Application of Artificial Intelligence in Quality Test of Vibrating Fruit Harvesting Mechanical Operation

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Abstract. Harvesting operations were an important part of the production of fruit. In order to improve the efficiency of harvesting fruit and reduce the cost of harvesting, in view of the small working space in the dwarf dense planting mode of China's orchard, the artificial intelligence technology was applied to vibrating fruit harvesting mechanical operation, and the theoretical analysis of artificial intelligence technology application was analyzed; The equipment requirements of artificial intelligence in vibrating fruit harvesting machanical operation were studied. On this basis, the system application process of artificial intelligence in the harvesting machanical operation of fruit trees was deeply explored, and the work was carried out in the practice of mechanical operation, and the recovery rate was detected to be 90% to 95%. Tests had shown that the recovery rate was 36% higher than the traditional vibrating fruit harvesting technology.

1. Introduction
With the expansion of planting area and the arrival of fruiting period, the continuous reduction of rural labor force and the increase of labor costs, the problems faced by fruit harvesting operations are becoming more and more serious, which has become a bottleneck restricting the development of Most of the orchards in China adopt the dwarf dense planting mode, the working space is small, and the mechanized working conditions are poor. Therefore, the direct introduction of foreign harvesting equipment can not effectively solve the problem [1]. At present, the mechanized harvesting technology commonly used to separate fruit from the plant, its advantage is that the vibratory harvest can quickly and effectively separate the mature fruit, which is suitable for large area and large-scale fruit production. Vibration mechanical harvesting techniques include pneumatic vibration, continuous vibration and impact vibration collection. The continuous vibration collection technology is widely used, with good vibration effect and less damage to tree trunk, especially the structure of eccentric vibration mechanism, convenient manufacturing, and many foreign harvesting machines adopt this structure [2]. Combining with the actual situation that the research of the fruit harvesting machanical operation in China is late and the foundation is weak, this paper chooses the widely used vibration mechanical vibration harvesting technology as the research object, and integrates the artificial intelligence into the vibration collecting technology. On this basis, the dynamic model of vibration harvesting of fruit is studied, and the design elements, steps and calculation formulas of vibration harvester are obtained. On such basis, in view of the small space characteristics of the orchard dwarfing and dense planting mode in China, a scientific and rational vibration collector of artificial intelligent vibration type fruit and fruit is designed.
2. Study on Artificial Intelligence in the Operation of Fruit Harvesting Machenical Operation

The working process of the fruit-wound vibrating harvester is to apply forced vibration to the fruit trees. Under the action of forced vibration, the fruit branches vibrate at a certain frequency and amplitude, and the fruit accelerates under the vibration of the fruit branches, and the accelerated fruit is subjected to inertial force function, when the inertial force is greater than the binding force between the fruit and the fruit, the fruit will fall off [3]. At present, the research and application is widely used in mechanical vibration recovery technology. The theoretical research mainly involves vibration recovery dynamics model and vibration transmission law.

There are few studies on the theory of vibration harvesting technology in China. Wang Yecheng et al. studied the mechanical vibration recovery device of Blackcurrant and established a mathematical model for the relationship between blackcurrant recovery factor and vibration frequency, amplitude and excitation position, and the relationship between the three branches. The mathematical model analyzes the influence of various influencing factors on blackcurrant recovery and fruit branch excitation force [4]. Li Guoying of Nanjing Forestry University established a simplified mechanical model of trunk and branch vibration. The experimental and theoretical calculations show that the cantilever straight beam model is more accurate, which provides a theoretical basis for the study of vibration harvesting machenical operation.

From the domestic and international research on the theory of vibration harvesting technology, we can see that: Foreign research in this area has been carried out earlier and more mature, and domestic research on this aspect is only in its infancy. Researchers generally use the method of establishing dynamic models to analyze the response of fruit trees under vibration. The research shows that this method is more realistic. Therefore, the dynamic analysis of fruit vibration and the theoretical analysis of fruit abscission are the future research direction [5].

3. Artificial Intelligence Equipment in the Harvesting Machenical Operation of the Fruit Forest

Mechanical vibration harvesting equipment is mainly composed of exciting mechanism, clamping mechanism, loading device and so on. The working process of the harvester is to install the clamping mechanism on the tree trunk or branch, vibrate the fruits by the exciting mechanism and collect the fruits by the loading device.

3.1 Set Vibration Mechanism

The vibration mechanism is the source of vibration power of fruit tree. There are two types of vibration mechanism of fixed long stroke crank and unbalanced eccentricity, the first kind of vibration amplitude is larger, it is easy to hurt the fruit tree, and the application is not much. At present, the eccentrically active vibration mechanism is used. This kind of vibrating mechanism mainly has eccentric block type and crank connecting rod [6].

The eccentric block type vibration mechanism produces the inertial force excited by the eccentric block, and can form different vibration mechanism through different combinations of eccentric block to meet the work requirements, including the single eccentric vibration mechanism, symmetrical eccentric vibration mechanism, and torsion eccentric vibration mechanism, etc. The fruit vibration harvesting machine generally uses a single eccentric or symmetric eccentric vibration mechanism. The single eccentric vibration mechanism can generate lateral and longitudinal vibration of the fruit tree. The symmetric eccentric vibration mechanism can eliminate the longitudinal vibration and only output the lateral vibration, and can be adjusted by changing the mass of the eccentric mass.

