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CROP PICKUP AND DROP ROBOT

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Abstract - The agricultural sector is increasingly challenged by labour shortages, inefficiencies in manual harvesting, and the growing demand for higher productivity. This paper presents the design and development of a robotic system the Crop Pickup and Drop Robot aimed at automating the crop harvesting process. The proposed system is capable of identifying ripe crops, picking them without causing damage, and transporting them to a designated drop zone.

The robot integrates a microcontroller-based control system, object detection algorithms, and motor-driven mobility. It is equipped with sensors for crop recognition, a robotic arm for delicate handling, and a navigation mechanism for operation in semi-structured environments such as farms and greenhouses.

Experimental validation demonstrates that the system can perform crop handling tasks with improved accuracy and efficiency, thereby reducing dependency on manual labour. This work contributes to the advancement of smart agricultural solutions and supports the broader goal of sustainable and automated farming practices.

Key words: Agricultural Robotics, Crop Harvesting, Automation in Agriculture, Robotic Arm, Microcontroller , Smart Farming, Autonomous Navigation.

1. INTRODUCTION

Agriculture remains a foundational sector in many economies, particularly in countries with large rural populations. Despite significant technological advancements across various industries, a substantial portion of agricultural labour—especially crop harvesting and handling—continues to rely on manual processes. Manual harvesting is labour-intensive, time-consuming, and often inefficient. These challenges are further exacerbated by a growing shortage of agricultural labour, largely driven by urban migration and the physically demanding nature of farm work.

At the same time, global food demand is increasing rapidly due to population growth, placing additional pressure on agricultural systems to enhance productivity, reduce waste, and maintain quality. In this context, the adoption of automation technologies in agriculture has become increasingly important. Robotics and automation present promising solutions by enabling precision agriculture, reducing reliance on manual labour, and improving operational efficiency.

This paper presents the development of a prototype system titled "Crop Pickup and Drop Robot," designed to automate the harvesting process. The robot is capable of identifying crops, picking them carefully using robotic arms and grippers, and transporting them to a designated drop-off zone. It integrates mechanical and electronic components including sensors, autonomous navigation systems, and microcontroller-based control units to replicate the actions of a human harvester.

The system is adaptable to different crop types through modifications in the picking mechanism and programming logic. By combining robotics with basic artificial intelligence and pattern recognition techniques, the robot can be enhanced for smarter and more efficient operation over time. The goal of this project is to develop a cost-effective and reliable automation solution that can be deployed in real agricultural settings, particularly for small- and medium-scale farmers.

This work contributes to the broader vision of smart farming, where technology-driven solutions foster sustainable, scalable, and productive agricultural practices.

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2. OBJECTIVES

- **To design a mobile robotic platform** capable of efficient and stable movement across agricultural fields, including navigation over uneven terrain.
- **To develop a crop-picking mechanism**, such as a robotic arm with an end-effector (gripper), that can handle delicate crops without causing mechanical damage.
- **To integrate environmental and object-detection sensors**, including cameras, infrared (IR), and ultrasonic sensors, for accurate crop identification and terrain navigation.
- **To implement control strategies**—manual, semi-automatic, or fully autonomous—to govern the crop pickup and drop operations based on real-time input.
- **To ensure reliable operation** of the robotic system under practical field conditions, including variability in weather, crop types, and soil textures.
- **To test and evaluate the system's performance** in terms of crop identification accuracy, handling safety, harvesting efficiency, and operational speed.
- **To develop a user-friendly interface** or remote-control mechanism to allow farmers or operators to monitor and interact with the system easily.

3. WORKING PRINCIPLE

The working process can be described in the following steps:

1. **Crop Detection**:
   The system uses a combination of **sensors**—typically RGB cameras for image acquisition and optionally IR or ultrasonic sensors for proximity detection—to identify ripe crops based on predefined visual or spatial parameters. Image processing or machine learning algorithms (e.g., colour segmentation or object detection models) are used to recognize and locate the target crops within the field.
2. **Positioning and Alignment**:
   Once a crop is detected, the robot adjusts its position using **DC or servo motors** controlled by a **motor driver circuit**. Real-time feedback from the sensors helps the robot align itself accurately with the crop for precise harvesting.
3. **Crop Pickup Mechanism**:
   A **robotic arm or gripper** is actuated to perform the harvesting operation. The gripper is typically designed using soft materials or controlled pressure to ensure **non-destructive handling** of delicate crops. The arm performs movements in multiple axes (e.g., X, Y, Z) to reach, grasp, and detach the crop from the plant.
4. **Navigation to Drop Zone**:
   After picking the crop, the robot navigates to a pre-assigned **drop-off location** using either line-following, GPS, or sensor-based path planning. Obstacle detection and avoidance are handled by onboard proximity sensors or vision modules.
5. **Crop Drop-Off**:
   At the drop zone, the robotic arm or a simple actuator releases the crop into a collection bin or container. The robot then resets its arm to the initial position and resumes scanning for the next crop.
6. **Control System and User Interface**:
   All operations are controlled by a **microcontroller** (e.g., Arduino or Raspberry Pi), which manages sensor inputs, motor outputs, and task sequencing. A **basic user interface or remote control** allows the operator to start/stop operations, switch between manual and autonomous modes, and monitor system status.

