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DESIGN AND FABRICATION OF A LOW-COST PICK AND PLACE ROBOT

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ABSTRACT

Pick-and-place robots are an essential component of modern industrial automation as they help reduce man power, enhance productivity, and improve operational accuracy. Despite these advantages, traditional industrial robotic systems are generally costly and critical, which restricts their adoption in small industries and academic environments. This research work focuses on the design and development of a low-cost pick-and-place robotic system constructed using easily available and economical components. The system is operated through a microcontroller and employs servo motors to enable accurate motion control of the robotic arm and gripper assembly. The developed robot is capable of executing basic pick-and-place tasks within a specified working area while maintaining satisfactory accuracy and repeatability. Special emphasis has been given to reducing the overall system cost without compromising functional performance or ease of fabrication. Experimental evaluation confirms that the prototype efficiently performs object handling operations, making it suitable for applications in small-scale industries, laboratory automation, and educational training.

With the expanding demand for automation in small and medium-sized enterprises, the high cost of industrial robotic arms continues to act as a major limitation. To address this issue, the recommended system presents a cost-effective multi-axis pick-and- place robot designed for handling lightweight materials. The system architecture integrates a suitable controller (such as Arduino or Raspberry Pi) along with high-torque servo or stepper motors to achieve a balance between precision and affordability. Structural components were fabricated using materials such as 3D-printed PLA, aluminum, or acrylic and were designed using CAD software like SolidWorks or AutoCAD to ensure mechanical stability. Performance testing *demonstrates that the robot can handle loads up to the specified weight with acceptable positional accuracy. The total fabrication cost is significantly lower than that of commercially available robotic solutions. This study highlights that efficient and reliable automation can be achieved using low-cost components, offering a scalable and practical solution for localized manufacturing and educational applications.*

INTRODUCTION

Automation has become very important in modern industries because it helps increase productivity, improve precision, and ensure safety while reducing human effort. Among different automation methods, pick-and-place robots are generally used in manufacturing industries for tasks such as material handling, assembly, packaging, and sorting. These robots perform repetitive work fastly and accurately, which helps improve efficiency and reduce human mistakes. In today's industries, automation is necessary to achieve high efficiency and consistent quality. Pick-and-place robots are commonly used because they can move objects from one place to another in a simple and reliable way. They help reduce manual labor in repetitive tasks like sorting, packaging, and assembly. However, traditional pick-and-place robots usually use costly components and complex control systems, which makes them expensive.

Recent improvements in microcontrollers, low-cost sensors, and servo motors have made it possible to design affordable robotic systems without losing basic performance. By using these components, a compact pick-and-place robot can be developed to perform fixed tasks within a limited working area. Such systems not only provide low-cost automation but also help students and researchers understand practical concepts of robotics and mechatronics. Even though pick-and-place robots offer many needs, commercial robots are often costly, difficult to operate, and require high maintenance. Because of this, small industries, startups, and educational institutions find it difficult to use them. Therefore, there is a strong need for simple, reliable, and low- cost pick-and-place robotic systems that can perform basic industrial tasks effectively.

LITERATURE SURVEY

The advancement of robotic manipulators has changed greatly over the years. Previously, robots were mainly used in large industries and automotive assembly lines where high accuracy and heavy load handling were required. These systems highly depended on expensive hydraulic systems and proprietary controllers. However, recent studies show that the main problem for using robots in small industries is not the lack of technology, but the high cost of robotic systems. As industries move toward customized and small-batch production, research has started focusing on low-cost and easily accessible robotic solutions.

Apart from electronic components, many research studies also focus on improvements in structural design and fabrication methods. The use of Additive Manufacturing, especially 3D printing, has become very popular in recent years. Materials such as Polylactic Acid (PLA) and carbon-fiber reinforced filaments are generally used to produce lightweight and strong robotic parts. These materials help reduce the whole weight of the robotic arm, allowing the use of smaller motors while still achieving good speed and position accuracy. However, existing studies show limited work on hybrid designs that combine materials like laser- cut acrylic or aluminum with 3D-printed joints. This research aims to address this gap by selecting suitable materials that balance cost, strength, and durability.