The vibration of the crank-link type vibration mechanism is to make the output rod reciprocate by the circular motion of the crank. The amplitude can be adjusted by changing the length of the crank, and the vibration frequency can be adjusted by changing the rotation speed. This kind of mechanism has a greater force on the fuselage. The vibration vibrating mechanism designed by D. Erdogan et al. and the seabuckthorn vibration harvester designed by Roger Chagnon et al. adopt this type of vibration mechanism.
3.2 Setting the Clamping Mechanism
The function of the clamping mechanism is to transmit the vibration of the excitation mechanism to the fruit tree. The clamping mechanism mainly has a translational clamping type, a claw type, and the driving type mainly has hydraulic and pneumatic driving. To avoid damage to the bark, a soft pad is placed on the inner surface of the jaws.

Roger Chagnon et al. designed an aerodynamic clamping device consisting of a fixed collet and a movable collet. The movable collet is driven by a cylinder. When the fruit tree is clamped, the clamping device can be opened and closed by operating the cylinder. D. Erdogan et al. designed a hydraulically powered clamping device of similar construction that is driven to open and close by a hydraulic cylinder. Reynolds et al. invented a jaw-type clamping device consisting of two movable jaws, the movable jaws being driven by a cylinder, the two movable jaws being held in a staggered manner when gripping, and the inside of the two movable jaws are fitted with nylon lining Pad [7].

3.3 Adjusting the Loading Device
The main problem of mechanical harvesting is the damage of the fruit. In order to reduce the damage of the fruit, the plant should be placed under the tree to collect the vibrating fruit. For artificially collecting fruits, it is generally possible to collect cloth under the tree. Among them, the inverted umbrella type is more common, and the conveying device is located at the lowest point of the umbrella center, and the fruit vibrates backward to the umbrella-shaped center conveying device. The key to the design of the pick-up device is the choice of the buffer material for the contact surface. D. Erdogan et al. studied the damage of the fruit when the cushioning material of the contact device was canvas, sponge, nylon and no pick-up device. The results show that when the loading device is not added, the fruit falls directly to the ground and the damage is greatest; The three kinds of cushioning materials are ideal, the fruit damage is small, and the canvas material is the best, and the fruit damage is less than 5%.

4. Application Analysis of Artificial Intelligence in Harvesting Machenical Operation
In order to better carry out artificial intelligence in the vibrating fruit harvesting machenical operation, the quality of its work is tested. A specific experimental study was carried out on a walnut forest farm in Northwest China. In order to improve the credibility of its application, 12 walnut trees with the same growth and matured were selected in this experiment. The relevant characteristic parameters are shown in Table 1.

| project          | unit | The numerical |
|------------------|------|---------------|
| Line spacing     | m    | 4.0           |
| The column spacing | m  | 3.0           |
| Tree height      | m    | 3.0-4.0       |
| Canopy width     | m    | 4.0-5.0       |

Using the artificial intelligence vibrating fruit harvester studied in this paper, set several vibration values of vibration frequency 10, 15, 18, 20Hz, and repeat the test 3 times for each test value. The test clamping position is at the trunk 800mm from the ground. The amplitudes at different vibration frequencies in the test were recorded and the amplitude was based on the nip point.
Through the analysis of the actual work of artificial intelligence in the fruit picking machine, the picking action accurately completed during the operation mainly includes three steps. The first step is to take the picking machine to the fruit plant and determine the vibration clamping position according to the capture analysis of the binocular vision system; The second step is to pick the arm to the direction of the trunk, and then adjust the horizontal position and height of the picking head and the trunk; The third step is to move the picking head closer to the trunk. According to the growth direction of the trunk, the picking head is adjusted by the up and down pitch and horizontal rotation of the picking head. The picking machine motion analysis is shown in Fig.2:

![Picking machine motion analysis diagram](image)

**Figure2  Picking machine motion analysis diagram**

### 4.1 Selection Of Artificial Intelligence System In Vibrating Fruit Harvesting Principle

The basic working principle of artificial intelligence in vibrating fruit picker is to apply mechanical vibration with a certain vibration frequency and amplitude generated by the excitation structure to the fruit tree, so that the fruit tree also vibrates corresponding frequency and amplitude under forced vibration. When the inertial force of the fruit is greater than the combination between the fruit and the fruit branch, the connective part of the fruit and the fruit branch is relatively weak, which will cause the fruit to separate from the mother branch and complete the shedding process. The artificial intelligence picking machine excitation mechanism designed in this thesis is a crank-link mechanism. The circular motion is used to drive the connecting rod to form a reciprocating motion by the circular motion of the crank, and the exciting force is transmitted to the fruit tree through the clamping mechanism to generate vibration.

