A Study on Robotic Nutmeg Harvesting

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Abstract

With a 5DOF robotic arm and a linear actuation mechanism, an autonomous robot can identify mature nutmeg fruits and pick them from any height. The camera analyses real-time video of the tree to identify mature fruits and their coordinates. A Raspberry Pi 3 model is used to control this action. The OpenCV platform is used to process the image. This information is sent to an Arduino UNO board, which controls the robotic arm's movement. The required inverse kinematics algorithms are then executed on the arduino board, which moves the joints at proper angles to achieve the goal location. The fruit is then plucked and placed into a container attached to the robot using a gripper end-effector. The robotic arm platform travels to a greater height on its own once the fruits at a specific height level are entirely plucked, thanks to a linear actuator mounted at the bottom. The robot just reaches for the fruit because it is set at a certain distance from the tree's trunk.

Keywords: *Nutmeg harvesting, computer vision, Robotic arm, OpenCV platform*

INTRODUCTION

The traditional method of harvesting is labor-intensive and inefficient in terms of both cost and time. Machine harvesting systems offer a partial answer for overcoming challenges by efficiently plucking fruits from trees, lowering harvesting costs to around 35–45% of overall production costs. Schertz and Brown suggested and investigated the notion of an automatic harvester in the early 1960s, employing an automatic robotic picking system. They devised a device that uses a robotic arm to place a manipulator within reach of target fruit before extracting it from the tree. A machine vision system detects the fruit and uses it to guide the manipulator.

We present the concept and development of an autonomous nutmeg harvesting robot in this work. Mechanization of the farm is increasing in nutmeg cultivation in order to automate and improve fruit growth. Fruit harvesting, on the other hand, is not yet sufficiently automated. We presented a robotic arm and computer vision-based automated nutmeg harvesting system that outperforms existing solutions. This robot could help reduce the amount of manual labour required to pluck nutmegs from tall trees, saving time and money.

The above-mentioned robotic arm is unique in that it contains an autonomous linear actuation system for height adjustment, which sets it apart from other robotic arms. In the field of harvesting, there are a few similar robots on the market, but none are inexpensive or commercially available in India. This paper discusses the development of a cheap and user-friendly autonomous robot for nutmeg fruit harvesting for common Indian farmers.

SURVEY OF LITERATURE

A research of numerous autonomous harvesting robots was conducted in order to create and deploy the nutmeg harvesting robot. There were other past initiatives that dealt with the harvesting application that were discovered.

Feng Quingchun et al. demonstrated a tabletop strawberry harvesting robot in their work [1]. The autonomous navigation system for the harvesting robot was developed using machine vision and sonar technology. The fruits were identified using the H (Hue) and S(Saturation) colour histograms, and the picking point was determined using a binocular vision system.

Fatemah Taqi et al. reported on the creation of a cherry-picking robot [2]. The robotic arm moves in x and y axes and picks cherries with a gripper. The coordinates of the location of matured fruit are transferred to the control unit via the Arduino when the colour of ripened fruit is identified by the pixy camera. The Arduino sends the coordinates to the control unit, which it uses to control the arm.

Qingchun Feng et al. offer a tomato harvesting robot that includes a vision unit for identifying mature fruits, a four-degree jointed manipulator, a railed vehicle, and system control [3]. Harvesting tomatoes was shown to have an 83.9 percent success rate.

Joseph R Davidson et al. proposed the construction of a robotic system to harvest fresh apples in modern orchard systems with planar architecture [4]. Clustered and occluded fruits are detected by the machine vision system. Following fruit localization, the system uses the robotic arm to make a linear approach to the apple, simulating the human process.

Ankur Bhargava and his colleagues built a 5 degree robotic arm as part of their research. It is controlled by an Arduino Uno microprocessor, which accepts user input through a set of potentiometers [5]. It consists of four rotating joints and an end effector, with servomotors providing rotary motion [6]. Chein-Wei Chen et al. provided various vision systems for fruit detection as well as the mechanism of a controlled robotic arm [7-9].

