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Fruit Plucking Robot Arm

Avanti Nachankar, Pranali Patil, Shruti Thakare, Dnayaneshwar Jadhao, Prathmesh Potdar
Students, Department of Electrical Engineering (Electronics and Power)
Shri Sant Gajanan Maharaj College of Engineering, Shegaon, India
avantinachankar856@gmail.com, pranalivpatil01@gmail.com,
thakareshruti1@gmail.com, dnyaneshwar1515jadhav@gmail.com,
sonarprathamesh323@gmail.com

Abstract*: In response to labor shortages and increasing demand for more effective harvesting techniques, this research suggests creating an autonomous robotic arm system for fruit picking. This robotic arm is engineered to carefully identify ripe fruits, handle them with precision, and harvest them without harming the plant or the fruit itself. The essential elements of the robotic arm system comprise advanced computer vision algorithms for identifying and assessing the ripeness of fruits, precise robotic arm kinematics for accurate positioning and movement, and gripper mechanisms designed to handle fruits delicately. This system relies on real-time data processing to make quick decisions and adjust to different environmental conditions as needed. Introducing this robotic arm system brings numerous benefits compared to conventional manual harvesting approaches. It cuts down on labor expenses and reduces reliance on seasonal workers, boosts harvesting efficiency by operating tirelessly without fatigue, and decreases fruit damage, resulting in superior quality produce. Moreover, the autonomous functionality enables 24/7 operation, ultimately maximizing productivity and yield.*

Keywords: Robot Arm

I. INTRODUCTION

The agricultural sector grapples with numerous challenges, notably the dwindling workforce and escalating expenses associated with fruit harvesting. Addressing these issues requires a concerted effort to streamline labor and expand agricultural operations. While strides have been made in automating various aspects of agriculture for labor efficiency and large-scale production, much of the fruit harvesting process still relies on manual labor. Developing an automated fruit harvesting robot emerges as a promising solution to this dilemma. This endeavor involves tackling two significant tasks: first, employing computer vision with sensors to detect and locate fruits on trees; second, orchestrating the robotic arm's motion to reach the identified fruit and delicately harvest it without causing damage to the fruit or its host tree.

The agricultural sector is vital for sustaining the ever-expanding global population's food needs. Yet, it grapples with an array of obstacles, from labor scarcities to soaring operational costs, all while striving to enhance productivity to meet escalating demand. Harvesting stands out as a critical juncture in agricultural operations, especially within the fruit industry, where manual labor has traditionally held sway. However, this reliance on manual labor poses various constraints, ranging from limited availability to cost and efficiency concerns.

In response to these challenges, there has been a burgeoning interest in leveraging robotic systems for agricultural endeavors, notably in harvesting tasks. Robotic innovations hold thepromise of transforming agricultural methods, offering automation for repetitive chores, reducing reliance on human labor, and ultimately heightening operational efficiency.

In recent years, the field of robotics has seen remarkable progress, particularly in key areas like computer vision, machine learning, and robotic manipulation. These advancements have set the stage for the creation of sophisticated robotic systems capable of executing intricate tasks with precision and autonomy.

One specific domain witnessing significant attention is the development of fruit-plucking robotic arms. These systems are engineered to autonomously detect ripe fruits, delicately grip them, and harvest them without harming the plant or fruit. By harnessing the power of computer vision algorithms, robotic arm kinematics, and advanced gripper

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mechanisms, these solutions aim to emulate human dexterity and efficiency while circumventing the limitations of manual harvesting.

The emergence of fruit-plucking robotic arms holds immense potential for the agricultural sector. By automating the harvesting process, these systems can help mitigate labor shortages, trim labor expenses, and enhance overall operational efficiency. Moreover, they stand to elevate the quality of harvested produce by reducing damage and ensuring consistent handling practices. This introduction lays the groundwork for investigating fruit-plucking robotic arms, emphasizing their significance in tackling critical issues within the agricultural sector and their capacity to transform harvesting methods. Subsequent sections will delve into the design, operation, advantages, and obstacles linked with these robotic systems, alongside an examination of ongoing research efforts and prospective avenues for development in this domain.

II. MATERIALS

In this segment, we outline the Image Acquisition System implemented through AUTOCAD software, which serves to determine fruit location, along with the vision targets employed in our experiments, and the mechanical apparatus devised for fruit retrieval. Additionally, we detail the control mechanism devised to direct the robotic arm during fruit harvesting. Live fruit detection is executed through MATLAB, and MATLAB scripts are utilized to transmit commands to the ARDUINO UNO for orchestrating the movement of the robotic arm in accordance with the fruit's position.

2.1. Arduino Uno

Here in this project Arduino Uno is programmed to control servo motors which are serving as joints of Robotic arm. Once the fruit position is detected, various scenarios dictate the movement of the robotic arm. These scenarios include commands such as moving left (L), right (R), forward (F), backward (B), or halting movement (S). These commands are transmitted to the preprogrammed ARDUINO, which then instructs the robot to execute the corresponding actions upon receiving instructions from the AUTOCAD software.

Fig 2.1. Arduino Uno

2.2. Stepper Motor

Stepper motors can be made to rotate at very precise rates, depending on the frequency of the current. This makes them ideal for robotics applications, where precise movement is required. For example, a robotic hand might be required to pick up an object. If the hand moves too fast, it could miss the object entirely. Similarly, if it rotates too slowly, it will take too long to pick up the object. The stepper motor can be programmed to move at a speed that is neither too fast nor too slow; it is precise.

Fig 2.2. Stepper Motor

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2.3. DC motor

High torque is the biggest advantage of using DC motors in robotic arm. They are capable of a high starting-torque used for driving heavy loads in starting positions and for applications requiring acceleration. They are also capable of constant torque over a given speed, where shaft power varies with speed.

