Agriculture Based Fruit Plucking Robot

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***Abstract** - This paper proposes the development of an automatic fruit harvesting system by combining a low-cost stereo-vision camera and a robotic arm. The stereo-vision camera is used to detect color, distance, and position of the fruit, whereas the robotic arm is used to mechanically pluck the fruits. The harvesting robot is based on a prototype. Combining the harvesting robot and moving platform demonstrated the potential for autonomous harvesting in the two-dimensional area. The harvesting robot has 3 DOF cylindrical shape that approached the target fruit from the path side. It was seen that the power consumption was less by using ARDUINO NANO, DC motors and Motor Drivers. The complete system has been tested in laboratory conditions with uniform illumination applied to the fruits. As a future work, this system will be tested and improved in conventional outdoor farming conditions and both the robot and moving platform can be developed individually.*

Key Words: Fruit-harvesting, stereo-vision system, size estimate, robotic arm, MATLAB, Image Processing.

1. INTRODUCTION

The agriculture industry is demanding technological solutions focused on increasing productions and benefits while reducing time and costs. Automation of agriculture tasks has improved all phases of the industrial process, from pre-harvest to harvest and post-harvest stages. In the cases of post-harvesting stages, fruit plucking and collection of plucked fruits is the most important task.

The fruit and vegetable market and retailers union of aimed to increase the production rate of tomato by 2020. A sustained and cost-effective devices for harvesting within in India coastal areas is of growing importance to achieve this goal.

This project describes an approach to image acquisition methodology of the fruits by developing an automatic, unmanned plucking device for detecting image properties. The stereo vision system measures the RGB values of the captured pictures. Additionally, the system allows to check the range of captured RGB values, if these values are in range of standard fruit which has been processed in the acquisition system, the system announces that fruit is detected.

Nowadays, there are many systems for the harvesting of strawberries. An overview of relevant work for agriculture is presented in agricultural robotics[1]. In this project, a low-cost stereo-vision system for acquisition of the fruits and detection of the fruits will be proposed. The stereo-vision system monitors the color of detected fruits (Red, Green, and Blue), the position of the fruits. The real-time data transmission through MATLAB is an important research field in recent years via serial communication. Requirements like low cost and less power consumption, limited energy capacity and range have to be met.

All presented system above allows a sustainable model and movable platform and robotic arm. The main issue of this system is not able to detect fruits which have been hidden behind the leaves. Moreover, the equipment can stay a long time on farm and can detect fruits. In combination with a robotic arm and stereo vision system using MATLAB, it is feasible to combine the ARDUINO NANO and MATLAB with the position of detected fruits. Furthermore, the long-term deployment of motor drivers needs to consider the topic of heating and power supply has given to the motor drivers with 3.25 ampere. These motor drivers usually get heated after a specific time of usage, where an inbuilt heat sink has given in a motor driver.

Although several applications in agriculture field have been published in the past few years, the use of image processing to solve possible tasks in and around the farm. stereo-vision system is in many cases a cost-effective alternative and user-friendly than other devices. In an accurate position and detection system for an image processing based on a stereo-vision system.

From 2012-2016 last five average monthly arrival rate of tomato in India is approx. 300 tones. According to the export rate of tomato, the market value for tomato is expected to increase in order to help stabilize farm finances. As such tomato harvesting is a labour-investive task, farmers need to handle the fruits with great care to maintain proper hygiene of fruit while plucking.

This paper includes a summary of the main results of the research project. A proposal for Fruit harvesting by combining a low-cost stereo-vision camera and a robotic arm. The objective of the projects was (i) To pluck fruits easily avoiding manual work. (ii) It can put plucked fruits into the basket. (iii) It can also pluck fruits during night time.

Here we took tomato as an example. In the future, others fruits such as mango, jackfruit can also be considered

1.1Related work

We have referred certain papers published by the International conference by Ashwini K and Davinia Font. Ashwini K proposed the paper 'Survey Paper on Fruit Picking Robots,' in which the robot was picking fruit. Davinia Font presented paper 'A proposal for automatic fruit harvesting by combining a low cost stereo-vision camera and a Robotic arm' in which they have used co-ordinates for detection of position, size, and shape of fruit. They have used OpenCV software for image processing.

2. Materials

This section describes the Image Acquisition System by using MATLAB software used to estimate fruit location, the vision targets used in the experiments, and the mechanical device proposed to pick up the fruits. The control has been developed to guide the robotic arm in order to harvest fruits is also presented. Live fruit detection is performed on MATLAB and using MATLAB script for different cases, commands are sent to ARDUINO NANO to move robotic arm according to the position of the fruit.