4. PROPOSED METHODOLOGY

The proposed methodology involves the design and development of an autonomous robotic system for efficient crop harvesting and transportation. The approach includes:

1. **Mechanical Design:** Develop a mobile robot platform with a robotic arm and gripper optimized for handling delicate crops without damage.
2. **Sensor Integration:** Equip the robot with cameras and proximity sensors (IR, ultrasonic) for real-time crop detection and navigation in semi-structured agricultural environments.
3. **Control System:** Implement microcontroller-based control logic to coordinate movement, crop picking, and drop-off operations, supporting manual and autonomous modes.
4. **Navigation:** Employ sensor data and path-planning algorithms to enable efficient movement over uneven terrain and obstacle avoidance.

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5. **Testing and Evaluation:** Conduct field trials to assess crop detection accuracy, handling safety, operational efficiency, and system reliability under real-world conditions.
6. **User Interface:** Provide a basic interface or remote control to facilitate user interaction and manual override.

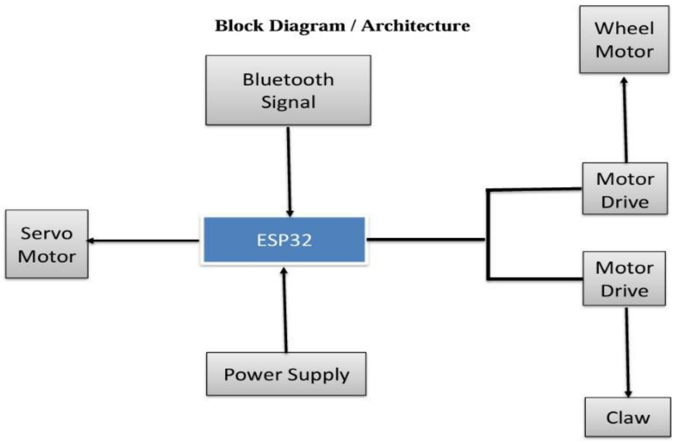

Fig 1. Block Diagram of the proposed model

The proposed model contains the following component as follows:

1. Esp32: -

The ESP32 is a low-cost, low-power microcontroller developed by Espresso Systems, widely used in IoT, robotics, and embedded systems.

Key Features:

- **Dual-core** 32-bit LX6 CPU (up to 240 MHz)
- **Wi-Fi** and **Bluetooth (BLE)** built-in
- **GPIOs**: 30+ programmable pins
- **Analog & Digital Interfaces**: ADC, DAC, PWM, UART, SPI, I2C
- **Flash Memory**: 4MB (varies by model)

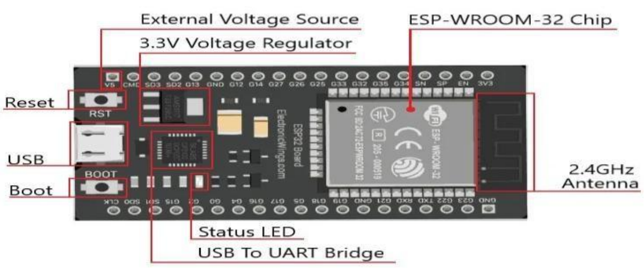

Fig.2 ESP32

2. DC Motor: -

A 60RPM DC motor is a geared DC motor designed to output a rotational speed of 60 revolutions per minute (RPM). It's typically used in applications where a slower, higher torque output is needed, and they are commonly found in robotics and other industrial settings.

