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Assembly Automation & AGV-Assisted Material Handling

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Abstract: Manual assembly processes often present significant challenges, including time inefficiency, human error, and safety risks particularly when handling small or delicate components. To address these issues, this research presents the development of a Raspberry Pi-controlled robotic arm prototype, specifically designed for assembly operations in a mechatronics laboratory setting. The system collaborates with an Automated Guided Vehicle (AGV) to create a semi-autonomous assembly line. Positioned at a designated workstation, the robotic arm performs precision assembly of 3D printed parts and transfers the completed units onto the AGV for further processing. Integration of sensors ensures the timely detection of the AGV's arrival, enabling seamless coordination between the robotic arm and the mobile platform. This prototype aims to automate repetitive tasks, minimize human intervention, and enhance safety and productivity. Future industrial adaptations of this system are expected to further streamline manufacturing processes and reduce operational risks.

Keywords: Robotic Arm Automation, AGV-Based Smart Assembly System, Raspberry Pi-Controlled Mechatronics Prototype

I. INTRODUCTION

The increasing demand for precision, speed, and safety in manufacturing environments has driven the integration of automation into traditional assembly processes. In particular, the use of robotic systems has revolutionized how repetitive and delicate tasks are performed, reducing dependency on manual labor and minimizing risks associated with human error. Educational institutions, especially those focused on mechatronics and robotics, are actively developing prototypes that simulate real-world industrial applications. This research explores the design and implementation of a Raspberry Pi-controlled robotic arm integrated with an Automated Guided Vehicle (AGV), aiming to replicate an automated assembly system suitable for a smart manufacturing setup. The project focuses on sensor-based coordination between the robotic arm and AGV, highlighting its potential for future scalability in industrial environments. By combining low-cost hardware and efficient control strategies, this prototype serves as a foundation for advancing automation in academic and industrial contexts alike.

II. PROBLEM IDENTIFICATION

This project is to design and develop robotic arm system using microprocessor (Raspberry pi) that can autonomously perform assembly tasks and collaborate with an Automated Guided Vehicle (AGV). The robotic arm, positioned at a designated workstation, will assemble parts and place the assembled product onto the AGV for further process. The system will integrate sensors to detect the arrival of the AGV near the workstation. The main challenge is to achieve coordination between the robotic arm and the AGV.

III. WORKING PRINCIPLE

The system operates on a closed-loop control principle, where a Raspberry Pi serves as the central controller, receiving commands from a connected PC or laptop. Upon receiving instructions, the Raspberry Pi processes the data and communicates with a control card equipped with a power module, which then distributes regulated power and control signals to servo motors. These servos actuate movements in mechanical components, such as a robotic arm. An R-Pi camera captures real-time visual feedback, allowing the Raspberry Pi to make adjustments for accurate positioning. The entire system is powered through a supply board connected via an electric switch, enabling on/off control, making it suitable for automation tasks like pick-and-place operations or robotic-assembly.