2.1 Stereo-vision Image Acquisition System

Image acquisition system used in this project is the USB 2D webcam. The Webcam used in our project is 6 LED night vision, 5 Megapixel webcam. It has 10x Digital Zoom. It captures a video up to 640x480 pixels. It has a 360^0 rotary function, all angle is available. It can support to the laptop also a computer.

Fig 1. USB Webcam

2.2 Robotic Arm for fruit harvesting

The stereo-vision system is applied to control a robotic arm designed for automatic fruit harvesting robot.

The base of robotic arm is able to spin 360° on its x-axis and place the gripper in radial position for fruit harvesting. Then, the elbow of the robotic arm (fig. 2(a)) is able spin 180° on its Y-axis in order to approximate the robotic gripper to the fruit.

Finally, the Table I summarize the dimensions of the robotic arm.

Table I. Robotic arm dimensions.

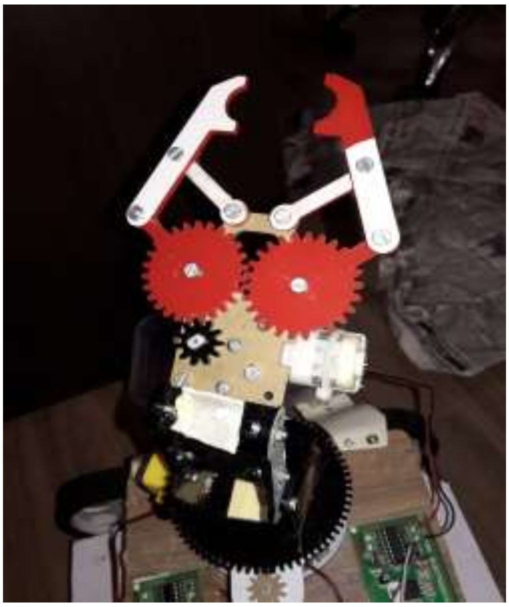
Parameter	Length (mm)
Base	**45**
Elbow	**110**
Wrist	**70**
Plucker	**65**

Table II: Degree of Freedom of robotic arm

Parameter	Angle of movement (^{0})
Base	360^0
Elbow	180^0
Wrist	0^0
Plucker	30^0 to 40^0

This design was inspired by the physical action performed by a human hand during the process of holding and plucking fruits. The gripper tool uses a single DC motor for opening and closing the moving fingers which are normally open. This system is very sensitive; the closing (or fruit grabbing) procedure is stopped when the torque applied by the motor of the fingers increases more than 10%. The torque applied by the DC motor is estimated by measuring its current.

Fig. 2(a): Robotic arm design



(**b**) Detail of the gripper tool with the imaging device.

2.3 Travelling Platform:

The traveling platform is designed by using the wooden plank and 4 DC motors is connected to it. The speed of DC motors are set to 100 rpm.

Whenever the fruit is detected, the traveling platform will stop and the movement of the robotic arm will start and exactly opposite to this when the fruit is not detected, the traveling platform will be moving.

3. Stereo-vision Fruit Detection Accuracy

The control of the robotic arm requires an estimate of the fruit distances, positions, and sizes in the herbs in order to propose an automatic fruit harvesting procedure. In this paper, this estimate will be performed with a stereo vision system.

3.1 Experimental Setup

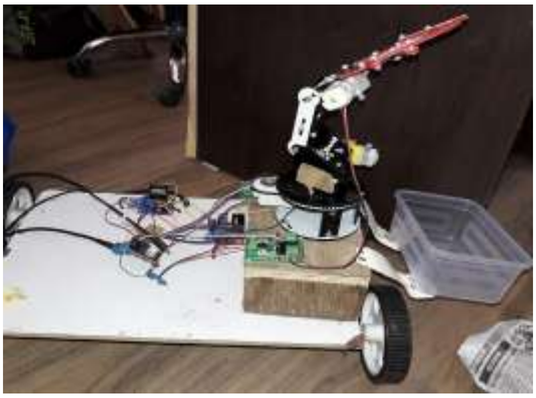


Fig.3: Experimental Setup

3.2 Image Processing: Fruit detection

The image processing involves background segmentation and environmental conditions. The white background used in the thresholding procedure of fruit detection. The RGB USB webcam is used, however no need to convert image from HSY to RGB image.

First, to get the information of image acquisition hardware system we used an '*imaqhwinfo*' command in the command window of MATLAB software. The result of this command gives the installed adapter, Toolbox version, and MATLAB version.

