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Design of a Robotic Pneumatic Pruner for Robotic Apple Harvesting

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Abstract

The robotic systems firstly developed in industrial production domain. But, in countries, in which the number of agricultural workers is limited and the costs are high, there is a tendency towards robotic technology in agricultural production. For this reason, the robotic system implementations started to seem in many agricultural activities. In the present study, the robotic system was discussed in terms of harvesting that is one of the agricultural activities. The robotic harvesting system consists of image processor, robotic arm, and gripper, which performs the final action. In this study, the position of fruit was determined in real-time by using the image processing. The X- and Y-coordinates sent to robotic arm directed the movement of it. Z-axis, which is the third axis and provides the forwards movement, was controlled using distance sensor. The designed pneumatic pruner system was mounted at the tip of robotic arm. The experiments were carried out on 100 Golden apples at different locations on the branch. Based on the coordinates of fruit, 85% positioning accuracy and 73% success rate were obtained in cutting the fruit from branch. The cutting success was statistically analyzed. At the end of study, the position of fruit stem corresponding to the tip of pruner, the position of pruner corresponding to the body of fruit, the fruit, or the beginning of stem rather than the stem itself, and the position of pruner on the shoot of stem were observed to cause failure during cutting procedure. According to the results obtained from experiments, it was concluded that the system to be used in such systems is the pneumatic pruner system.

Key words

Robotics,Harvesting,Apple, Pneumatic

1. INTRODUCTION

Mechanization technology field in the agriculture is in the important development in both our country and all around the world because of some reasons such as obtaining quality product and decreasing the labor force. Traditional production techniques have given its place to agricultural mechanization applications. For that reason, mechanization applications have became widespread in some fields such as planting, spraying, harvesting in different production areas. These kind of computer-aided systems have been used in the agriculture with the advancement of technology and the introduction of the computer technology. In particular, all workings are automatically maintained in combine harvesters. Such systems provide us the transition to the robotics agriculture. Robotics agriculture, hydraulic and pneumatic systems are the agricultural systems that include both computer control systems and image processing technologies.

Even if produced systems are intelligent systems, all encodings must be performed by people. The system must be encoded with the help of the control parameters according to the process can be applied. It is expected that the machine must act in the way that it encoded by the people by understanding of the complexity of the workings. This act is called as robotics system action.

Robotics system action depends on the human factor entirely. Sensibility in the defining of the parameters which belong to workings affects the robotics system action. If the parameters are not suitable for the working expected result will not be proper. Environmental impacts, product features, the structure of the field, weather conditions are the factors that determine the robotics system action.

All input and output results must be well-analyzed for the expected action. The codes and expected results must be encoded exactly. Other additional equipments which will be used in robotics agriculture must be chosen correctly. Which system is needed, which controllers will control these systems and the selection of them are the factors that affect the functioning of the system. If these descriptions are inadequate and incomplete wrong harvesting, wrong seed planting, incorrect operation of automatic irrigation or incorrect amount of water can occur.

Kataoka et al. (2001) conducted a study for an automatic discovery system in detecting the location of apples for robotic apple harvesting. Decisions involving embalming. They stated that the fruit is the most important criterion to decide the harvest time. The Munsell color system is pre-primed, colored and separated in XYZ color units. According to this color, the time of harvest was found according to apple color.

Bulanon et al. (2004) conducted a research on the development of a real-time machine vision system for the apple harvesting robot. In this research, the red Fuji apple harvester has developed a real-time machine vision system for robot manipulator guidance. They took images from apple garden with CCD camera. The acquired images were transferred to the PC and the locations of the appliances were determined by image processing method. Under different light conditions, it is possible to recognize the fruits and determine their location. The red and green coefficients are used to identify the fruit. As a result of the research, they defined the fruit with an accuracy of 80% and an error margin of less than 3%.