IV. BLOCK DIAGRAM

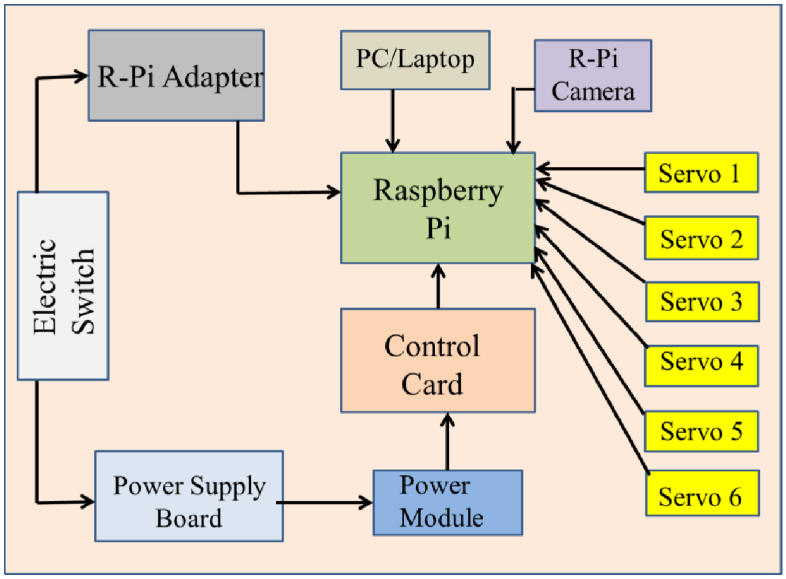


FIG.1

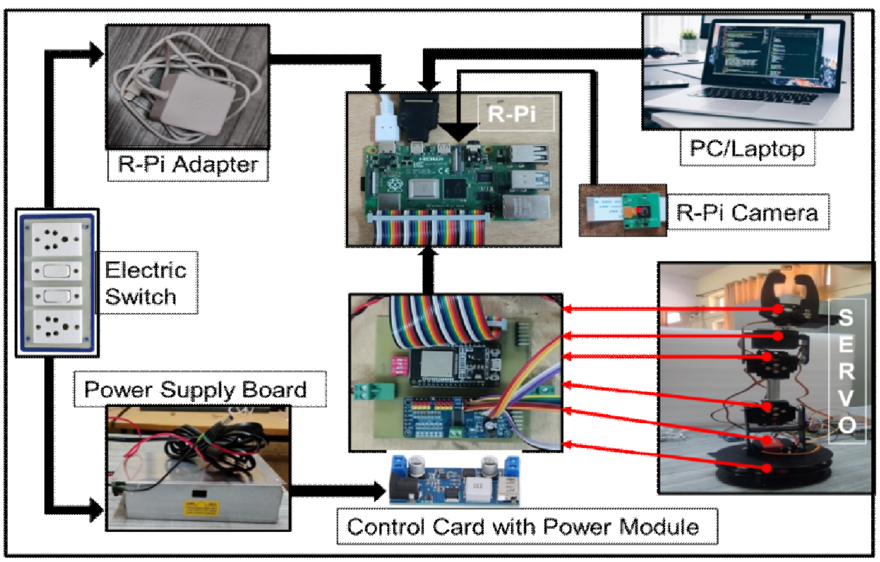


FIG.2

V. COMPONENTS

1) *Raspberry Pi 4 8GB :*

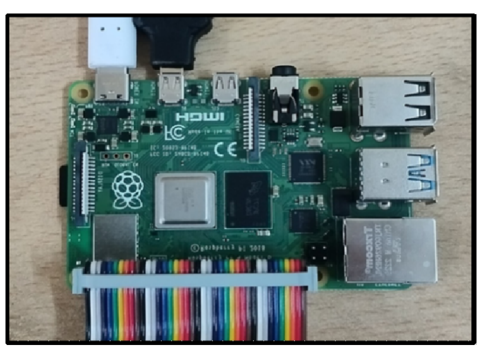


FIG.3

A small, single-board computer that can be used for a variety of tasks, including robotics, automation, and media serving. The Raspberry Pi 4 Model B is the latest version, featuring a faster processor, more memory, and improved connectivity.

2) Control Card:

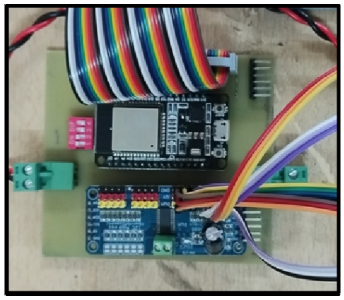


FIG.4

It is likely a custom-designed circuit board that interfaces with the Raspberry Pi and other components, enabling control of the robotic arm and other functions.

3) Robotic Arm Kit:

FIG.5

A set of mechanical components and actuators that can be assembled into a programmable robotic arm. These kits often include motors, gears, and structural elements, allowing for precise movement and manipulation

4) Power Supply Board:

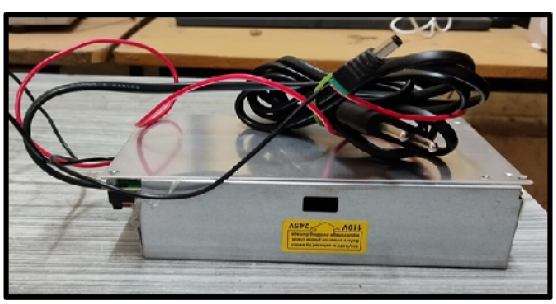


FIG.6

A circuit board that provides the necessary voltage and current to power the Raspberry Pi, control card, and robotic arm. It typically converts AC power from a wall outlet into DC power suitable for electronic components.