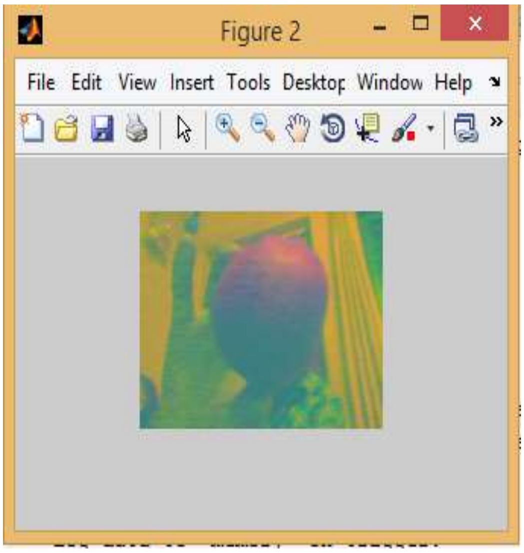


Fig 4: Captured Image of Fruit

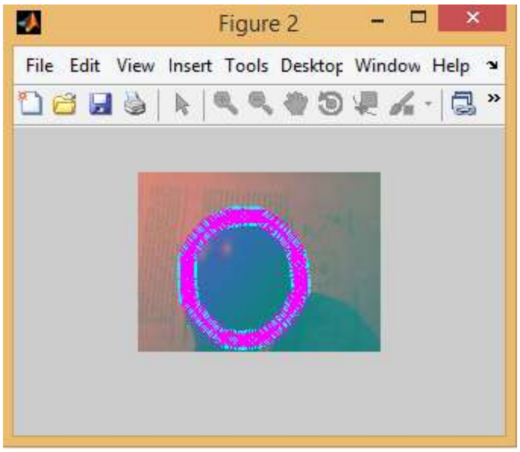


Fig 5 : Thresholding of fruit

In installed adapter, it gives the particular format which supports by software and installed hardware. By choosing that format we could check the no. of device IDs. For example, imaqhwinfo('winvideo'). This command gives the no. of ID's installed in the image acquisition system. After choosing the device which is installed on the robotic arm, the next step is to check the image format support by the webcam. For example, JPEG, MPEG with resolution.

By using video input function the webcam will turn ON and 'getsnapshot' function will capture the image of fruit. 'IMTOOL' command is used to threshold the image.

While thresholding the outer dimensions the shape of fruit had to be selected properly. This was a very sensitive job, because the improper thresholding may allow unnecessary noise. Whenever, the selection is done double click on the image. For the selected portion of fruit, the range of RGB values is given in a row.

From the RGB values in row, the lowest and highest value of RGB had to be selected, but the value supposed to be repeated. To get a view of how thresholding has been done 'IMPIXEL' command is used. The lowest and highest values of RGB are used in the IMAGE(I) in the way shown below:

I =((R>)&(R<)&(G>)&(G<)&(B>)&(B<))

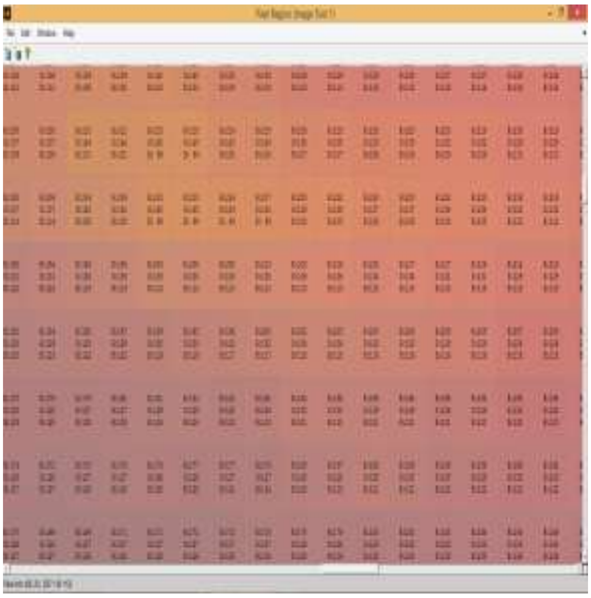


Fig. 6: Pixel region of Fruit

This 'I' value shows the range of thresholding. To check the thresholding 'IMTOOL(I)' command is used. This is how live detection has been done.

3.3 ARDUINO NANO:

After detecting the position of fruit, different cases are assigned to move the robotic arm. For example, move left (L), move right(R), move forward (F), move backward (B) and stop moving(S).

These cases are sent to the ARDUINO which is preprogrammed and the robot will move accordingly after receiving commands from the MATLAB software.