Fig.3 DC Motor

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3. Motor Drive: -

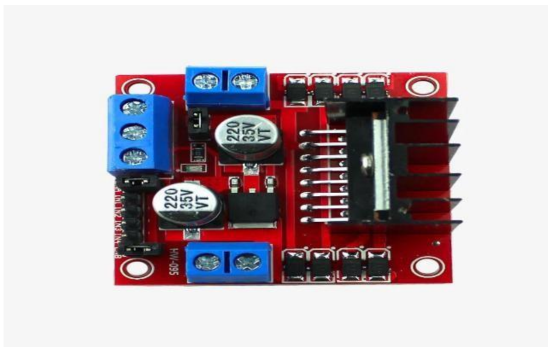

Fig.4 Motor Drive

A motor driver is an electronic circuit that interfaces between a control system, like a microcontroller, and a motor, enabling precise control over the motor's speed, direction, and torque. It effectively acts as a "translator" between the control signals and the motor's power requirements, allowing for efficient and controlled motor operation.

4. Servo Motor: -

A servo motor is a type of electric motor that can be precisely controlled to rotate to a specific angle or distance. It uses a feedback loop to monitor its position and adjust its movement to match a desired position, speed, or torque. This precision makes them ideal for

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applications requiring accurate and repeatable motion, such as robotics, industrial automation, and even remote-controlled vehicles.

Fig.5 Serve Motor

5. LiPo Battery: -

Fig.6 LiPo Battery

LiPo batteries, or lithium-polymer batteries, are rechargeable batteries that use a polymer electrolyte instead of a liquid electrolyte found in traditional lithium-ion batteries. They are known for their high energy density, lightweight design, and ability to be shaped in various ways, making them suitable for applications like consumer electronics, remote-controlled devices, and drones.

6.3D Printed Arms: -

3D-printed arms are prosthetic devices manufactured using additive manufacturing, offering customizable and affordable solutions for individuals with limb loss or mobility impairments. These arms can be designed with various functionalities, including myoelectric control for precise movements, and can be customized to fit the user's specific needs and preferences.

7. Dc Buck Converter: -

Fig.7 Dc Buck Converter

A DC Buck Converter is a type of DC-DC step-down voltage converter that reduces a higher input voltage to a lower output voltage efficiently. It works using a switching element (like a MOSFET), a diode, an inductor, and a capacitor to control and smooth the output. In a dual-axis solar tracking system, a buck converter is used to supply the correct voltage (e.g., 5V or 9V) to components like the microcontroller or sensors from a higher voltage source (like a 12V battery or adapter). It is preferred for its high efficiency, compact size, and ability to handle varying input voltages.

8. Chassis: -

The chassis, also known as the frame, is the fundamental structural support of a vehicle. It's like the skeleton of a car, providing support for the body and all its components. The chassis bears the vehicle's weight and withstands various forces and stresses during driving, as well as in a stationary state.

9. Lead Screw: -

Fig.8 Lead Screw

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A lead screw, also known as a power screw or translation screw, is a threaded shaft that converts rotational motion into linear motion. It's commonly used in applications requiring precise and controlled linear movement, like in linear actuators, machine slides, vises, and presses.

10. Connecting Wire: -

Connecting wires are used to establish electrical connections between various components in a dual axis solar tracking system, such as the microcontroller, sensors, motors, and power supply. These wires carry current and signals, enabling the system to function as a unified circuit. Different types and gauges of wires are used based on current requirements—thin jumper wires for low current signals (e.g., from sensors) and thicker wires for power lines (e.g., to motors). Proper wiring ensures safe, stable, and efficient operation of the system.

5. PROTOTYPE

The prototype developed for the Crop Pick and Drop Robot is a semi-autonomous system designed to perform basic agricultural tasks such as detecting ripe crops, picking them, and transporting them to a designated drop-off area. The system combines mechanical, electronic, and software components to simulate real-world agricultural automation.

1. Hardware Components:

- **Chassis**: A 4-wheel mobile platform suitable for farmland navigation.
- **Manipulator Arm**: A robotic arm with a gripper mechanism for picking crops.
- **Camera Module**: An RGB camera for image acquisition and crop recognition.
- **Microcontroller**: Arduino Uno or Raspberry Pi for central control.
- **Motors & Servos**: DC motors for movement and servo motors for arm control.
- **Power Supply**: Rechargeable battery unit.

2. Software and Control:

- **Object Detection**: Machine learning or colour segmentation algorithms to identify ripe crops.
- **Navigation**: Line-following or GPS-based navigation to move between crop rows.
- **Pick and Drop Mechanism**: Arm controlled by code to pick detected crops and place them in a storage bin.

3. Working Principle:

The robot scans the field using its camera and sensors. Upon detecting a ripe crop, the robotic arm activates, moves to the crop's location, grips it, and places it into the onboard container. Once the bin is full or the area is covered, the robot navigates to a drop point to unload.