Mao et al. (2009) conducted a study on the determination of the location of apples for robotic apple harvesting. They used two high-resolution digital cameras at the location of the fruit. They determined the selection of the fruit using color and shape analysis. The software they use for image processing is Microsoft C ++ based RelCtrl. RelCtrl for C ++ 'in vfw32.lib, JpegLib.lib, PRSDK.lib, and CDSDK.lib. They used their libraries. They are based on the following algorithm for the program. They determined 9.4% error rate in the process.

The important point for the above-mentioned systems is to obtain the data and information about the product to be harvested. Robotics system actions are provided at the end of the collected data and information. In the collected data; the robot is moved over this coordination by finding the coordination of the systems and lands.

Robotics agriculture systems use many technologies. It is an environmental approach that has a tight bond with the development of many technologic fields. Drug utilization, fertilization, irrigation and harvesting can be made more sensible. Robotics agriculture provides more sensitive agriculture. Energy consumption is maximum expense in the agriculture. It is required to provide the energy consumption less than before. Applications are applied only specific areas so, the lower energy consumption can be provided.

It can be achieved that more production will be done with less power and more efficient in the agriculture as a result of all this studies. Sensitive agriculture can provide that there can be less pollution in the world.

2. MATERIAL AND METHODS

2.1. MATERIAL

Figure 1 shows the locations of the values entered into the calculations for the pneumatic shear system. Table 1 shows the characteristics of the parallel holder used.

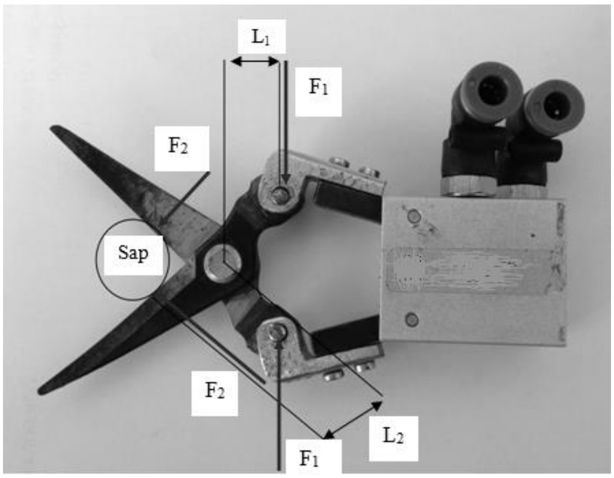

Figure 1. Values for pneumatic system

Calculation of the machine cutting force:

Cutting Strain(D. Dursun 2001) :

$$\tau = \frac{F}{A} \quad (1)$$

τ =Cutting Strain(N mm $^{2\text{-}1}$)

A= Cross-section area (mm^2) (D. Dursun 2001)

F=Force(N)

$$A = \frac{\pi * d^2}{4} \quad (2)$$

d=Stem Diameter(mm)

Cutting Force(D. Dursun 2001) :

$$F_1 * L_1 = F_2 * L_2 \quad (3)$$

L_1=Steam length(mm)

L_2=Cutting Length(mm)

F_1= Force applied to the arm(N)

F_2=Cutting Force(N)

Pneumatic pressure (D. Dursun 2001):

$$P = \frac{F}{A} \quad (4)$$

P=Pressure(Pascal)

F=Force(N)

A= Cross-section area (mm^2)

The system in Figure 1 is attached to the robotic system for cutting the fruit over the handle. Formulas 1, 2, 3 and 4 are used for the cutting stress applied during the cutting of the fruit. During formulas calculations, stem thicknesses were measured with calipers and values were recorded.

For L_1 and L_2 lengths,the measured values of pneumatic hose inner diameter with caliper are given below.

L_1=20 mm

L_2=25 mm

The inner diameter of the hose is 4 mm.

Hose Area (A) = 12,56 mm^2 .