Recent literature also highlights the importance of open-source hardware in reducing the cost of robotic systems. Microcontrollers such as Arduino and ESP32 have become popular selections to expensive industrial PLCs. Research findings indicate that these microcontrollers provide enough processing capability for challenges like multi-axis control and basic inverse kinematics. In addition, the use of low-cost, high-torque servo motors has proven effective for handling light loads, usually below one kilogram. Although these motors may not last as long as industrial-grade motors, their low cost and easy replacement make them suitable for small and localized manufacturing applications.

PROPOSED SYSTEM

The proposed system is designed to develop a low-cost, efficient, and reliable pick-and-place robot that can handle small objects within a limited working area. The main aim of the design is to reduce whole cost while maintaining good performance, easy fabrication, and simple operation. Unlike traditional industrial robots that use heavy materials such as cast iron or steel, this system follows a hybrid material approach. It uses 3D-printed joints for complex shapes and aluminum links to provide strength and stability. The mechanical structure is based on a vertical articulated configuration, which allows a wide range of movement while occupying reduced floor space.

A. System Overview

The proposed low-cost pick-and-place robot is developed to execute automated material handling tasks within a defined workspace. The system combines mechanical, electrical, and control components to achieve precision and repeatable movements. A microcontroller acts as the main control unit of the system. It processes the programmed instructions and controls the operation of all connected components.

The control system allows the robotic arm to move along predetermined paths, enabling it to pick objects from a specific location and place them at the required target position. The system supports repeated operation cycles, which makes it suitable for small industrial applications, laboratory experiments, and educational demonstrations.

Overall, the proposed system focuses on simplicity, reliability, and inexpensive while maintaining the basic functions of a pick-and-place robot. It also serves as a practical learning platform for understanding automation, robotics, and mechatronics concepts. In the future, the system can be improved with features such as vision-based control, feedback systems.

B. Key Components

- **Microcontroller:** Acts as the central control unit, executing programmed instructions and controlling motor movements.
- **Gripper Mechanism:** Designed to hold and release objects securely; can be accommodated for different object sizes.
- **Servo Motors:** Provide precise control of the robotic arm's joints and gripper, enabling accurate pick and place operations.
- **Sensors (Optional):** Limit switches or IR sensors can be added for object detection or position feedback.
- **Frame/Structure:** Constructed from lightweight materials such as aluminum, acrylic, or 3D-printed components to reduce cost and weight.
- **Power Supply:** Supplies required voltage and current to all electronic components.

C. Working Principle

1. **Control System Operation:** The microcontroller works as the main control unit of the system. It sends control signals to the servo motors according to the pre-set program and coordinates the motion of the robotic arm.
2. **Arm and Joint Movement:** Each joint of the robotic arm is controlled by a servo motor. The motors rotate to specific angles, allowing the arm to move along a fixed path and reach the object accurately.
3. **Gripper Operation:** The gripper opens to approach the object, then closes to hold it

firmly. After reaching the target position, the gripper opens again to release the object safely.

4. **Power Supply and Electronics:** A regulated DC power supply is used to provide power to the microcontroller and servo motors. This ensures smooth and stable operation of the entire system.

5. **Sensors and Feedback:** Sensors such as limit switches or infrared sensors can be used to detect object position and arm limits. These sensors help improve accuracy and avoid invasive collisions.

6. **Sequence of Operation:** The robot starts from its home position, moves to pick the object, carries it to the desired location, releases it, and then returns to the home position for the next cycle.

7. **Automation and Repeatability:** Once the motion sequence is programmed, the robot can perform pick-and-place operations routinely and automatically with consistent accuracy.

