

# ROBONEX – The AI Powered Pick & Place Robot

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**Abstract** - This paper presents Robonex – The AI Powered Pick & Place Robot developed through the integration of embedded systems and computer vision. The proposed robot is designed to detect the specified object, grasp it using four degree of freedom gripper, and autonomously navigate to place it at defined goal position. The robot is built on a four wheel drive mobile base having path following and obstacle avoidance capabilities to enable reliable navigation. The system has been physically implemented and subjected to continuous testing to evaluate its operational feasibility. This paper outlines the overall system architecture, including the embedded hardware and vision components, and discusses the successful execution of autonomous pick and place operations by the developed system.

**Keywords:** Pick and place operations, computer vision, embedded systems, robotic gripper (4-DOF), autonomous navigation.

## I. INTRODUCTION

In today's rapid advancements in Industry 4.0, the demand of pick and place robots, capable of performing repetitive & flexible tasks with high precision is increasing. Conventional pick-and-place robots are able to do the fixed assembly line task which limits their flexibility, while working in dynamic environment. Using the AI & computer vision capabilities, it is possible to make autonomous decisions, with minimal human interventions.

This paper focuses on developing an AI powered pick and place robot, while exploring the potential of AI and computer vision. The main objective of this project is to focus on practical implementation and feasibility of combining embedded technology with vision guided perception. The robot is designed to detect specified object using the visionbased technique, navigate to place it with obstacle awareness, using four degree-of-freedom gripper.

### 1.1 Project Aims and Objectives

The project aims and objectives which will be achieved after the completion of the project are discussed in this subsection.

- To develop an autonomous system that is capable of performing the detection of target object using vision-based technique.
- To design the mobile platform that can navigate along a defined path while avoiding obstacle.
- To implement four-degree-of-freedom gripper mechanism for stable object grasping and placement.
- To achieve coordinated operation between vision processing and embedded control units.
- To experimentally evaluate the system through physical implementation and continuous testing.

### 1.2 System Objectives

**Provide Autonomous Pick-and-Place Operation:** Enable the robotic system to autonomously detect a specified object, perform grasping using a four-degree-of-freedom and place the object at a defined without human intervention.

**Accurate Object Recognition:** Utilize deep learning-based computer vision technique to accurately identify cube-shaped target objects from visual input with minimal detection errors.

**Real Time System Response:** Ensure real-time processing of visual data and control commands, allowing the robot to respond promptly during object detection, navigation, pick and- place tasks.

**Reliable Navigation and Obstacle Avoidance:** Support safe and efficient movement through path following mechanisms combined with obstacle detection and avoidance to operate effectively in structured environment.

**Integrated and Stable System Performance:** Achieve seamless coordination between vision processing, embedded control and mechanical actuation to maintain consistent and reliable performance during continuous pick-and-place operations.

## II. COMPONENTS

This section describes the components that played major role in achieving the objective of the Robonex as follows:

**i) Arduino Uno:**

Arduino Uno is a microcontroller board based on ATmega32P architecture. It is preferred due to its ease of use and digital as well as analog input/output pins, pulse width modulation and the serial communication support. It is programmed using Arduino IDE (Integrated Development Environment) and can upload the program in arduino to communicate with other components.



Figure 1: Arduino Uno

**ii) Raspberry Pi 4 Model B:**

Raspberry Pi 4 Model B – 8GB is high performance single board computer consist of quad-core ARM Cortex-A72 processor. It has various interfaces such as USB, GPIO, and CSI camera interface can utilize for peripheral integration. This board operates on Raspberry Pi OS, responsible for object detection algorithm, processing image data acquired at the real time.



Figure 2: Raspberry Pi 4 Model B

**iii) Raspberry Pi NoIR Camera V2:**

The Raspberry Pi NoIR (No Infrared Filter) Camera V2 is 8 megapixel camera module. It is designed for compatibility with Raspberry Pi boards. The NoIR camera is preferred as it allows enhanced low-light image capture. It is utilized for real time image acquisition in the object detection phase.



