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Tomato Harvesting Arm Robot Manipulator; a Pilot Project

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Abstract. Promoting digital farming might be the answer for current challenges in the agriculture industry by employing a robot to provide continuous information of its deployed area and gives the right analysis in many aspects of farming. This paper discusses the pilot project of employing robot as a harvesting robot. The fruit to be picked is red and green tomatoes. The objective of this study is to set the initial project in creating a series of robots applied in agricultural to realize the idea of digital farming. The novelty of this study is that this method is simple, and image processing is kept simple to accommodate processors limited computation resources. The robot designed is customized according to the size of the tomato tree and tomato. The tomato location is indicated by a circle resulted from the image processing and divided into left, right, and middle position in the image plane. The image plane resolution in this study is 320 × 180 pixels. If x = 15 pixels and y = 42 pixels, then the output angle of servo motor on the based is 115^0, servo motor joint1 is 90^0, and servo motor joint2 is 100^0. The arm robot moves to the left and harvests the tomato. The average time for harvesting red tomato is 4.932 s, and green tomato is 5.276 s. The required time for the robot from detecting red tomato and return to standby position is 9.676 s, and 10.586 s for the green tomatoes. This time difference is due to robot distance to tomato and not the color of the tomato. The experiment shows that the robot successfully harvests the tomatoes in the setting given in this study, and proves the effectiveness of this robot design as an agriculture robot.

Keywords: *agriculture robot, arm robot manipulator, digital farming, eye in hand, harvesting robot,*

1. Introduction

Promoting digital farming might be the answer for current challenges in the agriculture industry, such as the lack of young people interest in this industry, ever-growing population that demands more food stock, and the requirement in keeping the quality and quantity checked all the times [1]. Digital farming or automatic farming is a method in applying automation in every aspect of farming, starting from seeding to harvesting the agriculture product [2, 3, 4].

Employing a robot is considered building a digital farming project. The robot can provide continuous information about the farm or area where it is deployed, and gives the right analysis in many aspects of farming. All the type of robot is possible to be a farming robot, such as a drone can spray pesticide effectively [5]. A robot can be a great help during harvesting since it can monitor the field continuously and pick the product at the right time based on the input criteria. Arm robot manipulator [6]-[16] and the mobile robot [17] can be employed as a harvesting robot. However, for picking motion during harvesting time, arm robot manipulator is the perfect one for the job since it has an arm that can be customized to pick or grab any objects [6]-[17].

To ensure the effectiveness during harvesting, the robot needs eye to detect, track, cut, and grab the agricultural product. As electronics components needed to build a robot are getting cheaper, everyone can build their robot, including equipping the robot with a good camera [6][7]. Camera size is also getting smaller that it can be attached to the robot without adding significant weight to it. There are two types of camera application on arm robot manipulator; eye in hand and eye to hand. Eye in hand is where the camera attached to the robot, and eye to hand or time of flight camera is where the camera is attached elsewhere. Both methods have their advantages and disadvantages. The eye in hand has a more natural function as an eye, however, is prone to occlusion[6]-[16].

Camera application needs image processing to differentiate the object to be grabbed/picked with the background; therefore, the robot knows which one to cut and grab, and which ones to ignore, for example, it is essential that robot understand the fruit location relative to vegetation [6]-[16]. Another necessary sensor is a proximity sensor to make the robot get a sense of distance between it and the fruit.

This paper discusses the pilot project of employing robot as a harvesting robot. The fruit to be picked is tomatoes, both green and red tomatoes. The robot is equipped with servo motors as the actuators, microcontroller ATMega as the main controller, Raspberry Pi to process the image, PI camera attached to the end-effector, and proximity sensor to give the distance information between the robot and fruit. To show the effectiveness of proposed method, the prototype robot harvests the fruit by cutting its branch; the fruit considered in this study is red and green tomatoes. The objective of this study is to set the initial project in creating a series of robots applied in agricultural to realize the idea of digital farming. The novelty of this study is that this method is simple, and image processing is kept simple to accommodate processors limited computation resources.

