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Autonomous Nutmeg Harvesting Robot

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Abstract

An autonomous robot that identifies mature nutmeg fruits and harvests them from any height with a 5DOF robotic arm and a linear actuation mechanism is developed. The camera processes real time video of the tree and recognizes mature fruits and their location coordinates. This action is controlled by means of a raspberry pi 3 model. The image is processed with the help of OpenCV platform. This information is forwarded onto an Arduino UNO board, which controls the movement of the robotic arm. The arduino board then runs the necessary inverse kinematics algorithms and moves the joints at appropriate angles to reach the target location. Then with the help of a gripper end- effector, the fruit is plucked and put into a container attached to the robot. Once the fruits at a certain height level are completely plucked, the robotic arm platform moves onto a greater height on its own, by means of linear actuator fixed at the bottom. Since the robot is placed at a certain radius from the trunk of the tree, it just reaches for the fruit.

Keywords: *Arduino, autonomous, computer vision, harvesting, nutmeg, robotic arm*

INTRODUCTION

Conventional harvesting method is highly labour intensive and inefficient in terms of both economy and time. Machine harvesting systems are a partial solution to overcome issues by removing fruits from the trees efficiently thus to reduce the harvesting cost to about 35−45% of total production cost. In the early 1960s, the concept of an automatic harvester was proposed and investigated by Schertz and Brown using automatic robotic picking device. They proposed a system which uses a robotic arm to position a manipulator within the picking range of target fruit before detaching the fruit from the tree. The guidance for the manipulator is achieved by a machine vision system to detect the fruit.

In this paper, we present the design and development of an autonomous nutmeg harvesting robot. In cultivation of the nutmeg, mechanization of the farm itself is progressing to automate and optimize growth of fruits. However fruit harvesting is not enough automated yet. We proposed an automated nutmeg harvesting system using robotic arm and computer vision which has more advantages than existing systems. This robot could help reduce the manual effort required to pluck nutmegs from tall trees, is time-saving and reduce labour charges.

The design for the above mentioned robotic arm is different from the usual robotic arms as it has an automatic linear actuation mechanism for height adjustment. There are some similar existing robots in the domain of harvesting but none are affordable and commercially available in India. This paper deals with the implementation of an autonomous robot for nutmeg fruit harvesting that is both affordable and user friendly for the common farmers of India.

LITERATURE SURVEY

In order to design and implement the nutmeg harvesting robot, a study was

carried out on different autonomous robots used for harvesting. Many previous projects tackling the harvesting application were found.

The work done by Feng Quingchun et. al. presented a table top strawberry harvesting robot [1]. Based on machine vision and sonar technology, the independent navigation system for harvesting robot was built. The fruits were distinguished according to H(Hue) and S(Saturation) color histogram and the picking-point was located by binocular-vision system.

The work by Fatemah Taqi et. al. reported the design of a robot to pick cherry [2]. The robotic arm moves in x, y directions and it uses a gripper to pick cherry. When the color of ripened fruit is detected by the pixy camera, the coordinates of its location is communicated to the control unit through the Arduino. The control unit receives the coordinates from the Arduino and uses them to control the arm.

The work by Qingchun Feng et. al. presents a tomato harvesting robot which contains vision unit for identifying the mature fruits, a jointed manipulator of 4 freedom degrees, a railed vehicle and the system control [3]. The success rate for harvesting tomatoes was found to be 83.9%.

In study done by Joseph R Davidson et. al. suggested the design of a robotic system to harvest fresh apples in modern orchard systems with planar architecture is presented [4]. The machine vision system detects clustered and occluded fruits. After fruit localization the system makes a linear approach to the apple using the robotic arm and replicates the human process.

Study done by Ankur Bhargava at al designed a 5 Degree Robotic arm has been developed. It is controlled by an Arduino Uno microcontroller which accepts input signals from a user by means of a set of potentiometer [5]. It is made up of four rotary joints and an end effector, where rotary motion is provided by the servomotors [6]. The different vision systems for fruit detection were presented in study done by Chein-Wei Chen et. al. and the mechanism of a controlled robotic arm [7-9].

SYSTEM OVERVIEW

The existing systems do not tackle the problem of reaching fruits at greater heights. Many of the systems damage the fruits due to lesser freedom of movement. Our proposed system has a 5 degree of freedom robotic arm with automatic height extension mechanism and light weight machinery.

