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Robotic Arm for Automated Pick and Place Operations

Meegada Anusha [1,a], Anantha rao Gondu[1,b], Ika Sobha[1,c] ,G Uma Maheswari[1,d], D Prakash[1,e], Juttada Jagadeesh [1,f]

[1]*Avanthi Institute of Engineering & Technology, Cherukupally, Near Tagarapuvalasa Bridge.*

Abstract

This project presents the design and development of a robotic arm for automated pick and place operations utilizing cost-effective and easily accessible electronic components. The system is powered by a 12V battery and controlled by an ESP8266 Node MCU, which enables wireless control via Wi-Fi. The arm's movement is driven by 60RPM 1kg torque DC motors, coordinated through an L298 motor driver module to ensure smooth and precise operation. At the end-effector, a custom 3D printed gripper is integrated for effective object handling, tailored for lightweight and moderate-load applications.The robotic arm is capable of identifying, gripping, lifting, and placing objects from one position to another with minimal human intervention. The wireless capability of the ESP8266 allows for remote operation, enhancing the system's flexibility and applicability in real-world scenarios such as material handling, small-scale automation, and smart manufacturing. This project highlights a compact, modular, and scalable solution for introducing automation in various domains while maintaining affordability and ease of use.

1.INTRODUCTION

Automation has become a key driver in improving efficiency, precision, and consistency across various industries. From manufacturing and packaging to healthcare and warehousing, automated systems significantly reduce the need for repetitive manual tasks, enabling higher productivity and lower operational costs. One of the most common and practical applications of automation is the pick and place mechanism, which involves identifying, gripping, and relocating objects with minimal human intervention[1].

This project aims to design and implement a cost-effective, compact, and functional robotic arm capable of performing basic pick and place operations. It serves as a prototype for real-world industrial applications and as an educational tool for understanding automation, control systems, and robotics[2]. At the heart of the system lies the ESP8266 NodeMCU, a Wi-Fi-enabled microcontroller that offers flexibility in wireless communication, remote control, and reprogramming. This feature makes the robot not only easy to operate but also adaptable to various scenarios, including integration with IoT platforms or remote servers for enhanced functionality[3].

For motor control, the project utilizes the L298N motor driver module, which allows bidirectional control of the DC motors by regulating both speed and direction. The robotic arm's motion is powered by 60RPM 1kg torque DC motors, selected for their balance between strength and speed, making them ideal for moving the arm's lightweight components efficiently[4].

All components are powered by a 12V rechargeable battery, ensuring portability and uninterrupted operation in environments where access to a constant power supply may be limited. The battery setup also supports the system's mobility, making it suitable for use in mobile robotic platforms or dynamic work environments.

2.RELATED WORK

In recent years, the development of robotic arms for automatic pick and place operations has gained significant attention across industries such as manufacturing, packaging, and agriculture. Several researchers and engineers have designed robotic systems to improve precision, speed, and automation in repetitive tasks[5].

For instance, Adebola S.O., et.al. designed a low-cost robotic arm controlled via Arduino for pick and place operations, demonstrating its potential in small-scale industrial applications[6]. Their system utilized servo motors and a basic gripper mechanism to handle lightweight objects effectively. Similarly, Patil C., et.al. developed an image-processing-based robotic arm using Raspberry Pi and OpenCV for object detection and sorting, which highlighted the use of computer vision in enhancing automation capabilities[7].

Moreover, commercial systems such as the UR5 by Universal Robots and ABB's IRB series have set benchmarks in the field, offering high repeatability and integration with advanced control systems. These systems, although costly, exhibit the potential of integrating AI and machine learning for dynamic decision-making and adaptive handling.

The scope of this project includes the design, development, and implementation of a wireless-controlled robotic arm system capable of performing automated pick and place operations with precision, efficiency, and portability. The robotic arm is built using cost-effective components such as the ESP8266 NodeMCU, L298 motor driver, 60 RPM 1kg torque DC motors, and a 3D-printed gripper, all powered by a 12V battery for independent and mobile operation.