2. Harvesting robot design

This paper presents the design of a harvesting robot for detecting and picking red and green tomatoes. The robot design is given by the diagram block in figure 1, electrical design in figure 2, and the 3D design of the arm robot manipulator in figure 3. Figure 1 represents the attached components related to the input, process, and output.

The inputs in figure 1 are given by camera and proximity sensors. The camera captures the raw image of the fruit and its background, including vegetation. The raw images are sent to raspberry Pi and personal computer. The proximity sensor is necessary to detect the distance between the end effector and the targeted fruit [7]. The end effector in this study consists of a scissor to cut the tomatoes branch, a webcam as the "eye," and a proximity sensor to sense the distance between the end effector and tomatoes.

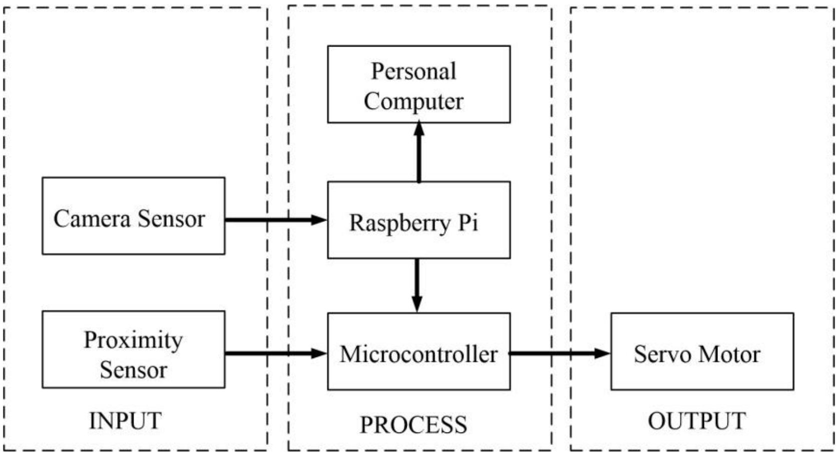


Figure 1. Diagram block of the proposed method

The process in figure 1 includes processing the raw image from camera in personal computer, and the result of the image processing (the detected tomatoes) are sent to Raspberry Pi. The detected tomatoes gives the binary number "1" and sent to microcontroller. The output in figure 1 are the servo motor angles that move the robot approaching the tomatoes. Servo motors are attached to joints and end effector, therefore servo motor angles create a certain motion of the robot. Proximity sensor attached to the end effector gives the input to microcontroller to ensure the right picking distance between the end effector and the tomatoes.

Figure 2 shows the electrical connections among the attached components of the harvesting robot. The camera used in this study is the commonly used webcam camera with a proper resolution, and its dimension is attachable to the end effector. The distance sensor used in this study is ultrasonic sensor HC-SR04 that can detect from 2 cm to 400 cm, with detection angle up to 30^o. Its dimension is small enough to be attached to the robot end effector (4.5 x 2 x 1.5 cm). The processor for image processing in this study is Raspberry Pi 3 Model B, and the main processor is Arduino Mega 2560, and the actuators are servo motors. The arm robot considered in this study is a 4DOF robot; a servo motor for the base, joint 1, joint 2, and end effector.

Figure 3 shows robot specification where the dimension of base and links are presented, including the full height of the robot. This specification is designed based