4. Limitations and Improvements:

Current limitations include detection accuracy under varying light conditions, limited payload capacity, and basic terrain navigation. Future improvements could include AI-based image recognition, solar power integration, and real-time remote monitoring.

COMPONENTS REQUIRED (for prototype):

Mechanical:

- Chassis with wheels (4WD or tracked base)
- Robotic Arm (servo/stepper based with gripper)
- Payload basket/container

Electronics:

- Microcontroller (Arduino Uno / ESP32 / Raspberry Pi)
- Motor driver (L298N / ESCs for motors)
- Servo motors for robotic arm
- DC/BLDC motors for mobility
- Ultrasonic/IR sensors (for obstacle avoidance)
- Camera module (for visual crop detection using ML – optional)
- GPS module (for location marking)
- Battery pack

Software:

1. Arduino IDE / Python (depending on microcontroller)
2. OpenCV (for image processing)
3. TensorFlow Lite (for onboard crop recognition – optional)
4. Android App / Web interface (for manual override or control)

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Working: -

1. **Field Mapping and Navigation**
    - Sensors: Utilize LiDAR, RGB-D cameras, and GPS to create a detailed map of the agricultural environment.
    - Navigation: Implement SLAM (Simultaneous Localization and Mapping) algorithms for autonomous movement between crop rows.
    - Obstacle Avoidance: Use real-time data to detect and avoid obstacles such as rocks, trees, and uneven terrain.

2. **Crop Detection and Localization**
    - Vision Systems: Employ machine vision algorithms to detect and assess crop maturity.
    - Localization: Determine the precise 3D position of each crop using depth sensors and cameras.
    - AI Integration: Apply machine learning models to classify crops and determine ripeness.

3. **Harvesting Mechanism**
    - End-Effector Design: Develop specialized grippers or cutters tailored to the crop type.
    - Actuation: Use actuators like servos or pneumatic systems for precise movement.
    - Harvesting Process: The robot approaches the crop, grasps it securely, and detaches it from the plant.

4. **Transport and Delivery**
    - Robotic Arms: Utilize articulated arms to transport harvested crops to collection points.
    - Storage: Place crops into bins or containers designed to prevent damage during transport.
    - Delivery: Transport the filled containers to designated drop-off locations within the field.

5. **Energy Management**
    - Power Sources: Incorporate solar panels or high-capacity batteries for extended operation.
    - Energy Efficiency: Optimize power consumption through efficient motor control and task scheduling.

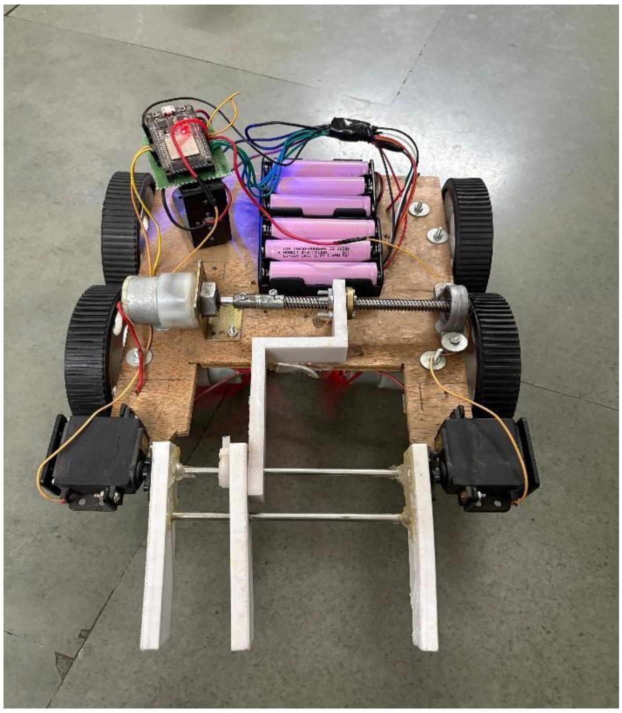

Fig. Proposed Prototype (front view)