EXISTING SYSTEM

In the field of automation and robotics, several existing robotic arm systems have been developed for pick and place applications. These systems are widely used in industries for packaging, assembly lines, sorting, and warehousing. Most traditional robotic arms are built using high-end industrial components, proprietary software, and advanced control systems, making them highly accurate and efficient—but also expensive and complex.

Many existing systems utilize servo motors with feedback mechanisms, programmable logic controllers (PLCs), and computer vision for object detection and placement. These systems are generally tethered to centralized control units and require significant infrastructure and maintenance, limiting their use in small-scale or educational environments.

PROBLEM STATEMENT

In many small-scale industries, educational labs, and startups, there is a growing demand for affordable, compact, and easy-to-use robotic systems that can perform repetitive tasks such as picking and placing objects. However, existing robotic arm solutions are often expensive, bulky, and require complex programming and wired control systems, making them unsuitable for low-budget or portable applications Moreover, most traditional systems lack wireless control, portability, and customizable components, limiting their flexibility and adaptability in different environments. There is a need for a cost-effective, wireless, and battery-powered robotic arm that can perform basic automation tasks efficiently using simple and readily available components.

3. METHODOLOGY

The primary aim of this project is to design and develop a cost-effective, wireless-controlled robotic arm capable of executing automated pick and place operations with a focus on flexibility, efficiency, and simplicity. This robotic arm is intended to function as a compact, standalone system that integrates mechanical motion, embedded control, and wireless communication to achieve precise object manipulation with minimal human intervention.

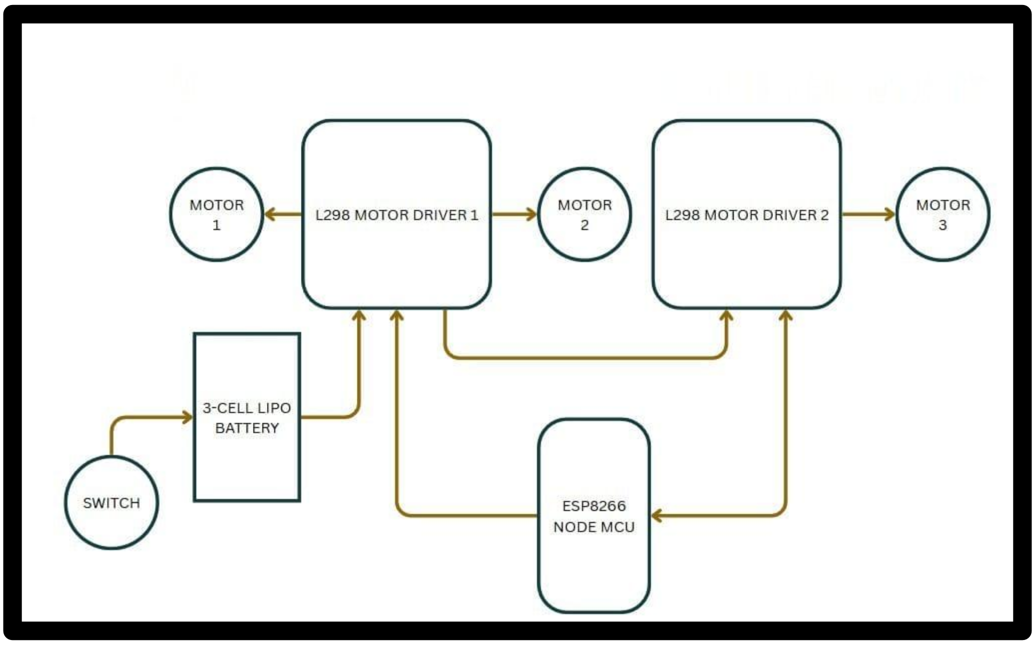

Figure 3.1.: Block diagram

The project utilizes essential components including the ESP8266 NodeMCU, a microcontroller with built-in Wi-Fi capabilities, which allows for wireless programming and real-time remote operation of the system. The movement of the robotic arm is powered by 60 RPM, 1kg torque DC motors, selected for their optimal balance of speed and torque, and controlled through an L298 motor driver. This setup ensures accurate directional control and speed regulation across the arm's various joints and segments.

To design and construct a robotic arm that is capable of performing automated pick and place operations with a high degree of precision, repeatability, and mechanical stability. The arm should be engineered to handle lightweight to moderately heavy objects in a variety of task-specific environments.