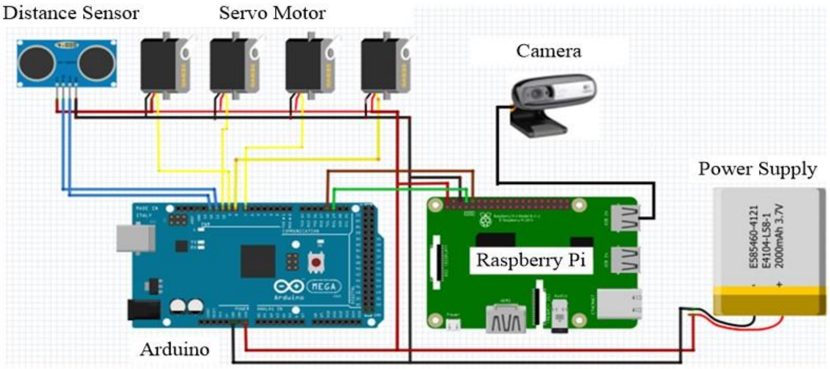
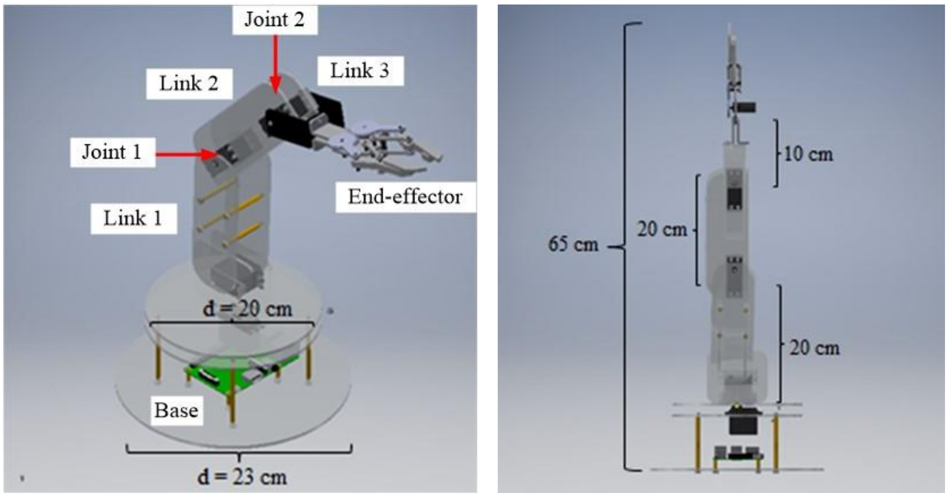


Figure 2. The electrical connection among the components of the harvesting robot.



(a) Robot specification (b) Robot links specification

Figure 3. The 3D design of harvesting robot considered in this study.

on the size of tomatoes tree and can be customized according to the needs and the size of targets to be harvested. The end effector of the 4DOF arm robot in this study is designed to cut the tomatoes branches. The camera is installed on the end effector and considered as eye in hand robot. The advantage of eye in hand method is occlusion free during the process of approaching and harvesting the tomatoes [4].

Image processing is conducted to locate tomatoes position by differentiating them with the background. The raw image captured camera is flatted and converted into a gray-scale image. The gray-scale image is then converted to the binary image where the tomatoes are given the value of ”1,” and others are considered ”0”. The coordinated position of tomatoes is mapped into the camera image plane of x and y position, as shown in figure 4 [7]. The webcam used in this study has an image plane with a resolution of 320×180 pixels, where x is from 0−320 pixels, and y is 0−180 pixels. By mapping the tomatoes location into position in figure 4, the robot can be programmed to approach that particular position more natural.

