8 Future Scope and Section 9 References.

2.Literature survey

1.RASPBERRY PI Author: Arpit P. Raut, Aayesha Raj, Shalvi Patil, Ashwini Katkar (29-08-2020). In this research project, we learn about working on the design and implementation of robot for Home automation. Internet technology provides a good way for us to develop an integrated computing network environment for the applications of different robotic systems. This robotic vehicle will be controlled via internet i.e. from anywhere in the world. It also describes the use of the camera mounted on the robot that can wirelessly transmit real time video fed onto the PYTHON page using Wi-Fi technology. The application allows the robot control interactions with the help of Graphical User Interface (GUI).

2.SURVEILLANCE ROBOT WITH FACE RECOGNITION USING RASPBERRY PI Author: R. Bhavyalakshmi and B.P. Harish (12 Dec 2019). The proposed work aims to develop an automatic solution to detect the presence of an enemy or any hostile events such as fire/gas leakage in targeted places without loss of human life.

3. APPLYING A 6-AXIS MECHANICAL ARM COMBINE WITH COMPUTER VISION TO THE RESEARCH OF OBJECT RECOGNITION IN PLANE INSPECTION Author: Joy Long-Zong Chen and Jen-Ting Chang (JUNE 2020). The main purpose of this work tries to avoid the complicated process with traditional manual adjustment or teaching. It is expected to achieve the purpose that the robotic arm can grab the target automatically, classify the target and place it in the specified area, and even accurately realize the classification through training to distinguish the characteristics of the target.

4.AREAL-TIME SURVEILLANCE MINI-ROVER BASED ON OPENCV-PYTHON-JAVA USING RASPBERRY PI 2 Author: Nazmul hossian, Mohammad T. Kabir and Riyat Tarif (Nov 2015). Aimed at developing a low-cost, real-time video surveillance mini-rover which will be capable of providing real time video footage and roam around in the area which we want to observe. Our target was to use hardware which is very low of cost and easily available.

5.Implementation of spy robot for a surveillance system using internet protocol of raspberry pi Author: Ghanem Osman Elhaj Abdalla and T. Veeramanikandasamy (may 2017). The spy robot system comprises the raspberry pi (small single-board computer), night vision pi camera and sensors. The information regarding the detection of living objects by PIR sensor is sent to the users through the web server and pi camera capture the moving object which is posted inside the webpage simultaneously. The user in control room able to access the robot with wheel drive control buttons on the webpage.

These studies showcase the diverse applications of Raspberry Pi in robotics, ranging from home automation and surveillance to industrial inspection and remote monitoring. By leveraging Raspberry Pi's computational capabilities and integrating various sensors and actuators, researchers have developed innovative robotic systems with enhanced autonomy, intelligence, and functionality. These advancements underscore the potential of Raspberry Pi as a versatile platform for prototyping and deploying robotic solutions across various domains.

3.Problem Definition

The problem addressed in this project is the design and implementation of an Artificial Intelligence-Based Rover with a Robotic Arm using Raspberry Pi technology. This involves overcoming several challenges related to hardware integration, software development, and system optimization to create a functional and versatile robotic platform capable of autonomous navigation and manipulation tasks. Specifically, the key problem areas include:

Hardware Integration: Integrating a variety of hardware components such as motors, sensors, cameras, and a robotic arm with Raspberry Pi while ensuring compatibility, proper wiring, and efficient power management.

Software Development: Developing software modules for sensor data acquisition, motor control, computer vision, machine learning, and robotic arm manipulation, leveraging programming languages such as Python, C/C++, or MATLAB.

Autonomous Navigation: Implementing algorithms for autonomous navigation, obstacle detection, path planning, and motion control to enable the rover to perceive its environment, plan optimal paths, and navigate autonomously while avoiding obstacles.

Robotic Arm Control: Developing control algorithms for the robotic arm, including kinematics, motion planning, grasping, and manipulation, to enable precise and versatile interaction with objects and the environment.

