# DESIGN AND DEVELOPMENT OF PICK AND PLACE COLLABORATIVE ROBOT

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**Abstract -** *This project, "Design and Development of a Pick-and-Place Collaborative Robot," aims to address the increasing demand for efficient and reliable automation solutions by creating a compact, user-friendly, and cost-effective robotic arm for educational purposes. The focus is on developing an Internet of Things (IoT)-based pick-and-place robotic arm that integrates both electronic and electrical engineering principles. Utilizing the Arduino microcontroller and the ESP8266 module from Microchip Technology, the project seeks to control all robotic activities with precision. The designed robot is capable of performing tasks that are either challenging or hazardous for humans, thereby expanding the scope of automation in various fields. This collaborative robot not only demonstrates the potential of robotics in simplifying complex tasks but also serves as an educational tool to enhance learning and understanding of robotics and IoT technologies. By prioritizing compactness, usability, and affordability, the project aims to make advanced robotic solutions accessible for educational institutions and hobbyists, fostering innovation and practical knowledge in the field of robotics.*

***Key Words*: Collaborative Robot, IoT Based, Robotics, Automation, Worker safety, Efficiency, Arduino, ESP8266, Pick-and-place mechanism.**

## 1. INTRODUCTION

In today's rapidly evolving technological landscape, the demand for efficient and reliable automation solutions is greater than ever. Among these advancements, pick-and-place collaborative robots have emerged as vital components of modern industry. These mechanical systems are specifically designed to transfer objects from one location to another with precision and efficiency. Structurally, they resemble human arms, consisting of multiple segments connected by joints and equipped with motors, sensors, and grippers. This configuration allows them to perform tasks with a level of accuracy and control that is difficult to achieve manually. The operation of pick-and-place collaborative robots is guided by various input methods, such as computer interfaces or remote controls, enabling them to execute movements in a controlled manner. The grippers of these robotic arms are designed to securely grasp objects, allowing the robot to move them to different locations reliably. This functionality makes them indispensable in industries like manufacturing, logistics, and assembly lines, where they automate repetitive tasks and contribute to significant time savings and reductions in human error. The versatility of pick-and-place robots is evident in their ability to handle a wide range of objects, from small, delicate components to larger, more cumbersome items. Their implementation in industrial processes enhances productivity and operational efficiency, showcasing their potential to revolutionize traditional workflows. As technology continues to advance, the design and development of these robots are focused on making them more compact, user-friendly, and cost-effective, thereby extending their accessibility and applications across various fields. This project aims to contribute to this ongoing innovation by developing an IoT-based pick-and-place robotic arm for educational purposes, leveraging the Arduino microcontroller and the ESP8266 module to achieve a high level of control and functionality.

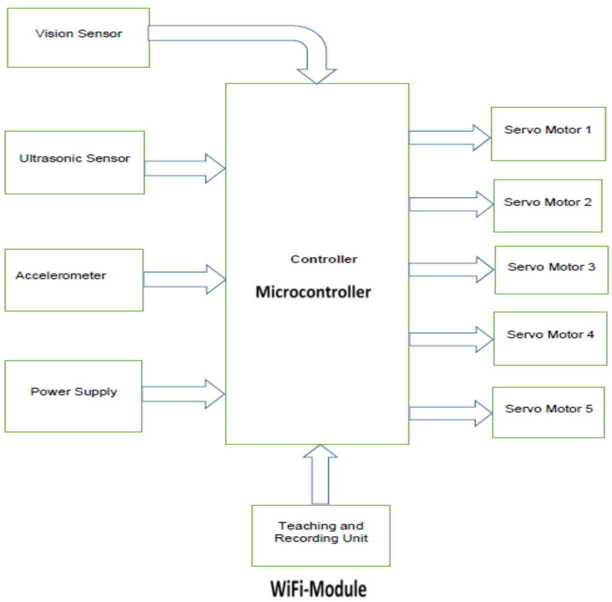


**Fig -1: Block Diagram**

## 2. Hardware

### 2.1 ESP8266

Node MCU is built on the mature ESP8266 technology to take advantage of the abundant resources available on the web. Node MCU has ESP-12-based serial Wi-Fi integrated onboard to provide GPIO, PWM, ADC, I2C, and 1-WIRE resources. It also has a built-in USB-TTL serial with super-reliable industrial-grade CH340 for superior stability on all supported platforms. This module is one of the cheapest available Wi-Fi modules on the market. V3, or Version 3, is the latest version of this module. This tutorial, however, will facilitate connecting all the versions of ESP8266 Node MCU, i.e., V1, V2, or V3.

