

Higher Efficient Fruit Robot with Improved End Effectors

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Abstract. Under the situation that the technology level is improving recent year and the labor cost is increasing rapidly. In this paper, an autonomous harvesting robot with high efficiency is presented. The robot needs a fruit harvesting process with high obstacle avoidance efficiency for picking in complex and unstructured environments. In this research, the end-effector of the robotic arm picking process is optimized to reduce the number of times the fruit is crushed and to obtain the nearest moving trajectory to improve the picking efficiency. Therefore, the research topic of this paper is to optimize the picking method of the picking robot when performing picking operations. The following describes this paper's research methodology: first, the mechanical part of this harvesting robot is modeled, and then the most efficient way of the robot arm is found by analyzing the data of this model and combining it with the existing research. In this paper, it was found that changing the robotic arm's end-effector to a cylinder with a cutting blade would not only maximize the efficiency of the arm, but also ensure that the fruit would not be scratched. From this study, it was concluded that the end-effector can be customized to ensure efficient fruit picking according to the type of fruit and the approximate growth of the orchard fruit.

Keywords: High efficiency, harvesting robot, end-effector, arm model.

1. Introduction

In modern society, with the development of intelligent algorithms and Internet of Things technologies becoming more and more sophisticated, the number of robots put into productive life has increased dramatically. And now we are facing rapidly rising labor costs due to labor shortages, for example, in California, Manual picking might cost up to 60% more than it does to produce fresh market strawberries [1]. The use of intelligent robots is one of the effective solutions to the severe labor shortage in agricultural production [2]. In addition, labor uncertainty in ripeness identification and gripping of fruit is a significant problem that impacts product quality. Consequently, automated harvesting in orchards is crucial to advancing agricultural modernization in addition to reducing labor costs and increasing economic efficiency. The performance of robots for automatic harvesting of fruits and vegetables has been stable over the years. To date, many robotic harvesting systems have been developed worldwide, none of which have been successfully commercialized. Among the fully integrated autonomous harvesting robots include apple picking robots [3] Orange harvesting robot [4], And some others. Among them, the research on the picking part of fruit picking robots is relatively vacant, and the picking success rate of most of them is about 66%, the time to pick each fruit is 15 seconds on average, and the fragile fruits have a chance to be scratched because they are grasped. This has led to difficulties in putting picking robots into commercial production [5]. So now there is a need for a machine with high precision and high speed, while satisfying the economic feasibility. Robotic harvesting consists of several tasks: detecting the fruit, trajectory planning, determining if the fruit is ripe, and finally grabbing the fruit and separating it from the stem. In terms of trajectory planning during grasping, A team has created a lychee harvesting robot that plans its obstacle avoidance path using particle swarm optimization techniques for a 6-degree-of-freedom manipulator, and a faster version of the Rapid Exploration Random Tree (RRT) method is employed to speed up path planning [6]. This way can improve the efficiency of the robot arm's movement, but the end-effector's impact on the fruit was not considered in their investigation. This is due to the limitations of the available robotic grippers and the inherent difficulties of the grasping scheme, so the grasping of fruits remains a difficult. This study investigates the picking link of the robotic arm based on a fruit picking robot picking model and proposes a feasible optimization method which can

substantially decrease the picking time and raise the success rate, and the feasibility is confirmed by simulation analysis and comparison. These processes mainly include MATLAB modeling of the robot arm, CATIA modeling of the end-effector, and arm of the robot's trajectory planning.

2. Method

In this research, the robotic arm model is first modeled utilizing MATLAB's Robotics Toolbox. Then the activity angle of the robotic arm joints is specified to derive the working space of the end-effector, and it is determined that the robotic arm end-effector can pick fruits in various positions during the picking work, and then the trajectory of the robotic arm is planned, and the data is derived.

2.1. The workspace of the robotic arm

From studies on the control of fruit tree height, it is known that the height of fruit trees can be controlled by artificial regulation in similar climates, and usually the height of fruit trees in orchards in a region will be similar [7]. In this case, this paper was first modeled by adjusting the DH parameters of the robotic arm and the angle of joint rotation but ensuring that the end-effector position could reach the target height. This is used to determine whether the physical structure of the robotic arm can meet the picking requirements of the robotic arm. To be able to cope with the situation that the fruit positions are distributed at different heights, the end-effector workspace is simulated by MATLAB in this paper, which is used to judge whether the fruit can be picked and to decide the feasibility of DH parameters. the DH parameters are set as Table 1.