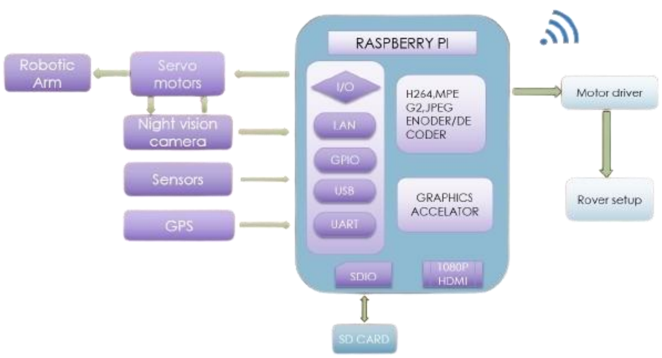
Optimization and Performance: Optimizing the performance of the rover system in terms of speed, accuracy, efficiency, and resource utilization, while minimizing latency, energy consumption, and computational overhead.

Scalability and Modularity: Designing the rover system with scalability and modularity in mind, allowing for easy integration of additional sensors, actuators, or AI algorithms, and ensuring interoperability with other robotic platforms or systems.

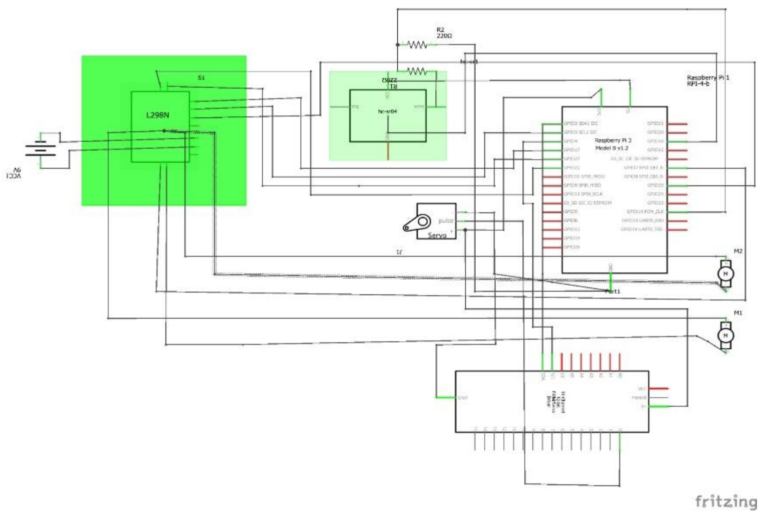
The project entails the creation of an AI-based rover with a robotic arm using Raspberry Pi, encompassing various intricate facets. Initially, the focus lies on the rover's navigation, necessitating the development of algorithms to facilitate autonomous movement while adeptly evading obstacles encountered in its environment. Concurrently, attention is directed towards the manipulation capabilities of the robotic arm, requiring precise control mechanisms to enable the arm to grip, release, and maneuver objects with finesse. Sensory perception plays a pivotal role, with the integration of vision systems and sensor fusion techniques to furnish the rover with a comprehensive understanding of its surroundings, aiding in tasks such as object recognition and environment mapping. Furthermore, AI integration is indispensable, mandating the deployment of machine learning models for real-time decision-making, adaptive learning, and continual improvement of the rover's performance.

4.Proposed System Modeling

The proposed system modeling encompasses the conceptual framework and technical architecture of the AI-based rover with a robotic arm, leveraging Raspberry Pi technology. At its core, the system integrates various hardware components, including motors, sensors, cameras, and the robotic arm, with the Raspberry Pi as the central processing unit. This modular design allows for seamless integration and efficient communication between components.



