Analysis of Bagging Trajectory of an Intelligent Mobile Electrical Robot in Hail Climate

WanJun Zhang¹,², *, Feng Zhang¹,², Jingxuan Zhang¹,², Jingyi Zhang¹,²

¹Gansu ZeDe Electronic Technology Company Limited, Gansu 741003, China
²Lanzhou Industry and Equipment Company Limited, Gansu 730050, China

*Corresponding author: wanjunzhang@xjtu.edu.cn

Abstract. Apple anti hail apple bagging robot is of great significance to reduce the labor intensity of fruit farmers, ensure the timely harvest of fruits, ensure the quality of fruits, and improve the level of automatic operation of orchards in China. The performance of the anti-hail apple bagging robot was verified by orchard comprehensive test. The experiments show that: the apple anti hail apple bagging robot can realize the intelligent coordinated control of the key actions such as intelligent mobile platform navigation, picking manipulator movement, end effector fruit grabbing and fruit automatic packing. The real-time and robustness of various algorithms can meet the operation requirements of Apple anti hail apple bagging robot.

Keywords: Intelligent mobile, Apple anti hail apple bagging robot, bagging performance, path detection, bagging trajectory, simulation and analysis.

1. Introduction

Since the 20th century, China is facing the problem of aging population, and with the rapid development of industry, agricultural labor force is gradually transferred to industry and other industries [1-9], and the agricultural labor force is in serious shortage and the cost is gradually increasing. The operation of Apple anti hail apple bagging robot is the most time-consuming and laborious link in fruit production, and the labor required during the harvest of Apple anti hail apple bagging robot accounts for about the whole production process. Moreover, in the fruit picking operation, it is often necessary to climb with the help of ladder. Long-time operation is not only labor-intensive but also dangerous [10-19]. These factors bring great difficulties to the fruit harvest, so it is urgent to research and develop an automatic fruit picking robot. Apple anti hail apple bagging robot can not only reduce the labor intensity of fruit farmers, improve labor productivity [20-29], reduce production costs, ensure the timely harvest of fruits and ensure the quality of fruits, but also has great practical significance for promoting the progress of agricultural science and technology in China [30-32], tracking the new agricultural technology in the world and accelerating the process of agricultural modernization in China [33-36].

Apple anti hail apple bagging robot is of great significance to reduce the labor intensity of fruit farmers [37-40], ensure the timely harvest of fruits, ensure the quality of fruits, and improve the level of automatic operation of orchards in China. The performance of the anti-hail apple bagging robot was verified by orchard comprehensive test. The experiments show that: the apple anti hail apple bagging robot can realize the intelligent coordinated control of the key actions such as intelligent mobile platform
navigation, picking manipulator movement, end effector fruit grabbing and fruit automatic packing. The real-time and robustness of various algorithms can meet the operation requirements of Apple anti hail apple bagging robot.

2. Apple anti hail apple bagging robot

When hovering, the rotation speed of four rotors is the same, and the sum of the lift generated by the rotors is equal to the sum of the gravity of the fuselage; when moving upward in the vertical direction, the rotation speed of four rotors increases and decreases at the same time, and the lift is greater or less than the gravity; When pitching or rolling, keep the rotating speed of one group of rotors unchanged, one group of rotors increases and the other decreases; when yaw, the rotating speed of one group of rotors increases and the other group of rotors decreases at the same time. The whole aircraft through constant adjustment of motor speed, collaborative change, thus completing the various degrees of freedom of the aircraft movement.

Due to Qingyang's lack of investment in apple bagging, apple bagging is in short supply, unable to meet demand, the majority of farmers to external purchase, the cost of larger, the entire Qingyang bagging industry industry appears industry hole. Apple Bagging Unmanned Quadrotor1 and Apple Bagging Unmanned Quadrotor2, as shown in Figure 1~Figure 2.

Fig. 1 Apple Bagging Unmanned Quadrotor1.