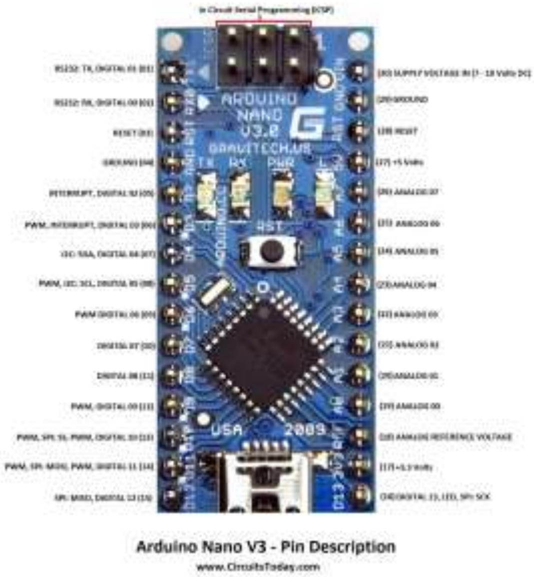


Fig. 7: ARDUINO NANO Pin Diagram

4. Automatic Harvesting

The automatic fruit harvesting system requires the control of the robotic arm based on the positioning information provided by the stereo-vision system. The stereo-vision system is directly attached to the gripper of the robotic arm in order to obtain relative positioning information between the gripper tool and the fruit. The complete modification of this experimental assessment requires three stages: (1) Initial fruit detection (2) Rough approach to a selected fruit (3) Fruit pickup. In this paper, the automatic fruit harvesting system has been applied to pick up some tomato in controlled laboratory conditions.

4.1. Initial Fruit Detection

The initial fruit detection procedure, limited to the case of harvesting tomato and tested under laboratory conditions, has been primarily addressed by applying a simple RGB color threshold to the stereo-vision images but real outdoor conditions affected by changing illumination conditions may require a more elaborated segmentation procedure.

The assumption made in this initial fruit detection was 'I'. stereo-vision system is placed over the wrist of the robotic arm, which is known as a reference position. The distance range of the fruits will be from 500 to 1000 mm from the stereo-vision system. This procedure ends with the selection of fruit in the image based on their diameter estimate.

4.2. Rough Approach to a Fruit

The initial displacements of the robotic arm in order to move the gripper tool in the direction of a selected fruit must be considered as a rough approach that will be affected by the uncertainty of the detection procedure. The estimate of the distance and position of a selected fruit relative to the stereo-vision system located in the gripper tool is first computed in order to rotate the robotic arm in the direction of the fruit.

Fig 8: Example of rough approach to a fruit.

4.3 Fine approach to a fruit

A specific procedure is proposed in order to control the fine displacement of the gripper tool to pick up the selected fruit. This approach is based on moving forward the gripper tool of the robotic arm according to the position of the centre of the selected fruit in the image acquired by the stereo-vision system. Then this fine approach algorithm suggests small vertical and horizontal relative displacements the gripper tool in order to center and finally pick up the fruit.

The use of the proposed stereo-vision system in this fine approach is somewhat problematic, because the limited angle of view of the stereo-vision system does not provide a complete image of the tracked fruit at very short distances.

In this paper, this iterative procedure was stopped by applying a threshold to the area of the fruit in the proximity images.

4.4 Final pickup

The mechanical actions proposed to pick up tomato are: 1. open the gripper 2. hold the tomato 3. cut the stem of fruit where fruit is connected.

4.5 Fruit pickup performance

As this robot is a prototype, hence the fruit pickup performance is low according to the requirement.

CONCLUSIONS

In this paper, we have presented a low-cost fruit harvesting system, a combination of a stereo-vision system and a robotic arm for post-harvesting. The stereo vision system, placed on the gripper tool, will provide direct information and control of the actions performed by the robotic arm.

Then, the complete development of a fruit harvesting system based on the use of a stereo-vision system attached to the gripper tool of the robotic arm. The gripper tool has been designed to facilitate fruit holding and manipulation whereas the stereo-vision system provides fruit size and positioning information relative to the gripper tool.

The findings of the image processing study are significant for academic and managerial implications. This study of image processing has certain limitations. We can detect only one type of fruit at a time. Every fruit requires a different range of RGB values. This study examined different types of fruits image processing and situations occur according to selected fruit. While selecting fruit, the height of plant, color and environmental conditions had to studied to prepare hardware. We analyze that this robot is low-operating device with better performance and has to improve the pickup gripper tool with a degree of freedom.

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