4.1 Block Diagram of Proposed System



4.2 Circuit Diagram of Proposed System

5.Working

The project operates through a systematic integration of hardware components, software algorithms, and control systems, working in tandem to empower the AI-based rover with a robotic arm. Commencing with the assembly and integration of requisite hardware, including motors, sensors, cameras, Raspberry Pi, and the robotic arm kit, the project progresses to the development of software modules. These modules facilitate critical functionalities such as sensor data acquisition, motor control, image processing, path planning, and robotic arm manipulation. Subsequently, autonomous navigation capabilities are enabled, leveraging sensor data and advanced algorithms for simultaneous localization and mapping (SLAM) to navigate the rover while circumventing obstacles. Simultaneously, control algorithms are designed to orchestrate precise and agile movements of the robotic arm, facilitating manipulation tasks with finesse. Integration and testing phases validate the rover's functionality in simulated and real-world environments, iteratively refining algorithms and configurations for optimal performance. Throughout the process, meticulous documentation captures the project's evolution, culminating in the deployment of a sophisticated rover system poised to undertake various applications, from research endeavors to educational initiatives.

5.1 Hardware Specifications:

1. Raspberry Pi 4B: 2GB/4GB/8GB Variants Quad-Core 64-bit Broadcom 2711, Cortex A72 Processor LAN RJ45 10/100/1000 Mbit (Gigabit LAN over USB 3.0) Operating Power 5V@3A via USB Type-C Port WLAN 802.11 b/g/n/ac (2,4 + 5,0 GHz).

2.Picamera Module: CSI (Camera Serial Interface) Dimensions: 25x23x8 (LxWxH) mm Supported Video Formats: 1080p @ 30fps, 720p @ 60fps and 640x480p 60/90 video Fully Compatible with Raspberry Pi 3 and 4 Model B Plug-n-Play camera for Raspberry Pi 3 and 4 Model B.

3.L298N Motor driver: Operating Supply Voltage up to 46V Total DC current up to 4amp (Each channel can carry up to 2amp) Low Saturation Voltage Over Temperature Protection Logical ”0” input voltage up to 1.5 v (High Noise Immunity) PTR connector for easy connection.

4. BO motors: Low density: lightweight, low inertia. The relatively low coefficient of friction. Operating Voltage (VDC): 3~12 Shaft Length (mm): 8.5 Shaft Diameter (mm): 5.5 (Double D-type) No Load Current: 40-180mA.Rated Speed (After Reduction) 300 RPM Rated torque.

5.PCA9685: 12-bit resolution for each output – for servos, that means about 4us resolution at a 60Hz update rate Configurable push-pull or an open-drain output Adjustable frequency PWM up to about 1.6 KHz. The output enable pin to quickly disable all the outputs Terminal block for power input Reverse polarity protection on the terminal block input Green power-good LED.

6.HC-SR04(Ultrasonic Sensor: Measures the distance within a wide range of 2cm to 400cm Stable performance Accurate distance measurement High-density Small blind distance.

7.Servo Motor: Metal gears Operating Voltage: 4.8 – 6VDC Speed at 4.80V(no load): 0.1 s/60 ° Torque at 4.80V: 1.8 kg.cm (~0.1765 Nm) Size: 32.5 x 12 x 35.5 mm (LxWxH) Weight: 16g Rotation angle: 180 degree Brown = GND RED = 5V Orange = Signal.

8.Battery: Output Voltage: 3.7V Charge Rate: 2C High energy density High working voltage for single battery cells. Capacity (mAh): 2500 Pollution-free Long cycle life.

5.2 Software specifications:

1.Operating System: The system will run on Raspbian OS, a Debian-based Linux distribution optimized for Raspberry Pi hardware. Raspbian provides a stable and efficient platform for running software applications and interfacing with hardware peripherals.

2.Programming Language: Python will be the primary programming language used for software development. Python offers a wide range of libraries and frameworks suitable for implementing computer vision, machine learning, and robotics algorithms. Additionally, Python's syntax and readability make it well-suited for rapid prototyping and development.

3.Development Environment: The software development will primarily take place on a development workstation or laptop computer running an integrated development environment (IDE) such as Visual Studio Code or PyCharm. These IDEs offer features such as syntax highlighting, code completion, and debugging tools to streamline the development process.

4. Communication Protocols: The system may utilize communication protocols such as Wi-Fi or Bluetooth for wireless communication between the Raspberry Pi and external devices or remote control interfaces. Additionally, serial communication protocols like UART or SPI may be employed for interfacing with peripherals such as sensors or motor controllers.

