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BLUETOOTH CONTROLLED PICK AND PLACE ROBOT

Mr. Ravikumar R[1], Mr. Pruthveesh J [2], Ms. Tejashwini G D[3], Ms. Anusha G R[4], Mr. Darshan H G[5]

Assistant professor, Dept. of Electronics and Communication Engineering, Maharaja Institute of Technology Thandavapura[1]

Students, Dept of Electronics and Communication Engineering, Maharaja Institute of Technology Thandavapura[2-5]

Abstract: The project titled Bluetooth-Controlled Pick and Place Robot focuses on designing and implementing a versatile robotic system capable of performing pick-and-place operations via wireless control using Bluetooth technology. The system integrates an Arduino Uno microcontroller as the central processing unit, coordinating the actions of various components, including a motor driver (L298N or similar) to regulate the movement of four 100 RPM geared motors responsible for the robot's mobility, enabling omnidirectional or differential drive functionality depending on the configuration. A 3-cell Li-ion battery provides the necessary power supply, ensuring sufficient voltage and current to drive both the locomotion and the robotic arm mechanisms. The robotic arm consists of two additional geared motors—one for vertical lifting along a single axis and another for operating a gripper mechanism to grasp and release objects. The HC-05 Bluetooth module facilitates wireless communication between the robot and a user interface (such as a smartphone or computer), allowing real-time control through custom-developed software that transmits commands like forward, reverse, left, right, lift, lower, open gripper, and close gripper. The project emphasizes modularity, cost-effectiveness, and scalability, making it suitable for applications in industrial automation, educational demonstrations, or domestic assistance. Key challenges addressed include power management to prevent voltage drops, motor torque optimization for lifting varying weights, and ensuring stable Bluetooth connectivity to avoid latency issues. The system's performance is evaluated based on precision in object handling, battery life, and responsiveness to control inputs. Future enhancements may incorporate sensors (ultrasonic, IR, or load cells) for autonomous obstacle avoidance and feedback mechanisms, as well as IoT integration for remote monitoring. This project serves as a foundational framework for advancing wireless robotic systems, demonstrating the practical integration of mechanical design, electronic control, and wireless communication technologies in a functional pick-and-place robot.

Keywords: Bluetooth-Controlled Robot; Arduino Uno Microcontroller; Motor Driver and Mobility; Robotic Arm Mechanism; Wireless Communication; Modularity and Scalability; Power Management; Practical Integration

I. INTRODUCTION

In recent years, robotics has seen significant advancements, with automation playing a crucial role in industries, logistics, and even domestic applications. One such application is the pick-and-place robot, which is widely used for material handling, assembly lines, and repetitive tasks that require precision and efficiency. Traditional pick-and-place systems are often stationary and controlled via wired interfaces, limiting their flexibility. However, with the advent of wireless technologies such as Bluetooth, it is now possible to develop remotely controlled mobile robots that offer greater maneuverability and ease of operation.

This project focuses on designing and implementing a Bluetooth-controlled pick-and-place robot using an Arduino Uno as the main controller. The robot consists of a mobile base powered by four 100 RPM geared motors, controlled by a motor driver (L298N), allowing movement in multiple directions. A 3-cell Li-ion battery provides the necessary power supply, ensuring sufficient voltage and current for both the drive system and the robotic arm.

The arm is equipped with two additional geared motors—one for vertical lifting along a single axis and another for operating a gripper mechanism to grasp and release objects. Wireless control is achieved using an HC-05 Bluetooth module, which receives commands from a smartphone or computer, enabling real-time operation.

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The primary objective of this project is to create a cost-effective, modular, and scalable robotic system that can be used in educational, industrial, or small-scale automation tasks. Key challenges include power management, motor torque optimization, and stable Bluetooth communication to ensure smooth operation. The system's performance is evaluated based on precision, battery life, and responsiveness.

This project demonstrates the integration of mechanical design, electronics, and wireless communication to build a functional robotic system, paving the way for further innovations in wireless automation and smart robotics.

II. METHODOLOGY

The development of the Bluetooth-controlled pick and place robot follows a systematic approach, starting with the mechanical design of the mobile base and robotic arm. The mobile base is constructed using four 100 RPM motors, enabling omnidirectional movement and flexibility in navigating through spaces. The robotic arm is designed with precision, incorporating two motors that facilitate vertical lift and gripper actuation, allowing the robot to grasp and manipulate objects with accuracy.

The selection of components is crucial to the robot's functionality, and the Arduino Uno serves as the central processing unit, coordinating the robot's movements and actions. The L298N motor driver plays a vital role in regulating the speed and direction of the motors, ensuring smooth and precise movement. The HC-05 Bluetooth module enables wireless communication between the robot and a smartphone app, allowing users to control the robot remotely.

