Automatic Apple Harvesting Using Computer Vision Based On Shape & Colour-Based Analysis and Object Positioning

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***Abstract*— in this paper, the automatic robotic apple harvesting algorithm is proposed. The new system is proposed for the automatic apple harvesting in the Himachal Pradesh and Jammu & Kashmir regions of India to overcome the labour shortage problem. The new algorithm will be developed using colour and shape analysis. Also, the new algorithm will be designed for the object positioning in 3-D space to increase the accuracy of the robotic arm movement. The new system will be developed using MATLAB simulator. The proposed algorithm will be developed to rectify the problem related to the false positives and false negatives (false decisions) by using 3-D depth analysis to facilitate the smooth and accurate robotic arm movement to minimize the crop damages due to wrong (false) decisions. The aimed accuracy is above 92% for the proposed algorithm.**

***Keywords*- 3-D depth analysis, Apple harvesting, Automatic robot, Colour and shape analysis, Robotic arm movement.**

1. INTRODUCTION

India is the second largest producer/harvester of fruits and vegetables, representing 10.9% and 8.6% of overall production respectively. India's share in the world fruit and vegetable production is 10 % and 13.28% respectively. Temperate fruits grown in India are apple, pear, peach, plum, almond and walnuts. Our thesis work is related to apples and harvesting system of apples. Today a great amount of different types of apple are implant in distinct regions of India but Himachal Pradesh and Jammu and Kashmir are the striking states, where the huge amounts of apples are produced. Harvesting practice of apple fruit is consumed a lot of time. Labour for harvesting apples is also a huge problem for apple farmers and labour is not easily accessible in these regions. Due to shortage of required labour apple farmers face the loss of apple crop.

The solution of this problem can be an Automatic apple harvesting using robots. A robot or an automatic machine should have the capability to separate an apple from its background, to detect the relative positions of an apple, and it should also be capable to measure the coordinate values of three dimensions from base point of robot. An existing system which is used to obtain such 3-D information in an outside field is Binocular stereo vision. However, the correspondence problem of stereopsis has not yet been solved practically. Thus, stereo vision system's use with an automatic machine remains unworkable. It is observed that the apple images acquired in apple orchards periodically display the correspondence problem or other image problems, such as, similar objects, overlapped fruits, and a congested or transformed image in which fruits covered by the leaves and the branches. So in order to apply the Binocular stereo vision method to such images there is a great need to discover a solution or to take actions against such kind of problems.

The search for corresponding points of the same object on a pair of image from a left camera and right one, respectively, in order to compute distance based on triangulation principal is a major point of conventional methods to calculate distance by Binocular stereo vision. Since each image of the pair is taken by an independent camera, it is hard to find out the corresponding points, especially when several similar objects exist on an epipolar plane, and it is assumed that the results are imperfect in reliability.

Monocular vision established a technique used in the present study that is consisted of two cameras used in cooperation with under triangulation rule to improvement of reliability of result. A central image of monocular vision is obtained by composing a stereo pair of images on a cross section of a search space in the direction of depth (Takahashi et al., 1998 and 2000a). Therefore, space is divided into slices for preparation of several central images, and combination of these slices uses 2-D images to recreate a 3-D version of the object. If the central composite images are obtained under the above mentioned situation the correspondence problem will be reduced. But a stereo vision system with current existing cameras that are not considered to serve this function is suitable to create false images, even if the method of composing central images is adopted.

Robotic harvesting should be commercially justifiable. Harrell et al. carried out the economics analysis of robotic citrus harvesting in 1987 and 19 factors were recognized, which have an effect on harvesting cost. It was found that robotic citrus harvesting cost was larger than Florida hand harvesting cost and concluded that robotic harvesting cost was mainly

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affected by harvest efficiency which is defined as the number of fruits harvested per unit time, harvester purchase cost, average picking cycle time and harvester repair cost. Thus, it was concluded that robotic harvesting technology should carry on and focus on the following areas: (a) harvest efficiency, (b) purchase cost, (c) harvester reliability and (d) modifications in work environment that would improve performance of robotic harvesters. In addition, it was also found that the most sensitive part which contributes in the increasing robotic harvest cost is harvesting efficiency which is defined as number of fruits harvested to the total number of fruits detected in the canopy. Therefore, it was suggested that the main design objective would be to minimize harvest inefficiency. It was concluded that to replace the human labour with robotic harvesting system 1-7% harvest efficiency would be required [3].