Table 1. DH Parameters

LINK	THETA	D	A	ALPHA
0	0	0.23	0	0
1	0	0.48	0	PI/2
2	PI/2	0	1.22	0
3	-1.413	0	1.23	0
4	1.413	0	0.54	0
5	0	0	0.4	PI/2

The data were collected using the robot workbox in MATLAB. Firstly, the random variables were generated in the joint space, and the iterations of the random variables in this paper were taken as 100k, so that the visualized working interval could be better obtained to determine whether the end-effector was within the working range. Then the positive kinematic function is used to get to a transformation matrix, and then the three-dimensional spatial coordinates are obtained using the transl function [8].

The formula for the random joint space variables is shown in (1) below.

$$q=q_{\min} + \text{rand} * (q_{\max} - q_{\min}) \quad (1)$$

2.2. Trajectory planning of the robotic arm

Next, the efficiency was tested by trajectory planning of different models. The end point set in MATLAB with the red sphere simulating the fruit position, and then the trajectory planning was sought for the model, and the data was derived, which included time, position, velocity and acceleration. As shown in Figure 1, this is the pose of the robotic arm in the initial state. The trajectory planning allows the robot arm to pick the fruit, and the pose during picking is shown in Figure 2.

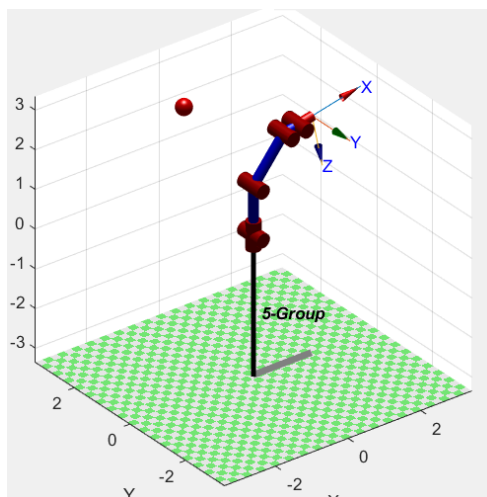


Fig. 1. Initial position (Picture credit: Original).

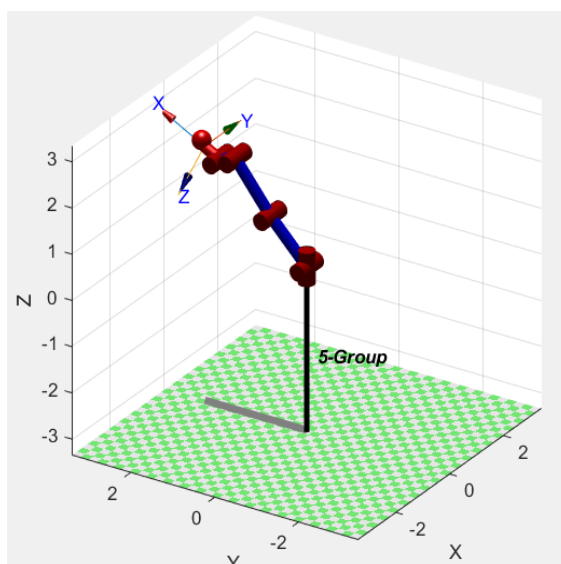


Fig. 2. Picking position (Picture credit: Original).

The robot arm's end-effector has been improved.: The end-effector is a critical part of fruit picking and it is the key to the overall picking success. In general, end-effectors for fruit picking are responsible for two parts: grasping and separating the fruit. Research has been done to create various fruit harvesting robot end-effectors. The most popular of them is the scissor end-effector, which closes two blades to cut the fruit stem [9]. In this type of end-effector, the lower and upper jaws are symmetrically constructed. The top and lower jaws implement the cutting action. When harvesting is being done, the upper and lower jaws are obtained to swing simultaneously using the movement of the internal linkage driven by the pneumatic machine, and the end-effector bites the citrus stem. In this study, it is found that this kind of biting device usually takes longer time in biting because it is easy to cause damage to the fruit. Therefore, the innovative proposal in this paper is to use a cylinder-type picker. As shown in Figure 3, this device relies on two blades that can move 180 degrees to shear, and the fruit will fall in the cylinder after shearing, and the blades will be expanded to the maximum to keep the fruit from falling out. This is compared to the ordinary claw design, you can quickly cut, and will not worry about damage to the fruit.

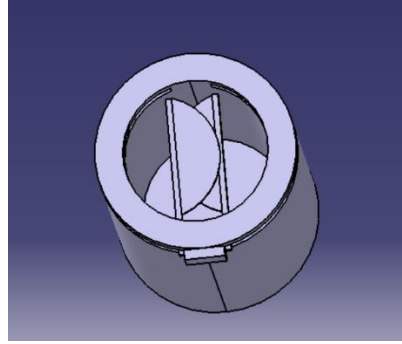


Fig. 3. End-effector (Picture credit: Original).