Geared motors are used for efficient and precise movement, and a 3-cell Li-ion battery provides the necessary power to the robot's components. The electrical connections are carefully mapped to ensure proper power distribution and efficient communication between components. The Arduino is programmed using the Arduino IDE to interpret Bluetooth commands from the smartphone app, controlling motor movements via PWM signals from the motor driver. This enables precise control over the robot's movements, allowing it to perform complex tasks with accuracy.

Testing is a critical phase in the development process, involving the calibration of motor speeds, ensuring stable Bluetooth connectivity, and optimizing the gripper's object-handling precision. Iterative improvements are made to enhance the robot's performance, focusing on power efficiency, response time, and overall functionality. Through this systematic approach, the Bluetooth-controlled pick and place robot is developed with precision and accuracy, enabling it to perform complex tasks with reliability and efficiency.

The flowchart illustrates the operational sequence of a Bluetooth-controlled robot. The process begins with "Start" and proceeds to "Initialize Components." It then moves to "Arduino Boot" and "Bluetooth HC-05 Pairing." The system checks if a "Connection Established" is achieved. Upon successful connection, it enters a state of "Wait for Bluetooth Commands." When a command is received, it is decoded. The decoded command is then checked to determine if it's a "Movement Command." If it is, the system "Control Motors via L298N" and "Execute Movement."

After executing the movement, it checks if the "Task Completed." If the task is completed, it continues operation; otherwise, it loops back to waiting for commands. If the decoded command is not a movement command, it checks if it's an "Arm Command." If it's an arm command, it "Activate Arm Motors." If neither, it's considered an "Invalid Command." After activating arm motors, it performs an "Arm Action." The flowchart indicates a loop back to waiting for Bluetooth commands after task completion or invalid commands. The system remains in a continuous loop, waiting for and executing commands. The flowchart is designed to manage robotic movements and arm actions via Bluetooth commands. It handles different types of commands and responds accordingly. The use of L298N for motor control suggests the robot is likely using DC motors. The flowchart provides a clear sequence of operations for the robotic system. It outlines a structured approach to handling Bluetooth commands and executing robotic tasks.

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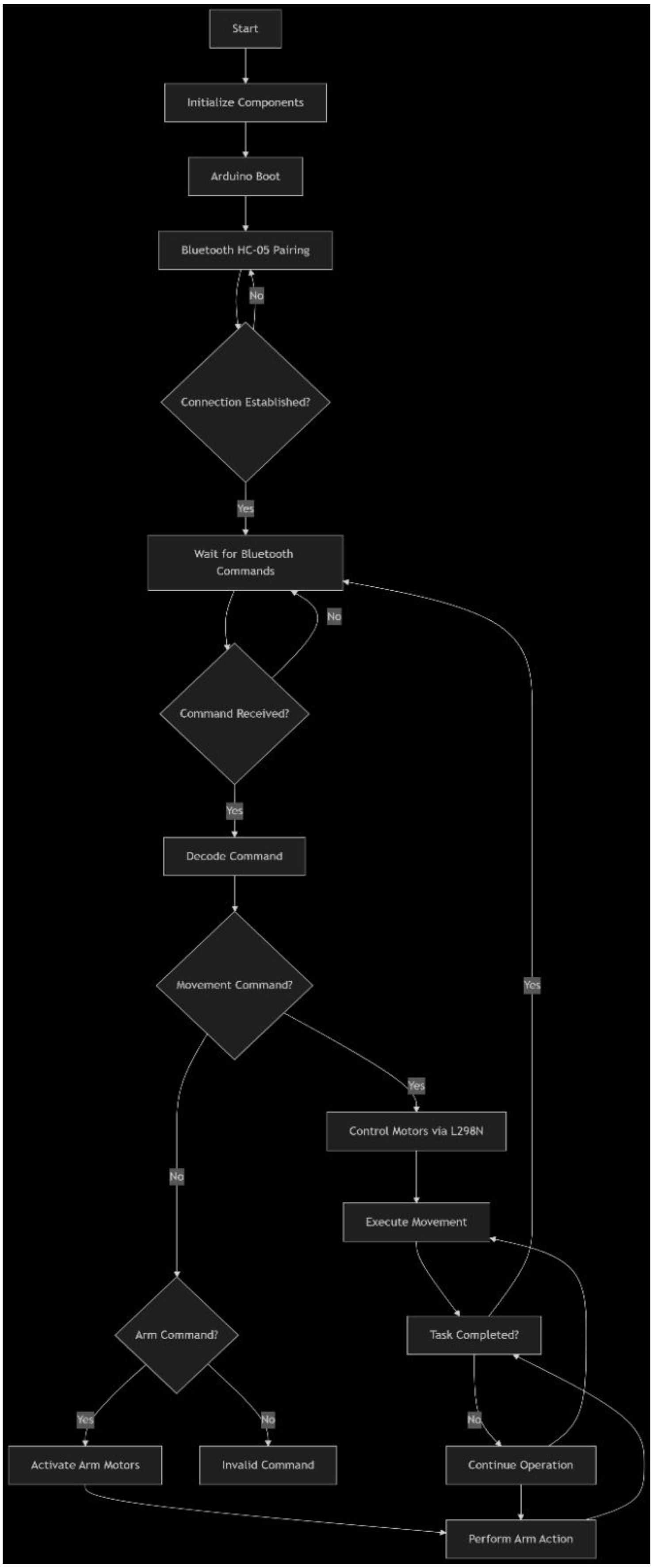