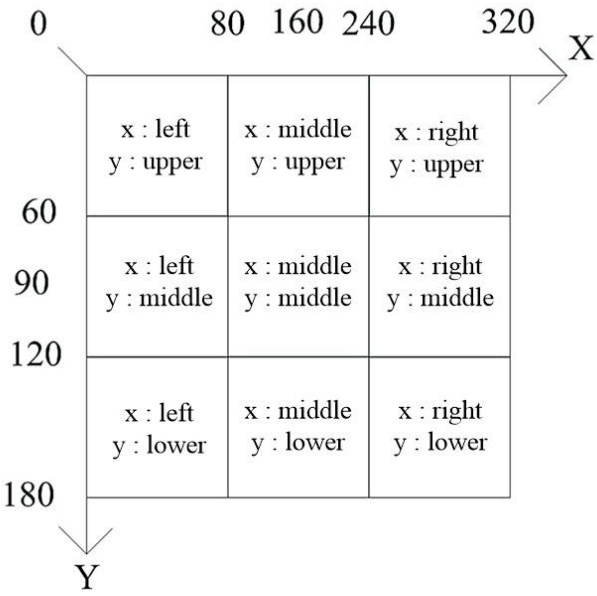


Figure 4. The coordinates mapping of tomatoes detection

3. Result and Discussion

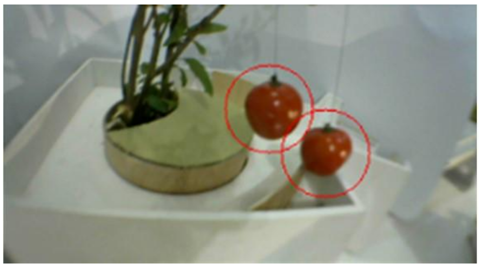
The harvesting robot in this study is deployed to harvest the red and green tomatoes, as shown in figure 5. The red and green tomatoes are chosen since these are the standard agricultural product in South Sumatra. The first step of harvesting is tomatoes detection that gives coordinates location of tomatoes. Figure 5 shows the detected tomatoes indicated by circles. Figure 5(a) to 5(c) is the detection of red tomatoes, and figure 5(d) to 5(f) are the circles of green tomatoes.

Table 1 presents the measurement of the voltage output of the servo motor during robot motion in harvesting the tomatoes. These measurement points refer to figure 2. The measurement is to show how the robot moves based on the position and motion of the robot. The left and right motion of the robot is moved by the servo motor installed on the based. During the up and down motion, motor servo at joint 1 and joint 2 move the robot. During harvesting, the active servo motor is a servo motor that moves the end effector.

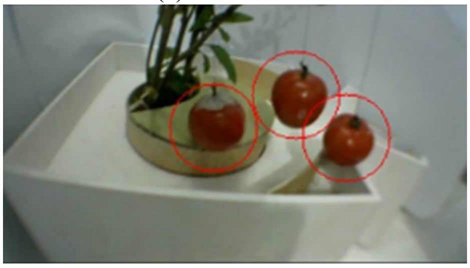
Table 1 shows that the voltage measurement results obtained from each servo motor are the same when going is 5.09 V, standby up is 5.10 V, going down is 4.98 V, standby down is 5.07 V, right is 5.08 V, standby right is 5.05 V, left is 4.96 V, and standby left is 5.08 V.

Figure 6 shows the process of harvesting the red and green tomatoes. Figure 6(a) is the condition where the robot's eye (camera) captures the images of tomatoes. These images are sent to the personal computer, as shown in figure 1. The personal computer automatically processes the image processing and sends to the Raspberry Pi attached to the robot. The robot records the location of tomatoes and starts to move to approach the tomatoes. In this study, the robot is designed to harvest the red tomato before