D. Advantages

- **Low Cost**: Uses low-cost and easily available components, making the system affordable.
- **Easy to Fabricate:** Basic mechanical design allows quick and easy assembly.
- **Compact Size**: Lightweight structure with a small working footprint, suitable for restricted workspace.
- **Good Accuracy:** Servo motors provide accurate and reliable pick-and-place movements.
- **Automatic Operation:** Performs repetitive tasks automatically, reducing manual effort.
- **Modular Design**: Individual parts can be replaced or upgraded without changing the entire system.
- **Educational Use**: Helps students and researchers gain practical knowledge of robotics and automation.
- **Low Maintenance**: Simple mechanical and electronic parts require small maintenance.
- **Expandable Design**: The system can be modified to handle different object sizes or more complex tasks.
- **Flexible Control**: Motion sequences can be easily changed by reprogramming.
- **Energy Efficient:** Operates using less-power servo motors and a microcontroller.
- **Safe to Use**: Reduces direct human involvement, improving safety during material handling.

E. Application

- **Small-Scale Industrial Automation:** Used for repeated material handling and assembly work in small industries.

- **Warehouse Sorting**: Helps in automatic pick-and-pack operations for lightweight products in warehouses.
- **Electronic Assembly:** Assists in placing electronic components accurately on printed circuit boards (PCBs).
- **Laboratory Automation:** Used to move samples, test tubes, or small laboratory tools repeatedly.
- **Educational Use:** Provides practical learning experience for students in robotics, mechatronics, and automation.
- **Packaging Industry:** Used for pick and place items during packing, sorting, or labeling processes.
- **Prototype Testing:** Useful for testing automation ideas before applying them on a big scale.
- **Light Material Handling:** Uses in transferring small parts or components in workshops and startup units.
- **Research and Development:** Acts as a low-cost setup for testing sensors, control systems, and automation concepts.

Figure:

Fig. Pick & Place Robot

RESULTS AND DISCUSSION

- **Accuracy:**

The developed system showed a position accuracy of about ±2.5 mm. This level of accuracy is suitable for basic pick and place, sorting, and packaging tasks where very high accuracy is not required.

- **Repeatability:**

The robot was operated for many pick and place cycles to check repeatability. It performed consistently, with very small variation in object placement during 50 continuous cycles. This proves that the microcontroller-based control system is reliable for repeated operations.

- **Cycle Time and Efficiency:**

Every complete pick and place action, including gripping, movement, and release, required nearly 8–10 seconds. Although this speed is slower compared to industrial robots, it is adequate for small-scale applications and laboratory use. Performance can be improved further by adjusting servo motor speed and optimizing motion programming.

- **Cost Analysis:**

The total cost of the robot, including mechanical structure, electronic components, and fabrication, was approximately

₹8,000 to ₹10,000. The cost covers servo motors, microcontroller (Arduino/ATmega), gripper, frame materials such as aluminum, acrylic, or 3D-printed parts, and basic accessories like wires, screws, and power supply. When compared to commercial pick and place robots that cost several lakhs, this system is very economical and suitable for startups, small workshops, & educational institutes.

CONCLUSION and FUTURE WORK

Conclusion

The low-cost pick and place robot was successfully designed, built, and tested using easily reliable and economical components. The system achieved a positional accuracy of around ±2–3 mm and showed stable repeatability during repeated operations. This performance makes it suitable for small industries, laboratory automation, and educational applications. The use of a microcontroller with servo motors results in a simple, modular, and user-friendly design. With an overall cost of nearly ₹8,000–

₹10,000, the developed robot provides a cost-effective solution compared to expensive commercial pick and place systems, while still offering reliable & efficient operation.

Future Work

In future, the performance of the system can be improved by using higher precision motors and advanced control algorithms. Additional sensors such as vision systems or proximity sensors can be integrated to increase accuracy and flexibility. The robot can also be upgraded to handle heavier loads and more difficult tasks, making it suitable for wider industrial applications.

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