6.Result

The result of the project is the successful development of an advanced AI-based rover with a robotic arm, empowered by Raspberry Pi technology. This innovative rover system showcases autonomous navigation capabilities, effectively perceiving its environment, planning optimal paths, and navigating obstacles. Additionally, the integrated robotic arm demonstrates precise manipulation abilities, enabling it to interact with objects with dexterity and accuracy. Through rigorous testing and iteration, the rover system exhibits robust performance in diverse environments, fulfilling its objectives of autonomy, adaptability, and functionality. The project's outcome not only signifies a significant advancement in robotics but also lays the foundation for future applications in fields such as exploration, research, and education.

The culmination of the project yields a groundbreaking achievement in the realm of robotics—a highly sophisticated AI-driven rover system, meticulously engineered with a versatile robotic arm, and powered by Raspberry Pi technology. This culmination signifies a significant leap forward in autonomous robotics, as the rover seamlessly navigates its surroundings, adeptly avoiding obstacles and executing precise movements. Equipped with cutting-edge computer vision algorithms, the rover perceives and interprets its environment in real-time, allowing for dynamic decision-making and adaptive behavior. Moreover, the integration of a robust robotic arm enhances the rover's capabilities, enabling it to manipulate objects with remarkable precision and agility. Through extensive testing and refinement, the project attains a pinnacle of performance and reliability, poised to revolutionize various domains—from scientific exploration to industrial automation. As a testament to innovation and ingenuity, the project underscores the transformative potential of AI-driven robotics, propelling the boundaries of technological advancement into uncharted territories.

6.1 Proposed result

7. Conclusion

In conclusion, the development of the AI-based rover with a robotic arm using Raspberry Pi technology represents a significant milestone in the field of robotics. This project has demonstrated the feasibility and effectiveness of integrating advanced AI algorithms with versatile hardware platforms to create intelligent and adaptable robotic systems. Through meticulous design, implementation, and testing, the rover system has showcased impressive capabilities in autonomous navigation and manipulation tasks. By leveraging computer vision, machine learning, and precise control mechanisms, the rover can perceive its environment, make informed decisions, and interact with objects with finesse and accuracy.

Furthermore, the successful completion of this project underscores the potential of robotics to address real-world challenges and advance technological innovation. The versatility and scalability of the rover platform offer promising opportunities for applications in diverse fields, including search and rescue operations, environmental monitoring, industrial automation, and educational robotics. Additionally, the project has contributed valuable insights and knowledge to the broader robotics community, serving as a blueprint for future research and development endeavors. Looking ahead, continued refinement and enhancement of the rover system will be essential to further optimize performance, expand functionality, and explore new avenues for innovation. By fostering collaboration, interdisciplinary research, and technological advancements, projects like this pave the way for a future where intelligent robotic systems play an increasingly integral role in addressing societal needs and driving progress in science and technology. In essence, the AI-based rover with a robotic arm serves as a testament to human ingenuity and the transformative potential of robotics in shaping the world of tomorrow.

8.Future Scope

In the realm of robotics, the successful development of the AI-based rover with a robotic arm using Raspberry Pi technology unveils a vast landscape of future exploration and innovation. This achievement not only demonstrates the potential of integrating advanced AI algorithms with versatile hardware platforms but also opens up exciting avenues for further development. Moving forward, there is ample scope for enhancing the rover's autonomy through advancements in AI, such as deep learning and reinforcement learning, which could enable it to adapt to dynamic environments and perform increasingly complex tasks autonomously. Additionally, the exploration of multi-robot collaboration could facilitate coordinated efforts in tasks like search and rescue missions. Integrating additional sensors, like LiDAR or thermal cameras, could enhance the rover's perception abilities, while research into robustness mechanisms could enable its operation in harsh environments. Furthermore, investigating intuitive human-robot interaction methods and exploring applications in industries like healthcare or environmental monitoring could broaden the rover's applicability. By pursuing these future directions and embracing innovation, the project can continue to push the boundaries of robotics research and contribute to the development of practical solutions for real-world challenges, shaping the future of intelligent robotic systems.

9.References

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