Fig. 2 Apple Bagging Unmanned Quadrotor2.
3. Bagging trajectory of an intelligent mobile

The camera model of the scene projected onto the imaging plane through the center point of the camera optical axis mainly involves pixel coordinate system, image coordinate system, camera coordinate system and world coordinate system:

\[
\begin{bmatrix}
    u \\
    v \\
    1
\end{bmatrix} = \frac{1}{Z_c} \begin{bmatrix}
    f_x & 0 & u_0 & 0 \\
    0 & f_y & v_0 & 0 \\
    0 & 0 & 1 & 0
\end{bmatrix} \begin{bmatrix}
    n_x & o_x & a_x & p_x \\
    n_y & o_y & a_y & p_y \\
    0 & 0 & 0 & 1
\end{bmatrix} \begin{bmatrix}
    x_w \\
    y_w \\
    z_w \\
    1
\end{bmatrix}
\]

(1)

Where: \(M_w\) is the camera four parameter internal parameter matrix; \(M_c\) is the camera external parameter matrix; \(M\) is the camera projection matrix.

Apple anti hail apple bagging robot, as shown in Figure 3.

![Apple anti hail apple bagging robot](image)

Fig. 3 Apple anti hail apple bagging robot.

The purpose of hand eye calibration is to establish the relationship between "pixel coordinate system" and "robot coordinate system", so that the robot can accurately move the end effector to the adsorption position according to the coordinate information provided by the "pixel coordinate system". From formula (1), it can be concluded that:

\[
\begin{bmatrix}
    x_v \\
    y_v \\
    z_v \\
    1
\end{bmatrix} = M^{-1} \begin{bmatrix}
    u \\
    v \\
    1
\end{bmatrix}
\]

(2)
Nine positions on the self-made calibration board were identified by camera image processing. The coordinates \((u,v)\) in pixel coordinate system were read out by using camera MODBUS output monitoring function. The tool coordinates calibrated by the robot were moved to 9 positions recognized by the camera in turn, and the records were made respectively.

The overdetermined equations are constructed

\[
\begin{bmatrix}
X_{u1} & X_{u2} & \cdots & X_{u9} \\
Y_{v1} & Y_{v2} & \cdots & Y_{v9} \\
1 & 1 & \cdots & 1
\end{bmatrix}
= \begin{bmatrix}
U_1 & U_2 & \cdots & U_9 \\
V_1 & V_2 & \cdots & V_9 \\
1 & 1 & \cdots & 1
\end{bmatrix}
\]

(3)

4. Kalman filter algorithm

Kalman filter is a linear filter, the algorithm mainly includes time update equation and state update equation. Kalman filter time update equation [20]:

\[
y = \frac{1}{n} \sum_{i=1}^{n} Y_i
\]

(4)

The state update equation of Kalman filter is as follows

\[
\theta = \frac{1}{n} \sum_{i=1}^{n} \theta_i
\]

(5)

\[
\tilde{X}_k = A \cdot \tilde{X}_{k-1} + U_{k-1} \cdot B
\]

(6)

When the valve pocket reaches the photoelectric switch, the camera is triggered to take photos every certain time. The camera will quickly extract the feature information. After experimental research, it is found that only x coordinate data increases proportionally in all the extracted valve pocket pose information results in order to improve the accuracy of y-coordinate and rotation angle and meet the real-time requirements of Kalman filter, y and \(\theta\) are processed as follows:

\[
P_k = A \cdot P_{k-1} \cdot A^T + Q
\]

(7)

\[
K_k = \frac{P_k \cdot H^T}{H_k \cdot H^T \cdot H + R}
\]

(8)

\[
\tilde{X}_k = \tilde{K} \cdot (Z_k - \tilde{X}_k \cdot H)
\]

(9)

\[
P_k = (1 - K_k \cdot H) \cdot P_k
\]

(10)

A two-dimensional variable \(a\) is used to define the system state, and the motion equation of the moving object is established as follows:

\[
X_s = X_{s-1} + V_s \cdot \Delta t
\]

(11)