Figure 3: Raspberry Pi NoIR Camera V2

**iv) MG90S Servo Motor:**

MG90S servo motor is a metal-gearred micro servo motor capable of delivering 1.8kg.cm – 2.2 kg.cm torques. It operates on the basis of PWM (Pulse width Modulation) and supports angular rotation suitable for precise positioning applications. It works at 50 Hz rate and requires operating voltage between 4.8V to 6.0V.



Figure 4: MG90S Servo Motor

**III. METHODOLOGY**

Robonex – The AI Powered Pick and Place Robot based on the integration of embedded system and computer vision. This section describes the proposed methodology and the architecture as shown in Figure 5.

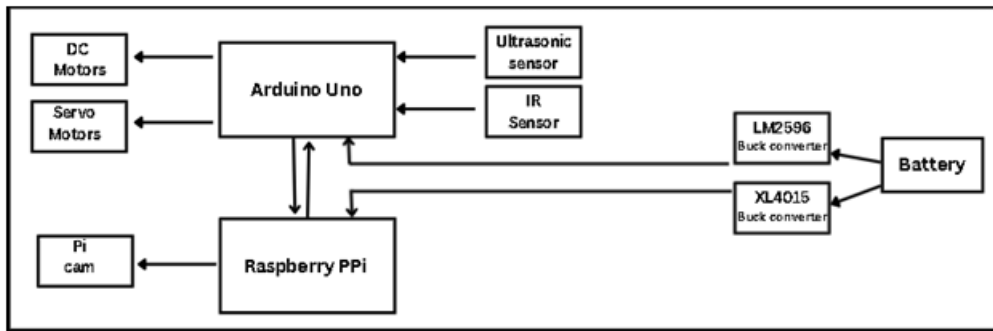


Figure 5: Robonex Architecture

**i) Development Approach:**

The project began with the requirement analysis and system planning followed by component selection, mechanical assembly, subsystem integration. To enable the progressive enhancement of system functionality a modular development strategy is adopted. For this it divides into three sub-phases to ensure reliability and ease of debugging.

**ii) Phase 1 - Navigation and Obstacle Avoidance:**

This is the first phase focusing on the autonomous movement of the robot using path following and obstacle avoidance mechanism. For this infrared sensor utilized for path detection to follows the trajectory. Ultrasonic sensor integrated to detect obstacle present in robot’s path. Based on the real time sensor feedback and control logic implemented to adjust motor actions. This phase served as the foundation for the subsequent development stages.

**iii) Phase 2 - Object Detection and Inter-Controller Communication:**

The second phase addressed vision-based object detection and serial communication between raspberry pi and arduino processing units. For this OpenCV and custom trained YOLO v8 deep learning model employed for detecting cube shaped target objects from camera input. In this raspberry pi handled the vision processing and decision making tasks, while actuator control was done by arduino. This phase has enabled real time perception and coordination between vision and motion of the robot.

**iv) Phase 3 - Gripper Integration and System Calibration:**

In the third phase of development four degree-of-freedom robotic gripper designed, and integrated with the robot. Servo motors used to control individual joints of the gripper, to enable the precise grasping and release of objects. Control algorithm with inverse kinematic implemented to synchronize the gripper grasping and robot’s navigation. Calibration

procedure performed to align the sensor reading, camera based object detection, gripper movement and navigation.

**v) Continuous Testing and Validation:**

The fully integrated system then subjected to continuous and rigorous testing under controlled condition. Multiple pick and place cycle done to evaluate the navigation and detection and object grasping. This iterative validation process ensured the feasibility and operational reliability of the robot.

**IV. RESULTS AND OUTPUTS**

The Robonex has successfully achieved objective of autonomous object detection, navigation along with the pick and-place of the object. The system has demonstrated coordinated pick and place operations without manual intervention.