Environmental Design

The environment that is designed for the harvesting robot is a miniature model of nutmeg tree.

It contains a plastic tree of height 70cm.The robot is placed in front of the tree. The robot takes the video using fixed web camera and the red colour of ripened nutmeg is detected. Then the arm of the robot will pick the nutmegs. After picking and placing the nutmegs in the basket the robot moves for the next fruit that has been detected in the same tree. After harvesting all the detected fruits in the base region of the same tree the robotic hand extends to a greater height for which it uses automatic linear actuation mechanism.

The robotic arm has links of lengths 15cm (x2) and 8cm(x1) and a base platform of dimension 10cm*10cm*10cm. The height extension mechanism moves to a

maximum distance of 20cm from the ground for the prototype designed.

Figure 1: *Miniature model of tree.*

Software Implementation

The video is captured using web camera and then fed into the Raspberry pi for image processing. The image is processed on OpenCV computer vision platform using Python language. First the captured image is converted to HSV from RGB, then the image is masked by setting up the lower and upper threshold values of red. The masking operation subtracts all other colors in the frame except the red color. The masked frame is a white and black frame where the ripened red color of the nutmeg in the image is displayed as white structures in the black background. To extract the red ripened part of the nutmeg as such a bitwise AND operation of the mask and image can be done so that only the red color is highlighted and stored in res frame. Thus, the detected ripened nutmeg can be displayed using the real time frame, masked frame and res frame.

Figure 2: *Real time frame.*

Figure 3: *Mask frame.*

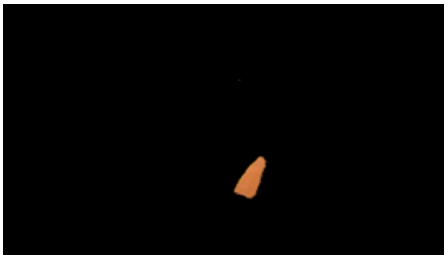

Figure 4: *Res frame.*

The location of a nutmeg is traced using moments calculation. The x coordinate of the position of the center of the nutmeg should be equal to the first order spatial moment around x axis. Similarly, the y coordinate of the position of the center of the nutmeg should be equal to the first order spatial moment around y axis. The coordinate values are then transferred to Arduino controller. The Arduino IDE software is used for coding the robotic arm movements by means of inverse kinematics algorithms. A trigonometric approach is used to find out the appropriate angles for the motors to rotate so that the end-effector reaches the exact target location.

Hardware Implementation

The hardware of the autonomous robotic system consists of a 5 DOF robotic arm made of 3 links, 5 motors, 1 gripper end-effector, a rotating base platform and a linear actuator height extension mechanism. The control unit consists of the Raspberry pi and the Arduino. The concept design of the system is shown below:

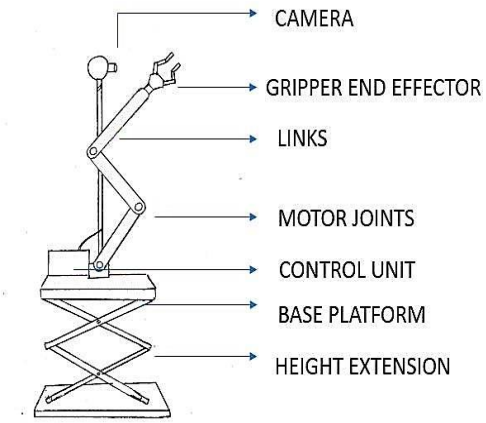

***Figure 5:** Hardware model concept.*

Links

The links used for the robot prototype are cuboidal in structure and made of aluminum. The two links from the bottom are of 15 cm each, whereas, the one on top has a length of 8 cm.

Motors

The motors used for moving the links are servo motors. The motors attached at the joints of the bottom links and at the rotating base are Tower Pro MG996R Servo motors whereas, the topmost link is attached to a Tower Pro SG90 Micro servo motor.

End Effector

In order to minimize fruit bruising and improve harvest efficiencies, a gripping mechanism based end effector was used. The gripper was 3D printed with a total length of 10.8 cm. The opening and closing of the gripper is done by means of a Tower Pro SG90 micro servo motor attached to the bottom of the gripper. The maximum length that the clamp of the gripper can open is 5.0 cm.