(a) 1 red tomato



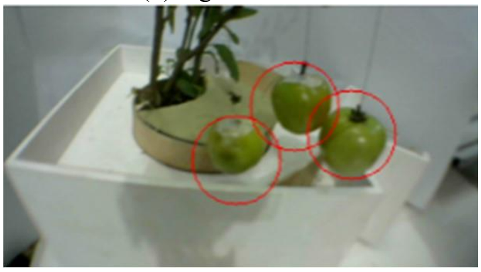
(b) 2 red tomatoes



(c) 3 red tomatoes

(d) 1 green tomato

(e) 2 green tomatoes

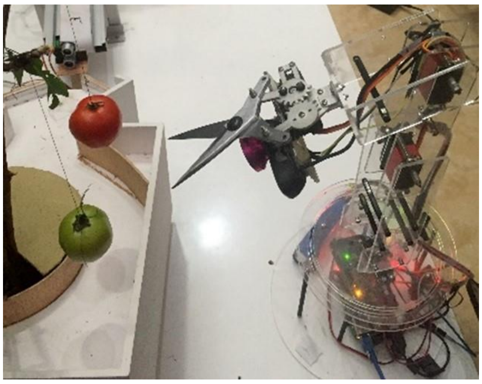


(f) 3 green tomatoes

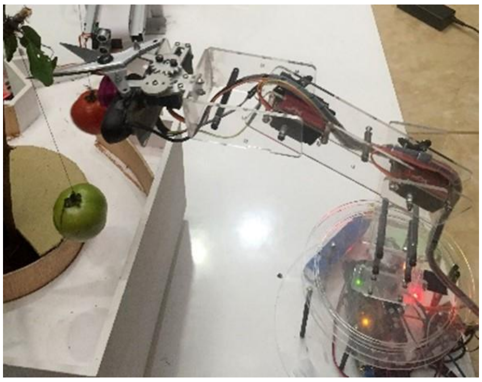
Figure 5. Tomatoes detection indicated by the red circles. **Table 1.** Servo motor voltage value measured during robot motion

Robot Motion	**Voltage of Servo Motor (V)**			
	Based	**Link 1**	**Link 2**	**Gripper**
Going up	5.09	5.09	5.09	5.09
Standby up	5.10	5.10	5.10	5.10
Going down	4.98	4.98	4.98	4.98
Standby down	5.07	5.07	5.07	5.07
Right	5.08	5.08	5.08	5.08
Standby right	5.05	5.05	5.05	5.05
Left	4.96	4.96	4.96	4.96
Standby left	5.08	5.08	5.08	5.08

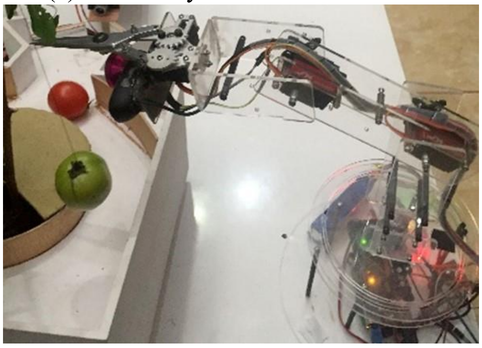
the green tomato. This scenario is intended to prioritize the red one due to in real application the red one is also picked first. The red tomato is the ripe one, as in the case of tomato, the reddish color indicates the level of ripeness. Therefore, the robot is also assigned to harvest the most reddish one.



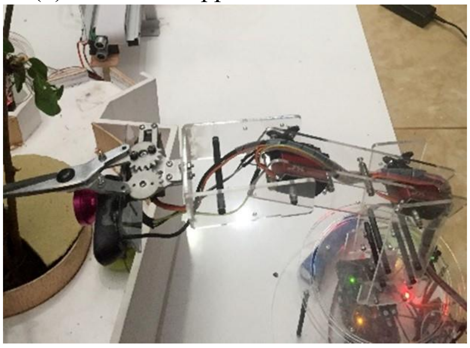
(a) Robot's eye detects the tomatoes



(b) Arm robot approach the red tomato



(c) Arm robot cut the red tomato



(d) Arm robot cut the green tomato

Figure 6. The process of harvesting red and green tomatoes

However, during the application, image processing is prone to illumination. Therefore, the robot is assigned to pick the closest red tomatoes indicated by the most extensive circle or detection. This scenario is decided due to the difficulty in differentiating shades of red during application. Figure 6(b) shows the robot is approaching the red tomato, and figure 6(c) is where the robot cut the branch of the tomatoes. As the robot detects the tomatoes, it assigned to cut about 3 cm above the tomatoes. It is expected that the robot cuts the branch and not fruit.

The next step is the robot cut the green tomatoes, as shown in figure 6(d). If more than one tomatoes are detected, the robot picks the closest green tomatoes, as indicated by the most prominent detection.

Table 2. Time required by robot to finish its task in tomatoes harvesting.