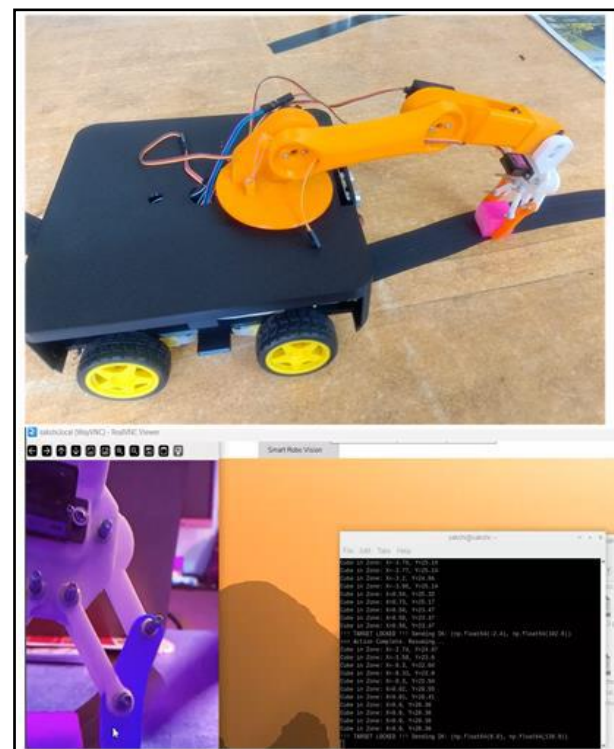
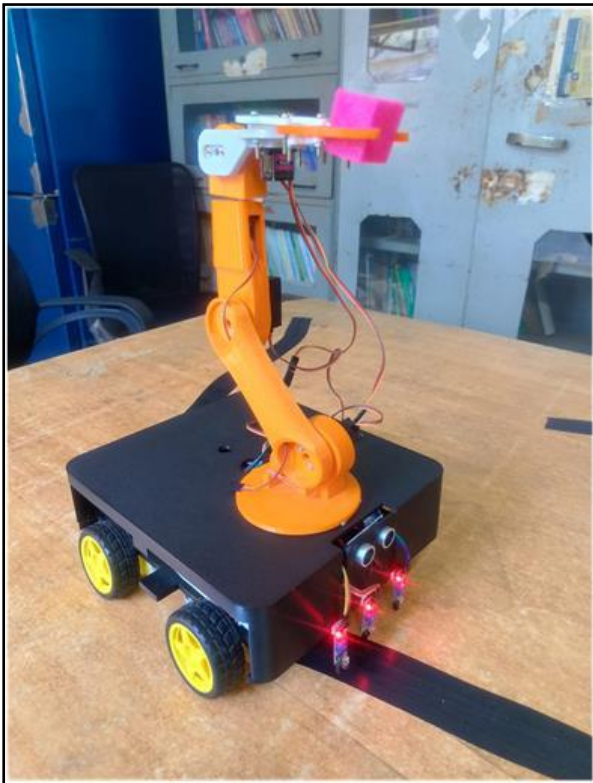


Figure 6: Robonex Output (while testing)



**Figure 7: Robonex**

Repeated pick and place trials confirmed stable gripper performance with consistent placement accuracy. Future development includes making it suitable to detect variable objects by increasing dataset and decision power to place it at the appropriate position.

## V. CONCLUSION

This Paper has presented the implementation of Robonex – The AI Powered Pick and Place robot developed through the integration of embedded system and computer vision. The system successfully achieved the objective of autonomous object detection, manipulation of the object and placement via proper navigation based on path following. With further optimization and precision along with environment adaptability, the proposed system can be extends for real time material handling.

## VI. FUTURE SCOPE

**Depth and Spatial Enhancement:** Incorporate the depth sensing so that spatial awareness and precise object localization can improve.

**Advance Gripper Mechanism:** By developing an intelligent gripper mechanism which will be capable of handling variable objects, vary in size and shape.

**IoT Based Monitoring:** Enable remote monitoring and cloud connectivity to make it suitable for industrial scalability.

**Advance Deep Learning:** Increased in dataset and model training will enable the object detection, classification in complex and dynamic environment.

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