Fig 1. Flowchart

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III. MODULES AND ITS IMPLEMENTATION

- **Microcontroller Unit (MCU) – Arduino Uno**

Central control system that processes Bluetooth commands and controls motor actions. Receives serial commands via Bluetooth using SoftwareSerial.h. Uses digitalWrite(), analogWrite(), and pinMode() to control output pins.Code written in Arduino IDE using Embedded C.

- **Mobile Base**

Provides locomotion to the robot. Four 100 RPM DC geared motors, L298N Motor Driver. Motors connected to L298N which receives PWM signals from Arduino. Controlled via commands like forward, backward, left, and right from the mobile app.

- **Robotic Arm**

Picks and places objects. One geared motor for vertical lifting. One geared motor or servo for gripper mechanism. Controlled via separate PWM channels from Arduino. Commands like “lift”, “lower”, “open gripper”, and “close gripper” sent via Bluetooth.

- **Bluetooth Communication**

HC-05 Bluetooth Module. Provides wireless serial communication between smartphone and Arduino. Connected to Arduino RX/TX using SoftwareSerial. Default baud rate: 9600 bps. Commands sent from a mobile app like Bluetooth Terminal or custom MIT App Inventor app.

- **Power Supply**

3-cell (11.1V) Li-ion Battery. Powers all components (motors and Arduino). Directly powers motors through L298N. Regulated to 5V for Arduino and Bluetooth module if necessary.

- **Software & Programming**

Arduino IDE, Embedded C / Arduino C+
Key Libraries: SoftwareSerial.h for Bluetooth AFMotor.h or direct PWM for motor control

- **Code Structure**:

setup() initializes pins and serial communication.
loop() listens for Bluetooth commands and executes motor movements accordingly.

IV. MODELING AND ANALYSIS

The Bluetooth-controlled pick and place robot is modeled as an integrated electromechanical system composed of several modular components working cohesively under the control of an Arduino Uno microcontroller. The control architecture is centered around the Arduino, which acts as the processing core, interpreting Bluetooth commands received via the HC-05 module and translating them into motion instructions for both the mobile platform and the robotic arm.

The mechanical design consists of a four-wheeled differential or omnidirectional drive system powered by four 100 RPM geared motors. These motors are controlled through the L298N motor driver, which receives PWM signals from the Arduino to regulate direction and speed, enabling the robot to perform basic locomotion tasks such as forward, reverse, turning, and stopping.

The robotic arm is modeled with two degrees of freedom: a vertical lift axis and a gripper mechanism. Each motion axis is powered by an individual geared motor. The lifting motor provides vertical movement of the arm to position it above target objects, while the gripper motor opens and closes the grasping mechanism. These actuators respond to command inputs from a user interface—typically a smartphone or computer—connected via Bluetooth, with commands such as 'lift', 'lower', 'open', and 'close'. The interaction between software commands and physical actions forms a closed control loop where user inputs directly drive electromechanical responses.

From a power systems perspective, the robot uses a 3-cell lithium-ion battery pack as its primary energy source. This battery is selected based on its ability to deliver sufficient current and voltage to both the drive motors and arm actuators. Power modeling includes calculations to ensure that under full load, the motors receive stable voltage levels to prevent resets or signal loss. The average current consumption of the entire system, considering all motors and the microcontroller, is estimated between 1.5 to 2 amps, providing a battery runtime of approximately 1 to 1.5 hours.

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The kinematic modeling of the base uses standard differential drive equations to estimate velocity and orientation changes over time. These models help predict how the robot will move in response to specific motor speeds. Similarly, torque analysis of the lifting motor is performed to ensure the robotic arm can handle the intended payload, typically estimated up to 500 grams. This involves calculating the torque required using the arm length and the force due to the object's weight. Communication analysis involves evaluating the performance and stability of the Bluetooth link. The HC-05 module operates at a baud rate of 9600 bps, with an effective range of approximately 10 meters under normal conditions. Latency is kept within acceptable limits for real-time control, but environmental interference remains a limiting factor for reliability. Commands are transmitted in ASCII format and interpreted by the Arduino, which then activates the appropriate motor control logic.