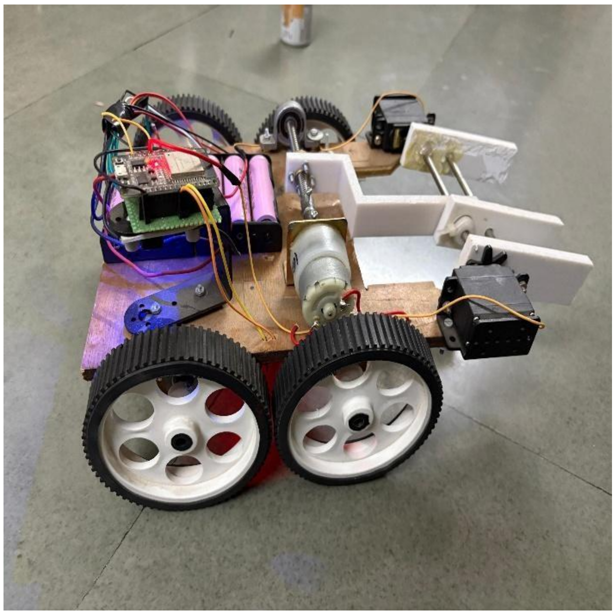

Fig. Proposed Prototype (Side view)

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6. MERITS OF THE SYSTEM.

1. Enhanced Efficiency and Productivity

- **Continuous Operation**: Robots can operate 24/7 without fatigue, significantly increasing the throughput of harvesting and post-harvest handling operations.
- **Speed and Precision**: Equipped with advanced sensors and algorithms, these robots can identify and harvest crops with high speed and accuracy, reducing the time between picking and packaging.

2. Reduction in Labor Costs

- **Lower Dependency on Human Labor**: Automating the crop pickup and drop process reduces the need for manual labour, leading to substantial cost savings, especially in regions facing labour shortages or high labour costs.
- **Scalability**: Once deployed, robots can handle increased workloads without the proportional increase in labour costs, making them scalable solutions for growing operations.

3. Improved Crop Quality and Reduced Waste

- **Delicate Handling**: Robots can be designed to handle crops gently, minimizing bruising and damage during the harvesting and transportation process.
- **Selective Harvesting**: Advanced vision systems enable robots to pick only ripe or market-ready crops, reducing waste and ensuring higher quality produce reaches the market.

4. Enhanced Sustainability

- **Precision Application**: Robots can apply fertilizers, pesticides, and water with high precision, reducing overuse and minimizing environmental impact.
- **Reduced Chemical Usage**: By targeting specific areas that require treatment, robots can decrease the overall use of chemicals, promoting more sustainable farming practices.

5. Data-Driven Decision Making

- **Real-Time Monitoring**: Equipped with sensors and cameras, robots can collect data on crop health, soil conditions, and environmental factors, providing valuable insights for farm management.
- **Informed Decisions**: This data allows farmers to make informed decisions regarding irrigation, fertilization, and pest control, optimizing resource use and improving yields.

6. Adaptability to Various Environments

- **Versatility**: Robots can be designed to operate in diverse agricultural settings, from open fields to greenhouses, adapting to different crop types and growing conditions.
- **Obstacle Navigation**: Advanced navigation systems enable robots to manoeuvre around obstacles such as rocks, trees, and uneven terrain, ensuring consistent performance across various environments.

7. RISK ASSESSMENT AND SAFETY GUIDELINES

1. Hazard Identification

- **Mechanical Hazards**: Moving parts such as robotic arms and grippers can pose risks of entanglement or crushing.
- **Electrical Hazards**: Exposed wiring or malfunctioning circuits may lead to electric shocks or fires.
- **Environmental Hazards**: Operating in diverse agricultural environments may expose robots to varying weather conditions, leading to potential malfunctions.
- **Human Interaction Risks**: Unintended contact between humans and robots during operation can result in injuries.

2. Risk Evaluation

- **Severity Assessment**: Determine the potential consequences of each identified hazard (e.g., minor injury, major injury, fatality).
- **Likelihood Assessment**: Evaluate the probability of each hazard occurring (e.g., rare, occasional, frequent).
- **Risk Level Calculation**: Combine severity and likelihood to classify the overall risk (e.g., low, medium, high).

3. Risk Control Measures

- **Engineering Controls**: Implement physical safeguards such as barriers, emergency stop buttons, and safety interlocks.
- **Administrative Controls**: Establish standard operating procedures, training programs, and maintenance schedules.
- **Personal Protective Equipment (PPE)**: Provide appropriate PPE to operators and maintenance personnel.

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7. CONCLUSION

The Crop Pickup and Drop Robot project successfully demonstrates the potential of automation in modern agriculture. By designing a robot capable of identifying, picking, and transporting crops, the project addresses key labor challenges faced by farmers and enhances operational efficiency. The implementation of sensors, mechanical arms, and navigation systems enables the robot to function with precision and reliability. This innovation not only reduces manual effort but also minimizes crop damage and increases harvesting speed. Moving forward, the system can be further improved with advanced AI algorithms for crop recognition and terrain adaptability, paving the way for smarter, more sustainable farming practices.

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