**Fig -2 Node MCU**

### 2.1.2 Specifications

| | |
|---|---|
| **Microcontroller** | Tensilica 32-bit RISC CPU Xtensa LX106 |
| **Operating Voltage** | 3.3V |
| **Input Voltage** | 7-12V |
| **Digital I/O Pins (DIO)** | 16 |
| **Analog Input Pins (ADC)** | 1 |
| **Flash Memory** | 4 MB |
| **SRAM** | 64 KHZ |
| **Clock Speed** | 80 MHZ |

### 2.2 Servo driver- PCA9685

PCA9685 servo driver for controlling a pick and place robot arm offers a convenient and efficient way to manage multiple servo motors. The PCA9685 is a 16-channel, 12-bit PWM (Pulse Width Modulation) servo driver. It's commonly used to control servo motors, LEDs, and other devices that require precise timing. Each channel of the PCA9685 can generate a PWM signal independently, making it suitable for controlling multiple servo motors simultaneously.

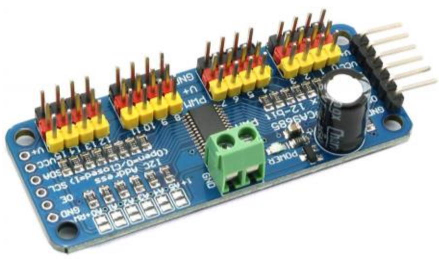

**Fig -3: Motor Driver**

### 2.2.1 Specifications

| | |
|---|---|
| **MCU operating voltage** | 3.3 V / 5 V |
| **PWM supply voltage** | 2.3 V ~ 5.5 V |
| **Input tolerance** | 5,5 V |
| **Output current per LED pin** | 25 mA |
| **Grounding** | 400 mA |
| **Operating temperature** | -40 ~ 85℃ |
| **Interface** | I2C |

### 2.3 Arduino Mega:

The Arduino Mega is a microcontroller board based on the ATmega2560. It has 54 digital input/output pins (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It's one of the most powerful boards in the Arduino family, suitable for projects requiring a large number of inputs and outputs or more complex processing tasks. With its extensive capabilities, it's often chosen for projects involving robotics, automation, and data acquisition. The Arduino Mega is a highly versatile microcontroller board renowned for its expansive array of input/output (I/O) capabilities, making it an ideal choice for projects demanding a rich assortment of sensors, actuators, and communication interfaces. Powered by the ATmega2560 microcontroller chip, it boasts a robust architecture featuring 54 digital I/O pins, of which 15 are capable of producing Pulse Width Modulation (PWM) signals, facilitating nuanced control over motors, LEDs, and servos. Additionally, the Mega incorporates 16 analog input channels, enabling precise measurement of physical phenomena such as temperature, light intensity, and voltage levels.

**Fig -4: Arduino Mega**

## 3. LITERATURE REVIEW

Ganesh U L, et.al. Showed the usage of mechanical drainage cleaner to replace the manual work required for drainage cleaning system. Drainage pipes are very dirty. Sometimes it is harmful to human life while it is needed for cleaning drainage systems. To overcome this problem, they implemented a mechanical semi-automatic drainage water cleaner, and the water flow is efficient because of the regular filtration of waste with the help of that project. Different kinds of environmental hazards are reduced with the help of a drainage system machine.

Elangovan K., et al. reviewed drainage cleaning to replace manual work with an automated system because manual cleaning systems are harmful for human life and cleaning time. To overcome this problem, they implemented an "automatic drainage water pump monitoring and control system using PLC and SCADA." PLC and SCADA were designed. In this project, we will use an efficient way to control the disposal of waste regularly.

NDUBUISI C. Daniels et al. showed the drainage system cleaner machine used to remove garbage and sewage automatically, which helped to protect the environment from different kinds of environmental hazards. The drainage system cleaner has three major parts, which are the propeller, the cleaner, and the pan, all of which make up for its effective functioning.

Prof. S.D. Anap et al. showed blockage is the major cause of pollution and flooding in metro cities. They have designed the drainage blockage detection system to avoid such problems. The system provides monitoring of drainage conditions and informs authorities of these conditions. This design presets an implementation of a wireless sensor network for the monitoring of drainage systems using a GSM system. To detect blockage and monitor it, Juha Latvala et al. aim to find out whether systematic improvement of drainage can produce significant savings in rail network maintenance.