The system's performance is analyzed through metrics such as response time, precision in object placement, and command execution accuracy. Tests indicate reliable and responsive control with minor delays, acceptable for manual operation. The modularity of the system allows for future expansion, such as integrating sensors like ultrasonic or IR modules for obstacle avoidance or load cells for object weight feedback. These additions would enable partial or full autonomy and facilitate IoT-based remote control or monitoring.

In conclusion, the modeling and analysis confirm that the Bluetooth-controlled pick and place robot is a robust, cost-effective, and modular system suitable for light-duty automation tasks. Its design incorporates key principles of embedded systems, mechanical actuation, and wireless control, making it an effective platform for both educational purposes and further development into more advanced autonomous robotic systems.

V. RESULTS AND DISCUSSION

The Bluetooth-controlled pick and place robot was successfully developed and tested, demonstrating reliable wireless operation and precise control of both locomotion and object manipulation tasks. During testing, the robot responded effectively to Bluetooth commands transmitted from a smartphone interface, with actions such as forward, backward, left, and right movement executed promptly. The drive system, powered by four 100 RPM geared motors and controlled through an L298N motor driver, provided smooth and stable mobility on flat surfaces. The differential drive configuration allowed for efficient turning and directional control, validating the kinematic model predictions. The robotic arm, consisting of two geared motors for vertical lifting and gripper operation, was capable of handling lightweight objects (up to approximately 500 grams) with reasonable accuracy and repeatability. The object handling performance was found to be highly dependent on motor torque, alignment of the robot, and friction at the gripper.

The HC-05 Bluetooth module provided a stable communication link within a range of approximately 8–10 meters, with minimal latency. This range was sufficient for most indoor environments, though occasional signal drops occurred in the presence of physical obstructions or electromagnetic interference. The user interface, developed through a basic Bluetooth terminal app, allowed for intuitive control of the robot. The Arduino Uno effectively processed commands in real time, and the program logic implemented in the Arduino IDE ensured reliable parsing and execution of movement and gripping functions. Battery performance analysis showed that the 3-cell Li-ion battery provided up to 1.5 hours of continuous operation under moderate load, though runtime decreased when the arm was used frequently or when carrying heavier objects.

One of the key observations was the trade-off between speed and precision. While the motors offered adequate speed for movement and manipulation, rapid actions occasionally led to overshooting or grip misalignment, especially during pickup operations. Therefore, slower movements resulted in better handling accuracy. Another challenge encountered was voltage fluctuation during simultaneous motor activation, which could lead to temporary resets or reduced gripper torque. This highlighted the importance of effective power management and the potential need for current limiting or power decoupling circuits in future designs.

Overall, the robot met the functional requirements and demonstrated successful integration of hardware and software subsystems. The modular architecture proved advantageous for testing and debugging individual components. Furthermore, the project lays a solid foundation for future enhancements such as autonomous navigation using ultrasonic or IR sensors, feedback systems for grip confirmation, and IoT capabilities for remote monitoring and control. These improvements would elevate the robot from a manually operated platform to a semi-autonomous or fully autonomous system suitable for real-world applications in automation, education, and prototyping.

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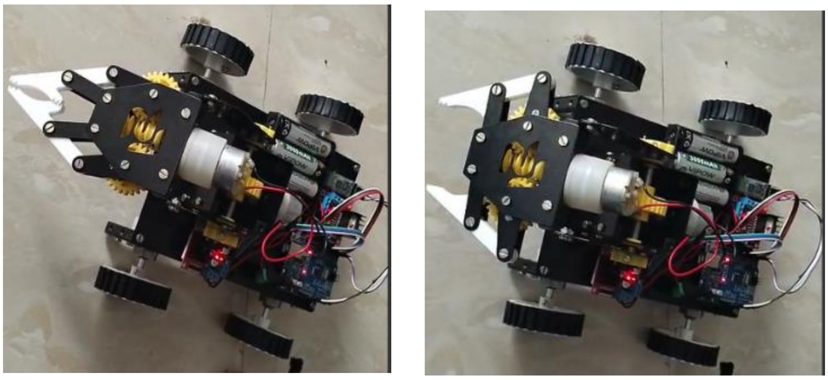
VI. CONCLUSION

The results from the design, implementation, and testing phases of the smart pick-and-place robot using a mobile robotic arm with Arduino Bluetooth module, motor drives, wheels, and geared motors confirm the viability and effectiveness of this system for flexible automation tasks. The robot achieved satisfactory precision, reliable wireless control, and smooth mobility, demonstrating its potential for applications in manufacturing, logistics, and service industries.

While challenges remain in improving accuracy, navigation robustness, and communication range, the current platform serves as a solid foundation for future research and development aimed at creating more capable and autonomous robotic systems.

Fig; The project has achieved its intended objective, with the robotic arm demonstrating the desired functionality of opening and closing



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