In order to make this actuating end work smoothly, the alignment with the fruit method of [10] is used in this paper. When placed at a specified distance from the navel point and aligned with the posture of the target fruit (referred to as action of alignment), the end-effector feeds in a straight line from the place of central point along the heading of fruits stance. (referred to as the linear feeding action). When the arm end is parallel to the citrus position, it has a feeding along a distance that pose's azimuth throughout its exploration, the final posture is achieved.

$$T_{eK+1}^b = \begin{matrix} R_{eK+1}^b & t_{eK+1}^b \\ 0 & 1 \end{matrix} \quad (2)$$

This is the last alignment that the end of arm into the navel point in a straight line.

$$T_{eK+2}^b = \begin{matrix} R_{eK+2}^b & t_{eK+2}^b \\ 0 & 1 \end{matrix} \quad (3)$$

3. Results

As shown in the Figure 4, these blue dots represent the end-effector's operational range on the robotic arm of this fruit-picking robot. These are generated randomly and iteratively to represent the operation in real situations. It can be clearly seen that the working range of this end-effector is very large, radiating into a near sphere range with the base as the center of the circle. This can meet the needs of working as a picking robot [11].

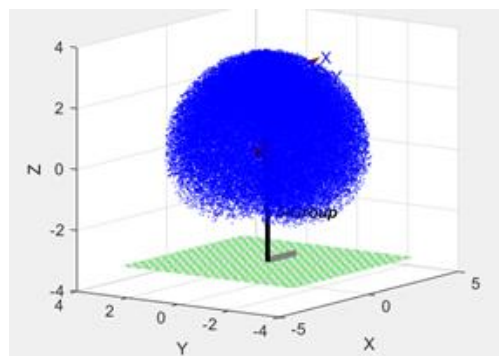


Fig. 4. Workspaces (Picture credit: Original).

Figure 5, 6, 7, 8 and 9 showed the three variation curves of all the robot arm joints during the trajectory planning process. The process of trajectory planning is carried out according to this process: simulate the actual work scene, first the standby state, then the sensor performs the first positioning, then turns the robotic arm to roughly position itself., and then performs the second positioning to correct the position of the robotic arm, and then adjusts the position of the claws for picking, and after the picking is completed, the arm of robot is retracted to the original position, and then the sensor recognizes the position of the fruit basket again and puts the fruit into the fruit basket. They are the position, velocity, and acceleration curves with time, respectively. All three curves are smooth curves, showing that the curves can be kept smooth without jumping. It accelerates rapidly and then slows

down. Finally, with a reduced speed and acceleration near to zero, it arrives at the place of the desired fruit. By doing this, the target fruit will be safely grasped and will not be harmed by the end-effector.

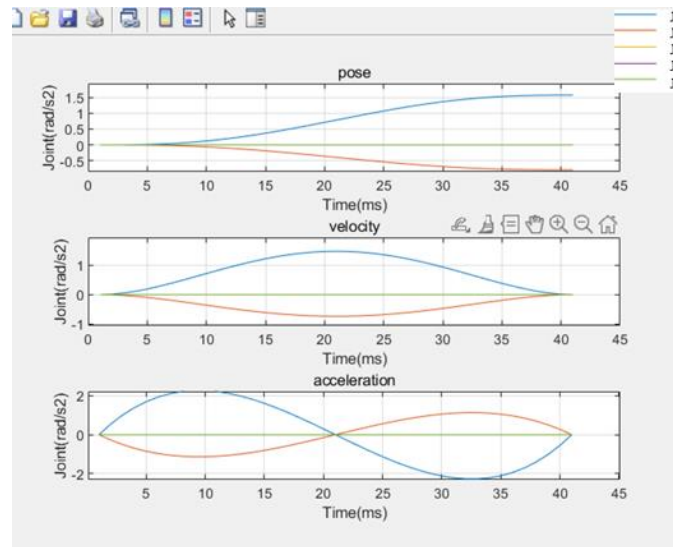


Fig. 5. First rotation process (Picture credit: Original).

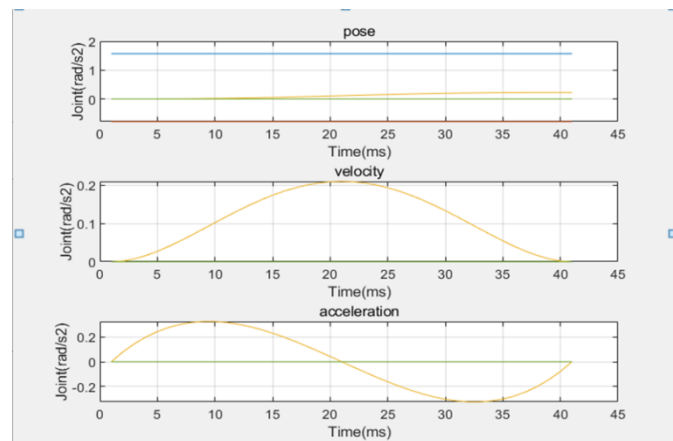


Fig. 6. Second rotation process (Picture credit: Original).