Table 1 Parallel the holder properties

	Parallel the holder
Movement Type	Double act
Pipe Type (mm)	16
Port Size	M5x0.8
Working environment	Air
Average pressure ratio (kgf cm^{2-1})	1.5~ 7 (0.15~0.7 MPa)
Operating temperature (C^o)	-5 ~ +60
Max. Frequency (Devir d^{-1})	180
Max. Arm length (mm)	30
Free Devergence Angle	-10^o ~ 30^o
Technical moment(kgf cm^{-1})	Close 0.4 x P /Open 0.5 x P.
Clamp Force (F) (kgf)	F=M / L x 0.85
Sensor key	RCE , RCE1
Weight (gr.)	53

Table 2. Pneumatic cutting system

Pressure Ratings (Bar)				
	5	6	7	8
F_1(N)	6.28	7.53	8.79	10.04
F_2(N)	5.02	6.03	7.03	8.04

2.2. METHODS

The most important variable is to know the space coordinate axes of the fruits in order to harvest the fruit with robotics system. Image processing technique has been applied in order to find the coordinate axes. 2D camera model has been used for image processing. Both horizontal axis (x) and vertical axis (y) have been found in the space coordinate axis of the fruits with this camera. Ultrasonic sensor has been used for the distance (z) which is the third coordinate axis. The code has been written in C# for the use of this sensor and the robot has been prevented when it reaches a certain distance. Necessary smooth and kinematic calculations have been written in C# which is necessary for image processing. These calculations and the program have been installed to the processor in the robotics system control card with USB port. The communication between the writing of the program and 2D camera has been provided. Coordinate axes to be obtained as a result of image processing and 2D camera coding have been found. Obtained results have been identified by using 2D camera interface and it has been recorded. It has been provided that robotics arm stops and cut when it is 10cm in front of the fruit according to the value from the ultrasonic sensor via written program.

The most important point in the system is to introduce the fruit shape to the camera with the program in the camera. Shape recognition screen is shown in Figure 2.

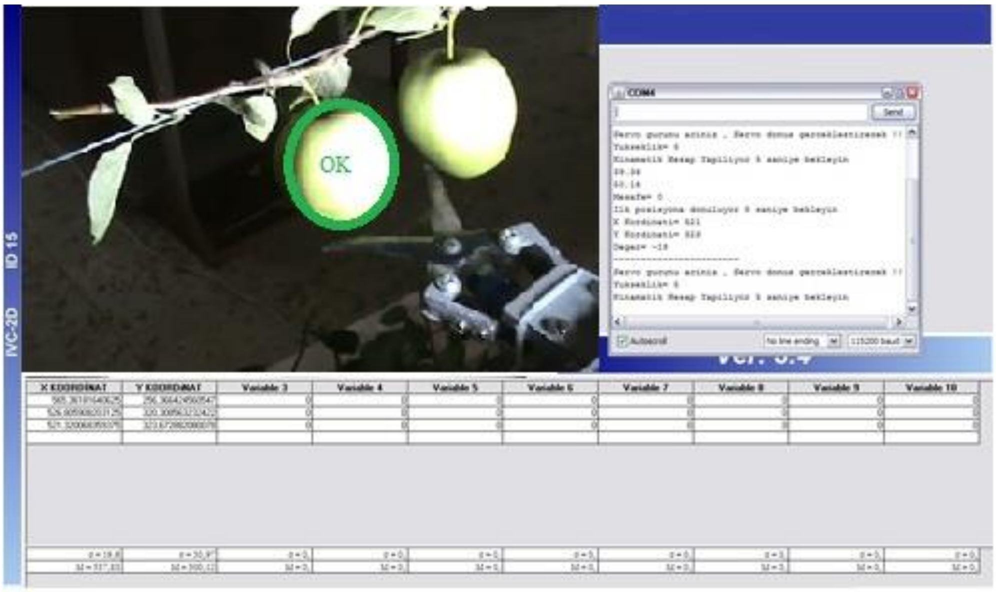

Figure 2.Shape Recognition Screen

Robot arm's movement has been provided after the calculation according to the coordinate from the camera in the Robotics Control card. Coordinate values from camera to processor are shown in Figure 3.