5) Power Module:

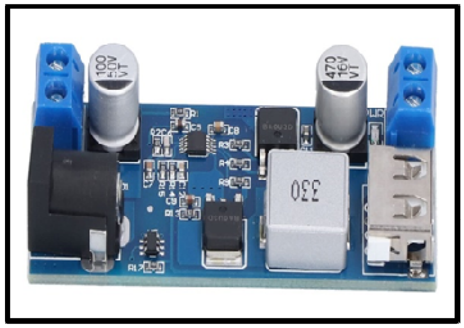


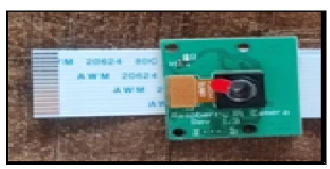
FIG.7

It could be a component that regulates and distributes power to specific parts of the system, ensuring stable and efficient operation.

6) R-Pi Adapter:

This might be an interface board or cable that facilitates communication and power delivery between the Raspberry Pi and other components, such as the robotic arm or camera.

7) R-Pi Camera:



A camera module designed to connect to the Raspberry Pi, enabling image and video capture for tasks such as object recognition or visual feedback in robotic applications.

VI. OBJECTIVE & SCOPE OF PROJECT

1) Fully automated 6DOF robotic arm for assembly purpose.
2) Arm for picking, placing and assembling parts.
3) Coordination between robotic arm and AGV.
Afterachievingtheobjectivethescopeofprojectis–
After achieving the objectives, the project holds strong potential across industries—from precision assembly in medical, jewelry, and 3D printing to large-scale automation in automotive, electronics, and logistics. This versatility enables its integration into both specialized and mass production environments, enhancing efficiency and scalability.

VII. EXPECTED RESULT

1) The 6DOF robotic arm will increase the speed of the assembly and packaging process, reducing manual labor
2) To detect the arrival of the AGV near the workstation
3) To achieve coordination between the robotic arm and the AGV

VIII. RESULTS AND DISCUSSIONS

The study of an automated robotic arm focuses on the integration of mechanical, electrical, and control systems to facilitate accurate object manipulation and enhance operational efficiency. The robotic arm is powered by a combination of stepper motors and DC motors for precise movement control. For object recognition and handling, the system utilizes a camera integrated with a machine learning-based object detection model, specifically leveraging Tensor Flow for enhanced detection accuracy. A gripper mechanism powered by a servo motor provides adaptable gripping power for various objects. The arm's movement is coordinated by an Arduino-based control system, which is linked to a Python interface for real-time command and control. The robotic arm's actions are further automated and optimized using pre-defined algorithms for path planning and motion execution. This allows the arm to perform tasks like pick-and-place operations with precision and efficiency. Despite the machine's capabilities, challenges related to dynamic object environments, real-time decision-making, and limited training datasets for machine learning models remain. Future improvements are expected to focus on enhancing object recognition speed, expanding the arm's range of operation, and integrating advanced machine learning techniques for dynamic path optimization. Result: The developed robotic arm system effectively automates object manipulation tasks, reducing human involvement and increasing operational efficiency. By incorporating stepper motors and DC motors for smooth and controlled movement, the system is able to achieve high precision in pick-and-place operations. The integration of machine learning for object detection allows for real-time identification and classification, significantly reducing errors associated with manual operations. The arm's gripper system ensures secure handling of a variety of objects, while the Arduino-based control system and Python interface enable seamless operation and easy customization. The system is capable of performing industrial automation tasks with improved speed, consistency, and accuracy. Despite some challenges related to environmental factors and machine learning model optimization, the robotic arm demonstrates substantial potential for applications in manufacturing, packaging, and assembly lines, contributing to increased productivity and reduced labour costs.

IX. CONCLUSION

In conclusion, the project exhibits significant potential for industrial integration, offering precision and efficiency in small-scale applications such as medical devices, 3D printing assemblies, and fine component manufacturing. Simultaneously, its scalability and adaptability position it as a valuable asset in large-scale sectors including automotive production, electronics assembly, and warehouse automation.

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