Robots can perform well in well regulated or structured environment. In this type of environment the location and direction of the target is well known, or object can be placed in the desired location and direction. These are the traditional industrial application of the Robots. But in these days, with scientifically and technologically advanced surroundings, robots or automated machines are used in non-traditional areas, where the environment is unstructured with application in medical robotics, vision guided warfare and agricultural robotics. In the present time the centre of attention of maximum researches in robotics fruit harvesting has been to design a harvesting system that can copy the accuracy of the human harvester, while increasing the efficiency and decrease labour of purely mechanical harvester. The classical design of robotic fruit harvester made up of a vision system for detecting the fruit, an operator to move towards the fruit, and an end effecter to pluck the fruit. The communication of the fruit detection algorithm with the robotic harvester is the most important part of a vision based robotic fruit harvester. The idea is to derive the information from the vision system about the detected fruit and convert this information into the commands for directing the robotic system to the desired position and do harvesting. [3]

2. LITERATURE SURVEY

Fruit recognition is usually the first image processing operation performed on images acquired for robotic harvesting. To be effective for outdoor fruit harvesting, fruit detecting algorithms have to be robust to changes in illumination and saturation. Most of the fruit detection systems use colour pixel classification, allow for rapid fruit detection and ability to detect fruit at specific maturity stage. Pla et al. implemented a fruit segmentation algorithm in 1991 based on colour images in the citrus harvesting robot CITRUS. The method is based on transformation from RGB space coordinates. They observed that 86% of the fruits visible to the human eye have been detected in images with 3.7% misclassification in fruits. Plebe et al. in his survey on fruit detection techniques studied that best results based on shape analysis indicate that more than 85% of the fruit visible in the images could be detected. Vision based depth sensors help in detecting multiple fruits in the image. The popular approaches to vision based depth estimation are: 1. Stereo vision, 2. Depth from focus/defocus, 3. Depth from shading and texture. Annamlai et al. developed an algorithm in 2004 which counts and identifies number of fruits in an image. The number of fruits was counted using blob analysis. Regunathan et al. in 2005 implemented three different classification techniques – Bayesian, neural network, and Fisher linear discriminant. These techniques are used to differentiate fruit from the background in the images using hue and saturation as the separation features. Some of the techniques used shape based analysis to detect fruit. However, systems based on shape based analysis were more independent of hue changes, were not limited to detecting fruit with color different from color of the background, although their algorithms were more time consuming. Feng et al. developed an image segmentation algorithm based on OHTA colour spaces introduced by Ohta for robotic harvesting of strawberries in 2008. OHTA colour space was found to be linear and computationally inexpensive. Meenu Dadwal et al. in 2012 represented different techniques to detect the rate of ripeness of fruits and vegetables like histogram matching, clustering algorithms based image segmentation and relative value of parameter based segmentation. In these techniques we set some threshold levels and by comparing the input data image with these threshold levels we can find the maturity level of given fruits and vegetables. King Hann Lim et al. developed the robotic vision system design in 2013 to locate the coordinate of pepper fruits from trees and leaves, and identify pepper ripeness for harvest in Sarawak region, Malaysia. The vision system comprises of three stages, i.e. salient point localization, contour extraction and pepper verification. Preliminary simulation results showed that the vision system spotted the salient regions with pepper in 91.3% of success rate; contour extractions covering a pepper boundary with 84.35% of success rate and the results for pepper verification stage are promising.