OVERVIEW OF THE SYSTEM

Existing techniques do not address the issue of reaching fruits at higher altitudes. Because the fruits have less freedom of movement, several of the systems harm them. Our proposed system includes a robotic arm with five degrees of freedom, an automatic height extension mechanism, and light-weight machinery.

Design for the Environment

A small model of a nutmeg tree serves as the harvesting robot's habitat. It includes a 70cm tall plastic tree. In front of the tree, the robot is put. The red colour of matured nutmeg is identified in the video taken by the robot using a fixed web camera. The robot's arm will then pick up the nutmegs. The robot then moves on to the next fruit that has been spotted in the same tree after picking and arranging the nutmegs in the basket. The robotic hand extends to a larger height after harvesting all of the detected fruits in the base region of the same tree, for which it uses an autonomous linear actuation mechanism.

The robotic arm contains 15cm (x2) and 8cm (x1) links, as well as a 10cm*10cm*10cm base platform. The height extension mechanism is moved to a new position.

The prototype was developed with a maximum distance of 20cm from the ground.

Figure 1: Miniature model of tree

Implementation of Software

A web camera is used to collect the footage, which is then put into the Raspberry Pi for image processing. The image is processed with the Python language on the OpenCV machine vision platform. After converting the acquired image to HSV from RGB, the image is masked by adjusting the lower and upper red threshold values. Except for the red colour, the masking procedure removes all other colours from the frame. The masked frame is a white and black frame in which the image's matured red nutmeg appears as white structures on a black background. A bitwise AND operation of the mask and image can be used to remove the red ripening part of the nutmeg as such, so that just the red colour is highlighted and stored in the res frame. The real time frame, masked frame, and res frame can all be used to display the detected ripened nutmeg.

Moments calculations are used to trace the location of a nutmeg. The first order spatial moment around the x axis should be equal to the x coordinate of the position of the nutmeg's centre. Similarly, the first order spatial moment around the y axis should be equal to the y coordinate of the position of the nutmeg's centre. After that, the coordinate data are sent to the Arduino controller. Inverse kinematics algorithms are utilised to programme the robotic arm movements using the Arduino IDE software. The proper angles for the motors to rotate so that the end-effector reaches the exact target spot are determined using a trigonometric approach.

Figure 2: Real time frame

Figure 3: Mask frame

Figure 4: Res frame

Implementation of Hardware

The autonomous robotic system's hardware includes a five-degree-of-freedom robotic arm with three links, five motors, one gripper end-effector, a rotating base platform, and a linear actuator height extension mechanism. The Raspberry Pi and Arduino make up the control unit. The system's concept design is as follows:

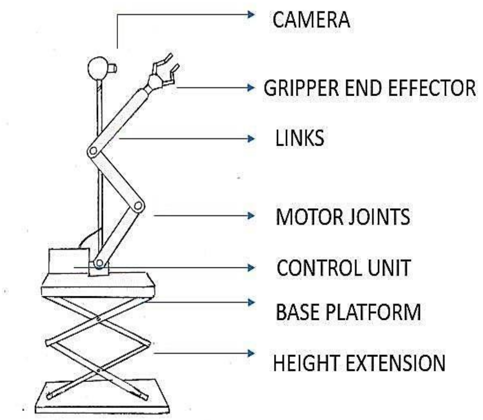

Figure 5: Hardware model concept

Links

The cuboidal linkages utilised in the robot prototype are composed of aluminium and have a cuboidal structure. The two links at the bottom are 15 cm long each, while the one at the top is 8 cm long.

Motors

The servo motors that move the links are servo motors. Tower Pro MG996R Servo motors are attached to the bottom links' joints and the spinning base, while a Tower Pro SG90 Micro servo motor is mounted to the highest link.

End Effector

A gripping mechanism-based end effector was employed to reduce fruit bruising and increase harvest efficiency. With a total length of 10.8 cm, the gripper was 3D printed. The gripper opens and closes with the help of a Tower Pro SG90 micro servo motor attached to the gripper's bottom. The gripper's clamp can expand to a maximum length of 5.0 cm.