## 4. MECHANICAL DESIGN

In designing machine components, it is necessary to have a good knowledge of many subjects such as Mathematics, engineering mechanics, strength of materials, theory of machines, and Engineering Drawing. Machines are always the same, they have combination of linkages, gears,and other mechanics and by which we make a complete mechanism to achieve a certain task.

**1. Selecting Robotic Arm Type:** The choice of robotic arm type depends on various factors such as the application, workspace constraints, payload requirements, and desired precision. For instance, if the application requires high-speed and precise movements within a small workspace, a SCARA or delta robot might be suitable. Conversely, for tasks requiring a larger workspace and flexibility in movement, an articulated or Cartesian robot might be preferred.

**2. Linkage Design:** The linkage design involves determining the number of joints and their arrangement to achieve the desired range of motion. This typically includes joints such as revolute (rotational) or prismatic (linear). Using CAD software, engineers can simulate the movement of the robotic arm to optimize the design for factors like reach, speed, and workspace utilization.

**3. Actuators and Motors:** The selection of actuators or motors depends on the specific requirements of each joint, including torque, speed, and precision. Servo motors are commonly used for their precise control and feedback capabilities, while stepper motors offer precise positioning but may lack the same level of feedback. Factors such as power consumption, size, and cost also influence the choice of actuators.

**4. End Effector:** The end effector, or gripper, is crucial for the pick and place operation. The design of the gripper depends on the objects being handled, their size, shape, and weight. For example, a robotic arm used in manufacturing may require a gripper with interchangeable fingers or suction cups to handle different types of parts efficiently. The gripper design should also consider factors like gripping force, compliance, and release mechanism.

**5. Frame and Base:** The frame and base provide structural support for the robotic arm and must be designed to withstand the loads and stresses experienced during operation. Engineers need to consider factors such as material selection, stiffness, and vibration damping to ensure smooth and accurate movement. Additionally, the base should be stable and securely anchored to the working surface to prevent tipping or instability.

**6. Mechanical Interfaces:** Mechanical interfaces are required for mounting sensors, cameras, and other accessories used for IoT functionality. These interfaces should be designed to accommodate the specific requirements of each component while ensuring proper alignment and accessibility for maintenance. Cable management systems can help organize and protect wiring, reducing the risk of interference or damage during operation.

**7. Safety Features:** Safety features are essential to protect both the robotic arm and its surroundings from accidents or damage. Limit switches can be used to define safe operating limits for each joint, while emergency stop buttons provide a quick way to halt operation in case of an emergency. Collision detection sensors can prevent collisions with obstacles or other objects in the workspace, reducing the risk of damage or injury.

## 4. METHODOLOGY

The methodology for developing the IoT-Based pick and place collaborative robot involves a systematic approach that encompasses several key phases, including research, design, development, testing, and implementation. Below is a detailed methodology outlining the steps involved:

**1. Research and Requirements Gathering:** Conduct a thorough literature review to understand existing technologies, methodologies, and best practices related to pick and place collaborative robot, Internet of Things, robotics, and automation. Identify and analyze the specific requirements and challenges associated with pick and place operation, including safety concerns, environmental factors, and cleaning efficiency metrics. Define clear project objectives and scope based on the research findings and stakeholder input.

**2. Design Phase:** Develop detailed design specifications for the pick and place collaborative robot, including mechanical, electrical, and software components. Design the mechanical structure of the robot, including the base of the robot, robotic arm, and gripper mechanism, ensuring compatibility with motor integration and smooth movement and payload requirements. Design the electrical system, specifying components such as motors, actuators, microcontrollers, controller and power supply units. Design the software architecture, outlining algorithms and control strategies for autonomous operation.

**3. Development Phase:** Construct a physical prototype of the pick and place collaborative robot based on the design specifications, integrating mechanical, electrical, and software components. Develop the pick and place collaborative robot using PLA material, 3-D print the parts using Raptor Lmg Mk 2 3-D printer, develop software interfaces for data acquisition and processing. Implement the robotic arm mechanism and pick-and-place functionality, including teach function algorithms to repeat the process.

**4. Testing and Validation:** Conduct comprehensive functional testing of the pick and place collaborative robot to verify its performance and functionality according to the design specifications. Evaluate the performance of the robot in simulated and real-world industrial environments, assessing factors such as pick and place operation accuracy, teach function, maximum payload testing, and maximum wireless communication radius. Perform safety testing to ensure compliance with safety standards and regulations, particularly regarding worker safety and environmental protection. Iterate on the design and software algorithms based on testing feedback to optimize the performance and reliability of the robot, Deployment and Maintenance. Develop plans for deploying the pick and place collaborative robot in real-world industries, including deployment logistics, operational procedures, and user training. Establish procedures for ongoing maintenance, troubleshooting, and software updates to ensure the continued functionality and effectiveness of the robot in long-term operation. Monitor and evaluate the performance of the deployed robot, collecting feedback from users and stakeholders to identify areas for improvement and refinement.