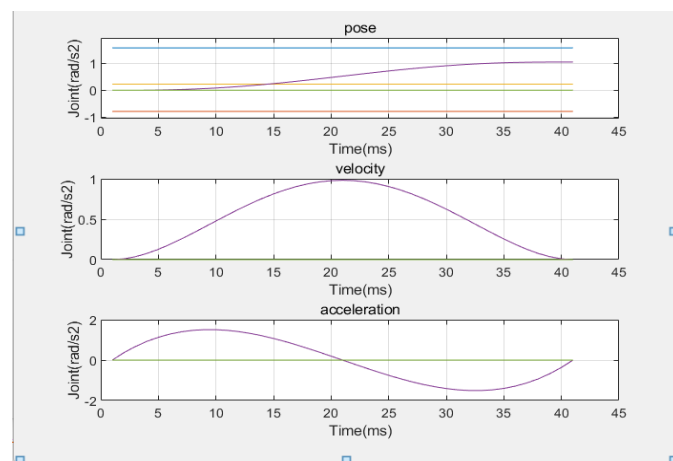


Fig. 7. Picking process (Picture credit: Original).

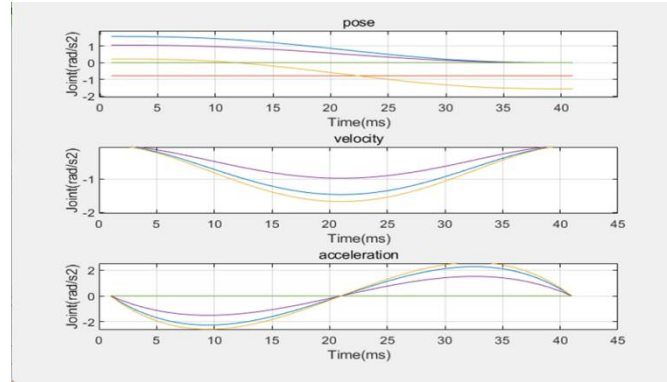


Fig. 8. Robotic arm retraction process (Picture credit: Original).

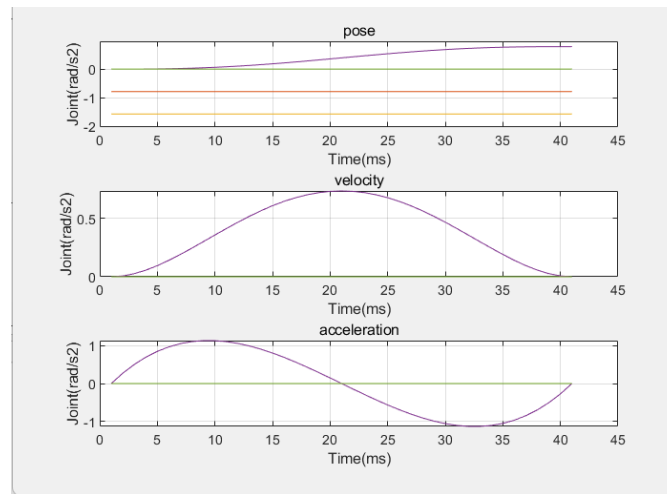


Fig. 9. Fruit placement process (Picture credit: Original).

4. Conclusion

After the study, the following advantages of the fruit picking robot were found: firstly, the robot arm has a large working range and can pick normally, and then the picking time of the modified robot arm is significantly reduced compared with the initial robot arm, mainly because the end-effector does not need to spend time to close when the fruit is removed from the fruit tree. At the same time, the improved end-effector can protect the fruit. The large working range of the arm of this fruit picking robot is due to the fact that how many degrees of freedom there are is usually proportional to the size of the working range, as the rotation of each joint of the 5-degree-of-freedom arm is less restricted. The reason for the improved efficiency of the robotic arm picking compared to the widely used end-effectors is that the present picking robot uses an innovative cartridge type picker. This picker not only saves time, but also reduces the risk of the fruit being crushed and damaged, as the process of closing the clips is eliminated and replaced directly with a cylinder set of fruit. This picking robot effectively solves the disadvantages of small working space, long picking cycle and easy damage to fruits of common picking robots. It is conducive to the rapid deployment of robots in the agricultural production industry and can effectively solve a series of problems caused by high labor costs. However, there are some shortcomings in this study. This study did not simulate the vision system, which is very important for robots, and the robot arm may touch the obstacles during the picking process, which is ignored in this study. In the future, this study will focus on how to use advanced algorithms to enable the robot to quickly identify and plan avoidance paths for obstacles, while at the same time the new path ends with the fruit to be picked.

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