Unit of Control

The Raspberry Pi 3 model and the Arduino Uno are housed in the control unit. The Raspberry Pi is in charge of the fruit detection and distribution. This information is sent to the Arduino Uno. The Arduino then directs the motors to the proper angles, ensuring that the gripper reaches the fruit precisely.

Camera

A webcam with a 16MP image resolution was employed in this experiment (interpolated). It aids in the acquisition of a high-quality photograph of the nutmeg with minimal distractions.

Extension of Height

Aluminum links measuring 20 cm in length make up the height extension system. A scissor lift linear actuation mechanism is utilised to extend the arm.

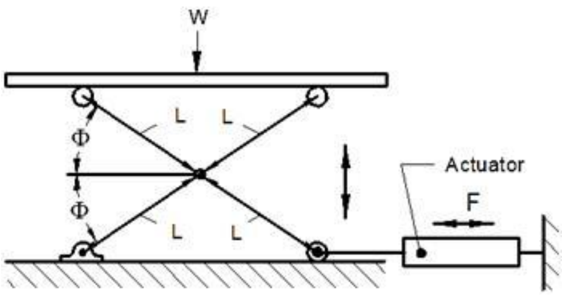

Figure 6: Height extension with linear actuation.

ROBOTIC SYSTEM OPERATING PROCESS

Initially, the camera uses colour detecting algorithms to look for ripe nutmegs on the tree. It uses moment's computation to calculate the location of the fruit once the nutmegs have been identified. This information is saved on the Raspberry Pi and then sent to the Arduino to control the robotic arm. The clamp opens to catch the fruit once the gripper reaches the designated location. Assume that equilibrium has been attained after 2 seconds and that the nutmeg has been securely grabbed and carefully removed from the branch. The fruit is placed in a container linked to the robot after the clamp is opened. This process continues until all fruits within the robot's perspective are harvested at a specified height level. When the robot detects no more fruits at that height, the base platform raises to a much higher height for the next fruit and continue with the harvesting process. This system's flow chart is shown below.

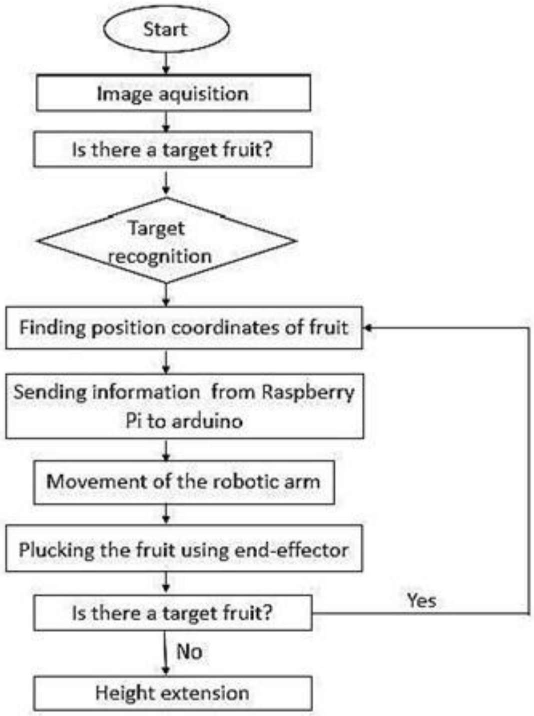

Figure 7: Flowchart of the operation.

SPECIFICATIONS

The nutmeg harvesting robot's specifications are summarised in Table 1.

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

The preliminary design for a low-cost robotic system to harvest fresh mature nutmegs from nutmeg plantations was given in this research. Existing automated fruit harvesting systems, in general, do not reach all of the requisite heights and are prohibitively expensive for the average person. The robot shown in this paper is inexpensive, automatically achieves the proper heights, and delicately plucks nutmeg fruits without causing damage.

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