Experiment to	T_{R1} **(s)**	T_{R2} **(s)**	T_{G1} **(s)**	T_{G2} **(s)**
1	4.81	9.83	5.61	10.44
2	5.34	9.5	4.84	11.82
3	4.59	9.15	4.81	10.16
4	4.84	10.03	5.47	9.55
5	5.08	9.87	5.65	10.96

Average	**4.932**	**9.676**	**5.276**	**10.586**

Experiment to	**Tomatoes Position**	**X (pixel)**	**Y (pixel)**	**Servo Base**	**Servo Joint 1**	**Servo Joint 2**
1	Right	15	42	115^0	90^0	100^0
2	Middle	224	72	69^0	96^0	94^0
3	Left	305	98	60^0	105^0	85^0
4	Right	33	49	115^0	90^0	100^0
5	Middle	163	77	88^0	980	92^0
6	Left	287	88	60^0	104^0	86^0
7	Right	39	55	115^0	90^0	100^0
8	Middle	162	75	89^0	97^0	93^0
9	Left	263	106	550	105^0	85^0

Table 3. Relation between tomato position and servo motor motion range

The experiment in figure 6 was conducted in 5 times. The time required for the robot to finish harvesting is shown in table 2, where T_{R1} is the time required from red tomato detection until finish cutting the branch, T_{R2} is the time required from red tomato detection until robot return to standby position, T_{G1} is the time required from green tomato detection until finish cutting the branch, and T_{G2} is the time required from green tomato detection until robot return to standby position. The average time for T_{R1} is 4.932 s, T_{R2} is 9.676 s, T_{G1} is 5.276 s, and T_{G2} is 10.586 s. Therefore, table 2 shows that red tomato harvesting is faster due to its location closer to the robot position.

The robot is moved by servo motors attached to every joint and scissor in the end effector. The servo motor moves the robot by exerting them in a certain angle showed in table 3. The input coordinates positions in x and y-axis of table 3 tomatoes shown in table 3 are represented by the pixels. The position is also translated into the right, middle, and left. For example, If x = 15 and y = 42, then the output angle of servo motor on the based is 115^0, servo motor joint1 is 90^0, servo motor joint2 is 100^0; therefore, arm robot moves to the left and harvest the tomato.

The arm robot manipulator designed in this study is assigned to be a harvested robot, where it is deployed to harvest red and green tomatoes. The detection was conducted using image processing, as shown in figure 5 and the process of harvesting in figure 6. The harvesting process is conducted five times, and the time required is shown in table 2. To show the effectiveness in picking up the tomatoes within the different location in the image plane as shown figure 4, each position of the right, middle, and left, were tested for two times and recorded in table 3.

4. Conclusion

This paper presents a pilot project of tomato harvesting robot. Therefore, the robot designed is customized according to the size of the tomato tree and tomato. The tomato location is indicated by a circle resulted from the image processing and divided into left, right, and middle position in the image plane. The image plane resolution in this study is 320 × 180 pixels. Robot motion is based on the x and y coordinate location of the robot, such as If x = 15 pixels and y = 42 pixels, then the output angle of servo motor on the based is 115^0, servo motor joint1 is 90^0, servo motor joint2 is 100^0; therefore, arm robot moves to the left and harvest the tomato. The average time for harvesting red tomato is 4.932 s, and green tomato is 5.276. The required time for the robot from detecting red tomato and return to standby position is 9.676 s, and 10.586 s for the green tomatoes. This time difference is due to robot distance to tomato and not the color of the tomato. The experiment shows that the robot successfully harvests the tomatoes in the setting given in this study, and prove the effectiveness of this robot design as an agriculture robot.

References

[1] Bhargava A and Bansal A, 2018 Fruits and Vegetables Quality Evaluation using Computer Vision: A Review, *Journal of King Saud University* - Computer and Information Sciences. https://doi.org/10.1016/j.jksuci.2018.06.002.

[2] Duckett T, Pearson S, Blackmore S and Grieve B, 2018 Agriculture Robotics: The Future of Robotic Agriculture, *UK-RAS Network Robotics & Autonomous System* ISSN 2391-4414.

[3] Shamshiri R R, et. al., 2018. Research and Development in Agricultural Robotics: A Perspective of Digital Farming, *Int. J. Agric & Biol Eng.* vol 11 no 4 pp 1-14.