Picking machine during the operation, the picking machine in the vibration state together with the fruit tree constitutes a multi-degree of freedom artificial intelligence vibration system. Under the action of exciting force, the kinetic energy and potential energy of artificial intelligence system in vibrating fruit harvesting machenical operation are:

\[
T = \frac{1}{2} Mx^2 (1)
\]

\[
V = \frac{1}{2} Mv^2 (2)
\]
Where $T$ is the system kinetic energy, J;
$M$ is the mass of system, kg;
$X_i$ is the system speed, m/s;
$V$ is the potential energy of system, J;
$K$ is the stiffness coefficient, N/m;
$X$ is the deviation of the relative equilibrium position of the system, m.

The above formula is only suitable for neglecting the ideal state of elastic and damping factors. However, in the actual study of the vibratory system of fruit tree picking machine, there is elasticity and damping in the forced vibration of fruit trees. In order to describe the vibration system more accurately, the equivalent viscous damping is introduced here.

$$D = \frac{1}{2} c x_i^2 (3)$$

In this formula, $D$ is a dissipative function of the Ruili. $c$ is the equivalent viscous damping coefficient of the system, N-s/m; $x_i$ is the system speed, m/s.

In order to analyze the dynamic characteristics of the system, Lagrange's second kind of dynamic equation is introduced.

4.2 Analysis Of The Effect Of Artificial Intelligence On The Operation Of Vibrating Fruit Harvesting Mechanical Operation

The number of fallen is counted, and the recovery rate is calculated.

$$P_r = 100 \frac{N}{N + N_f} (4)$$

Where $P_r$ is the harvest rate.
$N$ is the fruit count vibrated by harvester and failed.
$N_f$ is the fruit count which have been vibrated by harvester but not fallen.

The SAS software was used to analyze the test data to test the full amplitude saliency, and the regression analysis was used to analyze the recovery rate to determine the reliability. At the level of significance 0.05, the excitation frequency has a significant effect on the full amplitude, and the coefficient level is determined to be 0.945, the excitation frequency of 10, 15, 18, 20 Hz are significantly different. The full amplitude increases as the excitation frequency level increases, and the increase gradually decreases as the excitation frequency increases. The test data shows: the level of significance 0.05 T, the excitation frequency will have a significant impact on the recovery rate of 0.994, the excitation frequency of 10, 15, 18, 20 Hz several test values are significantly different (Table 2), most of the non-shedding fruits are immature fruits.

Table 2. Excitation frequency and full amplitude relationship application data

| Frequency/Hz | The amplitude | The standard deviation |
|--------------|---------------|------------------------|
| 10           | 4.670d        | 0.580                  |
| 15           | 5.800c        | 0.170                  |
| 18           | 7.830b        | 0.250                  |
| 20           | 8.830a        | 0.710                  |

Finally, the recovery rate was analyzed. Let the oscillation frequency be $f$ and the regression model be $P_r = B_0 + B_1 f + B_2 f^2 (5)$

Where $B_0, B_1$ is the coefficient, on this basis, the regression analysis table and regression parameter estimates and $t$ are obtained. Therefore,

$$P_r = -122.390 + 17990 f - 0.360 f^2 (6)$$
Through application tests, it is found that the harvesting rate of artificial intelligence in the vibrating fruit harvesting machine operation increases with the increase of the excitation frequency, and the excitation frequency of the fruit tree damage control is in the range of 19 to 20 Hz, and the recovery rate is 90% to 95%. Based on the kinetic model, the overall structure is designed, and the performance and working characteristics of the harvester are studied through practical application. It is concluded that the recovery rate increases with the increase of the excitation frequency. If the vibration control frequency of the fruit tree damage is in the range of 19-20 Hz, the recovery rate is 90% to 95%.

5. Experimental Results And Analysis
In order to better measure the working efficiency of artificial intelligence in vibrating fruit harvesting machine operation, this comparative experiment was carried out, and the traditional mechanical vibration harvesting technology and the harvesting technology research work in this paper were tested in the experiment situation. The experimental data is shown in Fig.3.

![Figure3 Fruit recovery rate regression model curve](image)

It can be seen from Fig.3 that as the excitation frequency increases, the recovery rate increases continuously, and the recovery rate at 15 Hz is about 3.2 times of the 10 Hz recovery rate. At 18 Hz, the recovery rate is 21.7% higher than that at 15 Hz. At 20 Hz, the recovery rate is 13.9% higher than that at 18 Hz. The change rate of the recovery rate in the range of 10 to 18 Hz is larger than that in the range of 18 to 20 Hz. At 20 Hz, the net rate is up to 92.6%, and most of the non-shedding fruits are green fruits that have not reached maturity. In this way, compared with the traditional vibrating fruit harvesting technology, artificial intelligence is more efficient in vibrating fruit harvesting machine operation, up to 92.6%, and 36% higher than traditional picking technology, and it is reliable and safe.

6. Conclusions
In this paper, the artificial intelligence is tested and analyzed in the quality of vibrating fruit harvesting machine operation. According to the vibration-type fruit harvesting technology system, according to the data feedback and sampling analysis data, the work has been improved and adjusted to realize the design of this paper. The experimental demonstration shows that artificial intelligence can effectively improve the quality of vibrating fruit harvesting machine operation, and its recovery rate is as high as 95%.

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