3. PROBLEM FORMULATION

The robots are not very intelligent devices. All of their intelligence lies in the programming modules developed for the task accomplishment by them. The robotic harvesters are being popular as a research area and may become a reality in the near future. To lead the robotic harvesting system toward the reality from the virtual reality, it requires a lot of research and development on the computer vision techniques. The harvesting robots are not such kind of intelligent, that they will be taught how to recognize one fruit or vegetable and they will automatically inherit the similar recognition intelligence for other fruits or vegetables. Hence, they has be programmed and trained for harvesting of different types of vegetables and fruits. In this research, we are working on apple harvesting in

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the Himachal Pradesh and Kashmir areas of India. We are addressing region specific apple harvesting issue because the visible properties of apple vary from region to region. So, the harvesting robots have to be trained individually for every variety of apples to make it able to automatically harvest all kinds of fruits.

4. PROPOSED SYSTEM

The apple harvesting computer vision technique will be developed using a combination of various digital image processing techniques. The whole system will work in a series of steps: Image acquisition, Feature Recognition, Feature Extraction, Feature Position and Harvesting. For the feature recognition and feature extraction, a combination of image segmentation using an effective and novel image segmentation algorithm and shape recognition algorithm will be used. The proposed automatic harvester will identify the apple fruit in 2-D and 3-D vision. In 3-D space, the computer vision technique will obtain the depth of the object i.e. Z-axis, whereas in 2-D space, computer vision technique will obtain the location of the fruit in flat ground or flat grid i.e. X-axis and Y-axis. For the position and counting of the apple fruits on apple trees, specific positioning algorithm will be used. The result will be measured by counting True Positive, True Negative, False Positive and False Negative. The final results would be compared to that of the base paper.

5. OBJECTIVES

A. Computer vision based automatic apple harvesting tools work independently, hence, decreases the dependency of the system on human.

B. Computer vision based automatic harvester will pluck the ripen fruits only, hence does not make mistakes like a layman laborer, who also plucks the unripe fruits, which may cause a loss to the farmer.

C. Proposed automatic harvester is designed to get the actual location of the fruit and 3-D and 2-D space separately, hence will be more perfect than the existing techniques.

D. Real-time location aware automatic harvester will not pluck the wrong objects like branches of the tree or leaves as the result of wrong object detection in existing harvesters.

E. To save the apple harvesting time and decrease the overall harvesting cost.

F. To improve the accuracy and results of various computer vision harvesting techniques.

6. RESEARCH METHODOLOGY

The research project based on automatic apple harvesting tool with intelligent computer vision will be developed using MALTAB simulator. The MATLAB version 11 or above will be used to develop the research project. At first, all the requirements of the algorithm design will be studied thoroughly. Then, the proposed algorithm design would be analyzed and corrected according to the notifications in the design analysis in the first phase. The corrected and modified algorithm in its initial phase would be then implemented in the MATLAB simulator. The first step of the proposed algorithm will be to detect the objects in the captured frame by using Contour Tracing technique. This technique is used to trace the outline of the object (apple fruit in our case). The objects detected through contour tracing will detect various objects of similar shape. The second task will be to select the apple fruit out of all of the objects outlined using contour tracing. The apple fruits will be shortlisted using the colour density or colour pattern. Then a fruit counting in the frame can be applied to make the robot aware about the number of fruits in a single event or single frame for apple harvesting. In the next step, the algorithm will be programmed to discard the unripe apple fruits. The remaining would be the ripen apples in the selection. After detection of the ripen fruits on the tree the algorithm may continue toward positioning of the apple fruit from edges of the robot's vision frame. It will measure the distance of the object (apple) from the side walls of the frame i.e. X-axis and Y-axis. Then it will measure the depth of the object (apple) i.e. Z-axis. Then it will pass the pluck command to its robotic arm and harvesting procedure will start.

7. CONCLUSION

The proposed research work is being developed for the apple farming in the Indian hill areas of Himachal Pradesh and Jammu & Kashmir. The proposed apple harvesting system will be developed using a hybrid object identification and verification algorithm using colour and shape analysis along with object positioning in 3-D space to facilitate the perfect robotic arm movement. The new system will facilitate the apple farmers to solve the labour shortage problem. New algorithm will also be designed to minimize the apple fruit damage usually done by the automatic harvesting robots.

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