Control Unit

The control unit contains the Raspberry Pi 3 model and the Arduino Uno. The Raspberry pi is responsible for running the fruit detection and allocation. This data is transferred to the Arduino Uno. The Arduino then drives the motors towards appropriate angles so that the gripper reaches the fruit accurately.

Camera

The camera used here is a webcam of 16MP image resolution (interpolated). It helps to capture a clear quality image of the nutmeg without any interference.

Height Extension

The height extension setup is made of aluminum links that are 20 cm in length. The mechanism used for extension is a scissor lift linear actuation mechanism.

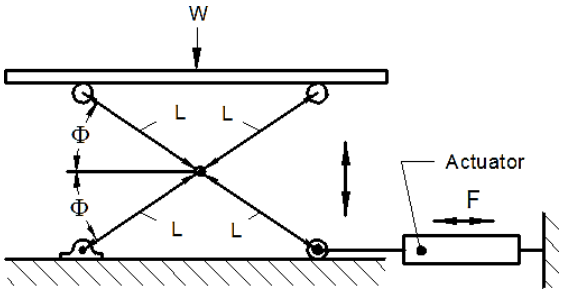

***Figure 6:** Height extension with linear actuation.*

OPERATION PROCESS OF ROBOTIC SYSTEM

Initially, the camera looks for ripe nutmegs from the tree by means of color detection algorithms. Once the nutmegs are identified, it determines the location of the fruit using moment's calculation. This data is stored in the Raspberry pi and then forwarded to the Arduino for the movement of the robotic arm. Once the gripper reaches the target location, the clamp opens to grab the fruit. After a time period of 2 sec, assuming that an equilibrium has been reached and the nutmeg is securely grasped and carefully removed from the branch. The clamp is opened and the fruit is put in a container attached to the robot. This process continues till all fruits at a certain height level within the view of the robot are harvested. Once the robot fails to detect any more fruits at that height, the base platform rises to a much greater height for

the harvesting process to carry on. A flow chart of this system is

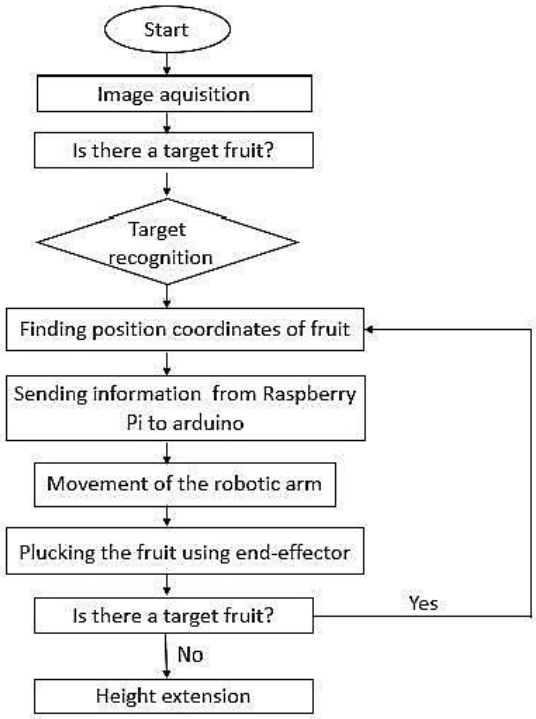

Figure 7: *Operation flow chart.*

SPECIFICATIONS

Table 1 summarizes the specifications of the nutmeg harvesting robot.

Table 1: *Harvesting robot specifications.*

Dimensions	25 cm* 25 cm (base platform) 15 cm * 1.8 cm * 1.8 cm (2 x bottom links) 8 cm * 1.8cm * 1.8 cm (1 x top link) 10 cm* 6.5 cm (gripper)
Weight	7 Kg
Picking rate	2 fruits/minute
Picking accuracy	100%
Distance to Obstacle	4-10 cm

CONCLUSION

This paper presented the preliminary design for a low cost robotic system designed to harvest fresh mature nutmegs from nutmeg plantations. The existing automated systems for harvesting fruits in general, do not reach all the required heights and are very much expensive for a commoner. The robot presented in this paper is cost effective, reaches required heights automatically and carefully plucks nutmeg fruits without damage.

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