To implement wireless control using the ESP8266 Node MCU, a microcontroller with built-in Wi-Fi capability. This allows for remote operation and real-time command execution via a web interface or mobile device, thus eliminating the need for wired control systems and enhancing system flexibility.

To utilize the L298 motor driver module for controlling the **60 RPM, 1kg torque DC motors**, ensuring efficient management of motor speed and rotational direction. This component is critical for enabling coordinated and smooth movements of the arm's joints and segments.

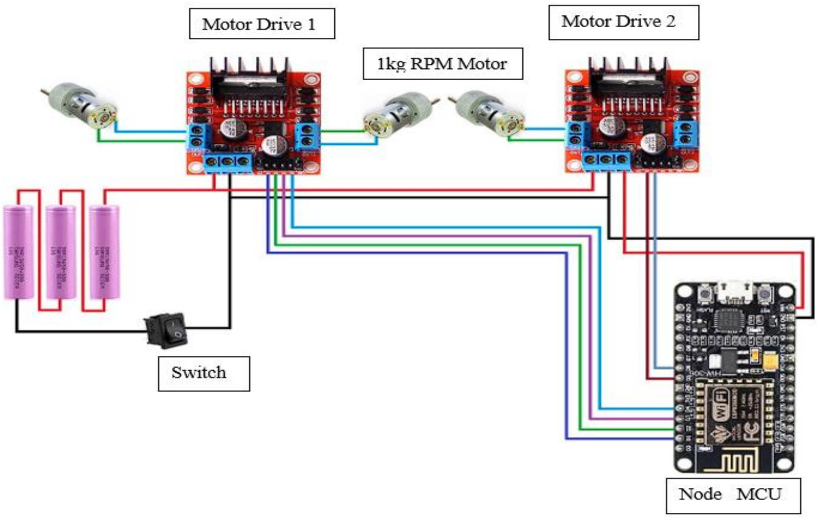

Figure 3.2: circuit diagram

The proposed system is a low-cost, wireless-controlled robotic arm designed to perform automated pick and place operations using easily accessible electronic and mechanical components. The system integrates the ESP8266 Node MCU
as the main control unit, providing wireless connectivity for remote operation via Wi-Fi through a mobile app or web interface.

The robotic arm is actuated by 60RPM 1kg torque DC motors, which offer sufficient speed and torque for moving lightweight objects. These motors are controlled using an L298 motor driver module, allowing precise bidirectional control and speed regulation. A custom-designed 3D printed gripper is mounted at the end of the arm to grip and release objects efficiently. The gripper is lightweight, customizable, and cost-effective, making it ideal for handling various object shapes and sizes

The entire system is powered by a 12V rechargeable battery, ensuring portability and independence from stationary power sources. The wireless functionality of the ESP8266 eliminates the need for physical interfaces, making the system more flexible and easier to deploy in different environments.

4. RESULTS

The developed Robotic Arm for Automated Pick and Place system was successfully assembled and tested using the components: ESP8266 Node MCU, L298N Motor Driver, 60RPM 1kg Torque DC Motors, 3D Printed Gripper, and 12V Battery.

The robotic arm was successfully controlled through Wi-Fi using a web/mobile interface.All four DC motors were driven effectively by the L298N motor drivers.The 60RPM motors provided sufficient torque for stable and accurate positioning.The gripper could securely grip and release lightweight objects.The 12V battery pack powered the entire system efficiently.The robotic arm could perform repetitive pick-and-place cycles successfully, validating its functionality for automation tasks.The system demonstrated consistent performance with good repeatability in object handling.

5.CONCLUSION

The development of the Robotic Arm for Automated Pick and Place using ESP8266 Node MCU, L298N motor driver, 60RPM DC motors, a 3D-printed gripper, and a 12V battery successfully demonstrates a cost-effective and functional automation system. The project showcases the ability to wirelessly control a robotic arm to perform repetitive tasks such as picking and placing objects with reasonable accuracy and reliability.Overall, the project proves the potential for integrating simple electronics with wireless technology to create smart automation solutions, paving the way for future enhancements involving computer vision, AI, and industrial deployment.

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