[4] Dewi T, Risma P, Oktarina Y and Muslimin S 2018 Visual Servoing Design and Control for Agriculture Robot; a Review *2018 International Conference on Electrical Engineering and Computer Science (ICECOS)* pp 57-62. doi: 10.1109/ICECOS.2018.8605209

[5] Zhao Y, Sun Q, Wang C and Zhang C 2015 Visual Control System of a Spraying Robot for Hyphantria cunea Larva Nets *Journal of Robotics* Article ID 436490, 7 pages. https://doi.org/10.1155/2015/436490.

[6] Stoelen M, Krzysztof K, Tejada V F, Heiberg N, Balaguer C and Korsaeth A 2015 Low-Cost Robotics for Horticulture: A Case Study on Automated Sugar Pea Harvesting *10th European Conference on Precision Agriculture (ECPA)* DOI: 10.3920/978-90-8686-814-8 34.

[7] Yusuf M D, Kusumanto RD, Oktarina Y, Dewi T and Risma P 2018 BLOB Analysis for Fruit Recognition and Detection *Compengapp Jurnal*, Vol 7 No 1 pp 626-631. http://dx.doi.org/10.1016/j.ijleo.2016.11.177.

[8] Wang C, Tang Y, Zou X, SiTu W and Feng W 2017 A Robust Fruit Image Segmentation Algorithm against Varying Illumination for Vision System of Fruit Harvesting Robot, *Optik*, Vol 131 pp 626-631. http://dx.doi.org/10.1016/j.ijleo.2016.11.177.

[9] Xiong C, Xiaoman C, Zou X 2017 A Method for Identification and Matching of the Picking Point for Mature Litchi under Structural Environment *Journal of Applied Biotechnology & Bioengineering* Vol 3 Issue 6 p 4.

[10] Barth R, Hemming J and van Henten E. J. 2016 Design of an Eye-in-Hand Sensing and Servo Control Framework for Harvesting Robotics in Dense Vegetation *Biosystems Engineering* Vol 146 pp 7184. http://dx.doi.org/10.1016/j.biosystemseng.2015.12.001.

[11] Ji W et al. 2012 Automatic Recognition Vision System Guided for Apple Harvesting Robot Computers and Electrical Engineering *Computers & Electrical Engineering* Vol. 38 No. 5 pp 11861195. https://doi.org/10.1016/j.compeleceng.2011.11.005

[12] Mehta S S and Burks T F 2014 Vision-Based Control of Robotic Manipulator for Citrus Harvesting Computers and Electronics in Agriculture", Vol. 102, pp.14658, 2014. http://dx.doi.org/10.1016/j.compag.2014.01.003.

[13] Mehta S S and Burks T F 2016 Multi-Camera Fruit Localization in Robotic Harvesting *IFACPapersOnLine* Vol 49 Issue 16 pp 9095. http://dx.doi.org/10.1016/j.ifacol.2016.10.017.

[14] Wang G, Yu Y, and Feng Q 2016 Design of End-Effector for Tomato Robotic Harvesting *IFACPapersOnLine* Vol 49 Issue 16 pp 190-193. https://doi.org/10.1016/j.ifacol.2016.10.035

[15] Li J, Karkee M, Zhang Q, Xiao K and Feng T 2016 Characterizing Apple Picking Patterns for Robotic Harvesting *Computers and Electronics in Agriculture* Vol 127 pp 633640. http://dx.doi.org/10.1016/j.compag.2016.07.024.

[16] Feng G, Qixin C and Nagata M 2008 Fruit Detachment and Classification Method for Strawberry Harvesting Robot *International Journal of Advanced Robotic Systems* Vol 5 Issue 1 pp 4148. https://doi.org/10.5772/5662.

[17] Blok P M, Barth R and van den Berg W 2016 Machine Vision for a Selective Broccoli Harvesting Robot *IFAC-PapersOnLine* Vol 49 Issue 16 pp 6671. http://dx.doi.org/10.1016/j.ifacol.2016.10.013.