## 5. RESULTS AND DISCUSSION

### 5.1 Software Requirements:

#### 5.1.1 Robot Arm Controller Application:

The Robot Arm Controller is a platform for building IoT applications without complex coding. It allows you to create a user interface for your IoT devices and provides a way to remotely monitor and control their usage in the system. Robot Arm Controller can be utilized to create a user-friendly mobile application interface for users to set up each control of the motor, start and stop the process, and teach function wirelessly from any distance.

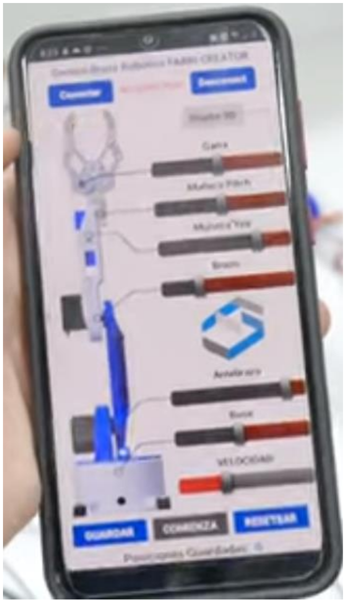

**Fig -5: Robot Arm Controller**

#### 5.1.2 Arduino IDE

The Arduino Integrated Development Environment (IDE) is a software platform used to write and upload code to Arduino boards. It provides a user-friendly interface for writing, compiling, and uploading code to your Arduino board. The IDE supports a simplified version of the C++ programming language, making it accessible for beginners while still powerful enough for more advanced users.

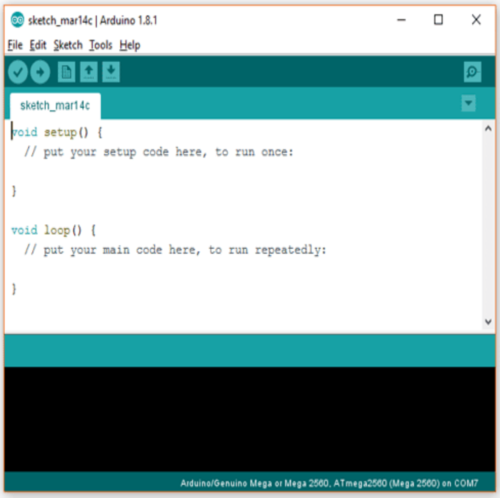


**Fig -6: Arduino IDE**

### 5.2 FINAL OUTPUT

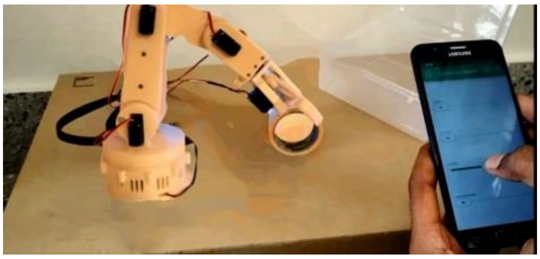

**Fig -7: Robotic arm controlled using Robot controller**

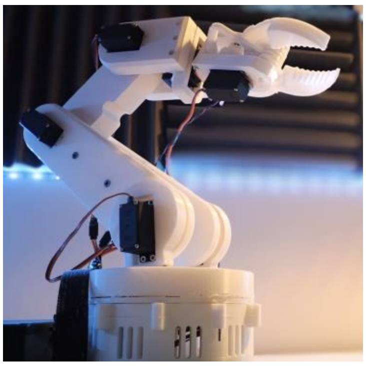

**Fig -8: Pick And Place Collaborative Robot**

## 6. CONCLUSION

A novel robotic arm which is robust and light with six degrees of freedom and can be re-programmed for various applications has been developed. This robotic arm uses Arduino controller and is especially developed for pick and place applications. The design is compact and cheap and has been proven practically also. However the present paper has discussed only the modelling aspect of the robot and various parts of the assembly. The experiments are conducted on the pick and place robot and the results obtained were very satisfactory. Motors with higher torque ratings can used to power the joints so as to ensure that the robotic arm remains in position even when electric current is not supplied to the motors. Object detection and collision avoidance can implement by adding proximity sensors to the robotic arm.

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