Where: \(\Delta t\) is the interval time between two adjacent frames. The matrix form is as follows:
\[
\begin{bmatrix}
X_s \\
V_s
\end{bmatrix} = \begin{bmatrix}
1 & \Delta t \\
0 & 1
\end{bmatrix} \begin{bmatrix}
X_{s-1} \\
V_{s-1}
\end{bmatrix}
\]  
(12)

The state equation of Kalman system is as follows:

\[
\hat{X}_k = X_{k-1} + V_k \cdot \Delta t
\]  
(13)

The observation model a value of the state is the X coordinate value corresponding to the output of the camera

\[
Z_k = x_k
\]  
(14)

5. Experiment simulation and data analysis
The optimal control model of unmanned quadrotor aircraft is established. The results of Matlab simulation show that the optimal control system of quadrotor aircraft based on genetic algorithm is simulated by Matlab and Simulink, and compared with the linear quadratic control based on test method.

![Fig. 4 Bag space test track of anti-hail bagging robot1.](image1)

![Fig. 5 Bag space test track of anti-hail bagging robot 2.](image2)
Fig. 6 Start track of bagging space test for anti-hail bagging robot.

Fig. 7 End track of bagging space test for anti-hail bagging robot.

The experiments show that: the apple anti-hail apple bagging robot can realize the intelligent coordinated control of the key actions such as intelligent mobile platform navigation, picking manipulator movement, end effector fruit grabbing and fruit automatic packing. The real-time and robustness of various algorithms can meet the operation requirements of Apple anti-hail apple bagging robot.

6. Summary
Apple anti-hail apple bagging robot is of great significance to reduce the labor intensity of fruit farmers, ensure the timely harvest of fruits, ensure the quality of fruits, and improve the level of automatic operation of orchards in China. The performance of the anti-hail apple bagging robot was verified by orchard comprehensive test. The experiments show that: the apple anti-hail apple bagging robot can realize the intelligent coordinated control of the key actions such as intelligent mobile platform navigation, picking manipulator movement, end effector fruit grabbing and fruit automatic packing. The real-time and robustness of various algorithms can meet the operation requirements of Apple anti-hail apple bagging robot.

References
[1] Zhao Jinying, Zhang Tiezhong, Yang Li. Object extraction of Tomato Picking Robot Vision System [J]. Acta AGRICULTURAE mechanica Sinica, 2006, 37 (010): 200-203.
[2] Xu liming, Zhang Tiezhong. Research status, key problems and Countermeasures of fruit and vegetable harvesting robot [J]. Journal of agricultural engineering, 2004, 20 (005): 38-42.
[3] Zhang Libin, Shi Jiming, Xu Fang, et al. Main application fields and key technologies of agricultural robots [J]. Journal of Zhejiang University of technology, 2002, 30 (001): 36-41.

[4] Wei X Q, Jia K, L J H, et al. Automatic method of fruit object extraction under complex agricultural background for vision system of fruit picking robot [J]. Optik, 2014, 125(19):5684-5689.

[5] Xu Liming, Zhang Tiezhong. Research status, key problems and Countermeasures of fruit and vegetable harvesting robot [J]. Journal of agricultural engineering, 2004, 20 (005): 38-42.

[6] Qiurong Guo, Wanjun Zhang, Feng Zhang, et al. Research on Parameter System Identification Characteristics of Physical Exercise Population in Gansu Province Based on Walking and Taijiquan [J]. Earth and Environmental Science, 2021, 01, Vol. 632 (2021) 032048: 1-9.

[7] Gou Xiaoping, Zhang Wanjun, Zhang Feng, et al. Research and analysis of least square method identification of children’s movement based on running and mountain climbing [J]. Journal of Physics, 2021, 01, Vol. 1650 (2020) 032154: 1-8.

[8] Chunhua Yang, Wanjun Zhang, Feng Zhang, et al. Research and dynamic analysis based on nonlinear identification of sports goods Econometrics [J]. Journal of Physics, 2021, 01, Vol. 1650 (2020) 032154: 1-8.