Fig 2.3. DC motor

2.4. L298 driver module:

The L298 driver module is designed for driving DC motors and stepper motors, offering the power and control needed. The motor ensures high quality and durable performance making it ideal for robotic arm.

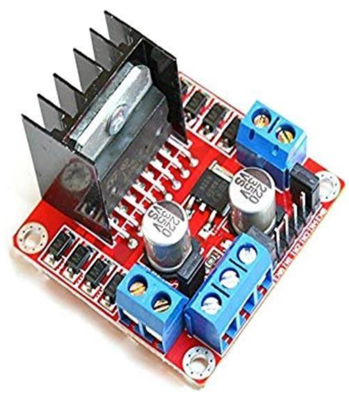

Fig 2.4. L298 driver module

2.5. Motor driver module

ULN2003A motor driver module is used to control the stepper motor used in robot hand. Motor driver is used to control motion of a motor and its direction. The main function of the ULN2003 is to amplify the control signals from the Arduino to drive stepper motor . It enables the low voltage and low current output of a microcontroller to drive a higher current stepper motor.

Fig 2.5. Motor driver module

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2.6. Gripper

These grippers feature an electric motor and a controller. The controller provides a signal relating to the force, position, or the speed required of the robot. The gripper receives the signal and its motor carries out the desired motion. When an object is sensed by the sensors ,a signal is sent to controller , which will send a signal to the DC servo motor to control the opening and closing of fingers.

Fig.2.6. Gripper

2.7. Ultrasonic sensor

Ultrasonic sensors are used for object detection i.e plant and fruit. The robot can measure the distance to the nearest object in its path with help of ultrasonic sensor . This sensor operates on sound wave property to measure the velocity and distance of the object

Fig 2.7. Ultrasonic sensor

2.8. Color sensor

The TCS34725 sensor is capable of accurately detecting and measuring the color of an object in terms of red (R), green (G), and blue (B) components. When an object is irradiated with light containing RGB components, the color of the reflected light will change depending on the color of the object.

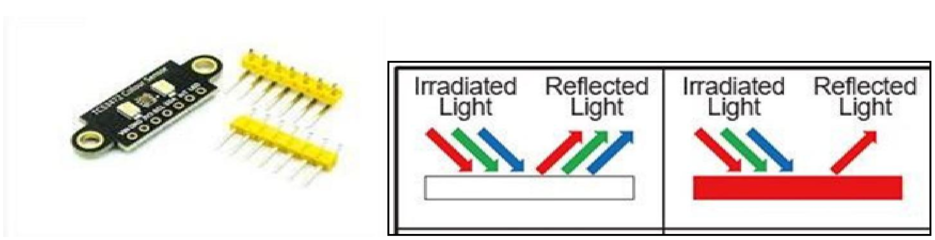

Fig 2.8. Color sensor

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III. AUTOMATIC HARVESTING

The automatic fruit harvesting system necessitates controlling the robotic arm using positional data obtained without relying on stereo vision. A specialized setup directly links the gripper of the robotic arm with a positioning system, facilitating the determination of relative positions between the gripper tool and the fruit. This experimental assessment undergoes three main stages: (1) Initial fruit detection, (2) Preliminary approach to a targeted fruit, and (3) Fruit retrieval. In this study, we apply the automatic fruit harvesting system to retrieve tomatoes under controlled laboratory conditions.

3.1 Initial Fruit Detection

The preliminary fruit detection process, focusing solely on harvesting tomatoes. It detects them based on the sensors.

3.2 Fine approach to a fruit:

A precise technique is suggested to regulate the delicate positioning of the gripper tool for selecting fruits. The method involves advancing the robotic arm's gripper tool followed by a series of small adjustments in both vertical and horizontal directions to precisely center and retrieve the fruit.

3.3. Final pickup:

The suggested mechanical steps for picking up a tomato are as follows: 1. Open the gripper, 2. Securely grasp the tomato, and 3. Cut the stem connecting the fruit to the vine.
Here's how the final model looks like:

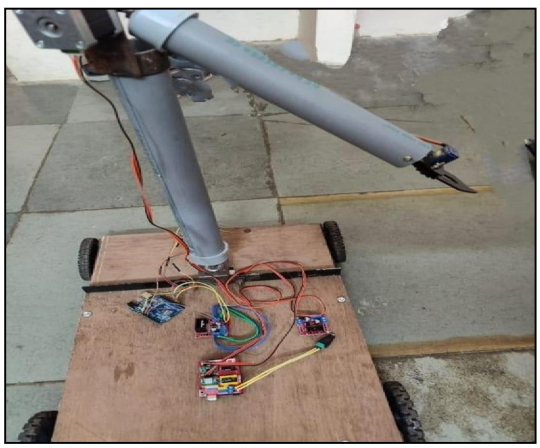
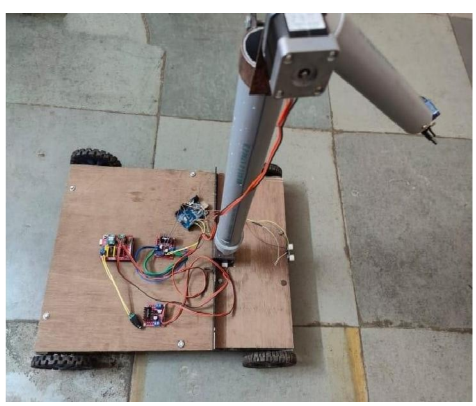


Fig 3. Model



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IV. CONCLUSIONS

The development of a fruit-plucking robot arm presents a solution to challenges in agriculture, particularly in labor shortage and efficiency. Using this system in harvesting will be more precise, adaptable , and cost effective. One notable conclusion is the potential for increased productivity and reduced operational costs for farmers.

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