Index	DB Value	Value	Description
994	0	0	
995	0	0	
996	0	0	
997	0	0	
998	0	0	
999	0	0	
1000	160,402...	160,40225...	X KOORDİNAT
1001	76,8049...	76,804977...	Y KOORDİNAT
1002	0	0	
1003	0	0	
1004	0	0	
1005	0	0	
1006	0	0	
1007	0	0	
1008	0	0	

Figure 3. Coordinate values from camera to processor

The positioning of the robot arm has been conducted for both kiwi and apples. Fruits have been cut with the help of pneumatic cutting. Cutting action for apple is shown in Figure 4.

Figure 4. Cutting for apple

3.RESULTS AND DISCUSSION

The pressure value of the compressor which enables the operation of the pneumatic system varies between 5 - 8 bar.The force (F1) applied to the arm is calculated by the formula (4), the cut force (F2) by the formula (3).In Table 2, values F1 and F2 are shown.

The force (F1) and the cut stretching (F2) applied to the arm calculated by using formulas 3 and 4 are substituted into formula 1 and the cut stretching (τ) is calculated.For each type of fruit, 100 calculations were statistically analyzed.Statistical analysis was calculated according to the cutting conditions of the fruits. The results are summarized in Table 3.

Table 3. Exchanges cutting force for Apple

		Sum of Squares	df	Mean of Squares	F	Sig.
a*	Between Groups	95.118	73	1.865	4.111E32	.000
	In-Group	.000	27	.000		
	Total	95.118	100			
b*	Between Groups	137.609	73	2.698	8.753E32	.000
	In-Group	,000	27	.000		
	Total	137.609	100			
c*	Between Groups	186.847	73	3,664	1.188E33	.000
	In-Group	.000	27	.000		
	Total	186.847	100			
d*	Between Groups	244.169	73	4.788	6.351E32	.000
	In-Group	.000	27	.000		
	Total	244.169	100			

*a=5 bar, b=6 bar, c=7 bar, d=8 bar

At the end of the experiments, the wrong value of the robot arm has been determined as 15% for apples. The reason for this is that the camera chooses the fruit randomly during finding the coordinate in the fruits that stand side by side or back to back in the experiments. It has been determined that the most suitable fruit coordinates have been given. It is required to choose color camera which processes three-dimensional image in order to prevent this.

The cut rate for the fruit is 73%.It has been found that the cause of the difference between finding and cutting is the location of the fruit on the scissors.As a result of the constructed T-test, it has been determined that not only the x-axis but also the y-axis are important for breaking the fruit over the branch.It has been found that during positioning of the scissors, the y-axis scissors are positioned on the stalk of the fruit.When the stalk of the fruit is on the tip of the scissors, when the scissors touches the fruit, when both fruit and the stalk of the fruit come to the initial point, they can cause errors for breaking process.According to the Anova test, pressure values ranging from 5 to 8 bar applied by the compressor were found to be significant for the cutting force.It is understood that the compressor pressure operating the pneumatic system provides sufficient pressure for the cutting operation.The change in pressure between 5 and 8 bar was found to have sufficient pressure values for the shear force.It has been determined that the pressure change in the compressor will not affect the cutting force.

4.CONCLUSION

It is understood that the system to be used in the gripper for the robotic system fruit harevesting is the pneumatic system.It has been determined that the applied pressure values are sufficient for cutting.It has been shown that the fruit must be pulled inward from the point of the scissors and held constant to increase the success rate in the cutting process.It was understood that the cutting performance would be increased by the vacuum system attached to the scissors system.It is considered that the special design of the fruit of the vacuum pad at the end of the vacuum generator used for pulling the fruit into the fruit will increase the success of holding the fruit constantly.It is understood that with this research the most important factor in the robot design is the gripper which provides the latest movement.As a result of the study, it has been seen that pneumatic cutting is the factor that will affect the system success besides all the parts and software of the robotic system.

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