[9] Qiurong Guo, Wanjun Zhang, Feng Zhang, et al. Research and Analysis on the Identification Algorithm Based on the Random Near Parameter Estimation of Children's Running [J]. Journal of Physics, 2021, 01, Vol. 1650 (2020) 032154: 1-8.

[10] Chunhua Yang, Wanjun Zhang, Feng Zhang, et al. Research and Analysis on Adaptive Model Identification of System Parameters Based on Sports Safety Model for Children with Different Physique, 2021, 01, Vol. 632 (2021) 042001: 1-6.

[11] Zhang Wanjun, Gou Xiaoping, Zhang Feng, Zhang Jingxuan, Zhang Jingyi, Zhang Jingyan. The influence of urbanization on temperature change trend in Lanzhou [J]. Gansu science and technology, 2020, v.36 (18): 71-73 + 79.

[12] Zhang Wanjun, Gou Xiaoping, Zhang Feng, et al. Study on quantitative analysis of land use structure in Qingyang City [J]. Gansu science and technology, 2020, v.36 (19): 60-62

[13] Zhang Wanjun, Gou, Xiaoping, Zhang Feng, et al. Based on the research and analysis of the income gap of rural residents in former Gansu, [J]. Gansu science and technology, 2021, 2, V. 37 (3): 1-2.

[14] Gou Xiaoping, Zhang Wanjun, Zhang Feng, et al. Research and analysis of bipedal running device based on Sports Assistant [J]. Gansu science and technology, 2021, 2, V. 37 (4): 131-33.

[15] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et al. Research and analysis of nonlinear model identification control algorithm based on improved neural RBF for short term heatload forecasting of heat supply network [J]. Earth and Environmental Science [J]. Earth and Environmental Science, 2021, 04, Vol. 714 (2021) 042028.

[16] Gou Xiaoping, Zhang Wanjun, Zhang Feng, et al. Research and Analysis on the temperature and humidity performance of fruit guard apple bagging [J]. Gansu science and technology, 2021, 4, V. 37 (4): 200238-43.

[17] Gou Xiaoping, Zhang Wanjun, Zhang Feng, et al. Research and Analysis on a transparent anti hail apple bagging shell [J]. Gansu science and technology, 2021, 6, V. 37 (4) 38-43.

[18] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et al. One-dimensional mathematical model of coal combustion in furnace and its simulation [J]. Earth and Environmental Science, 2018, 12, Vol. 252: 1822-1833.

[19] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et al. Application of digital image processing technology in polyamine deposition on the surface of carbonyl iron powder [J]. Earth and Environmental Science, 2018, 12, Vol. 252: 491-500.

[20] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et al. Optimization of identification structure parameters based on recursive maximum likelihood iteration [C]//Proceedings of the IEEE International Conference on Computers, Signals and systems. Dalian, 2018: 119-124.

[21] Chen y, Liao T, Lin c k, et al. Grape detection and grading system based on computer vision [J]. Acta AGRICULTURAE mechanic Sinica, 2010, 41 (3): 169-172.
[22] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et al. Parameter optimization and model identification of identification model control based on improved generalized predictive control [C]//Proceedings of the IEEE International Conference on Computers, Signals and systems, Dalian, 2018: 125-129.

[23] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et al. Study on System Recognition Method for Newton-Raphson Iterations [C]//Proceedings of the IEEE International Conference on Computers, Signals and systems, Dalian, 2018: 130-135.

[24] Huopeng Zhao, Wanjun Zhang and Xiaoping Gou, et al. Research and analysis of on-line optimization algorithm of nonlinear model predictive control based on hydropower installation field [J]. Journal of Physics, 2020, 10, Vol. 1652: 2078-2088.

[25] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et al. Application of PLC in Pneumatic Measurement Control System [J]. Materials Science and Engineering, 2018, 8, Vol. 042074:1-11.

[26] Zhang Wanjun. An intelligent bagging robot system: cn207135689u [P]. 2018.

[27] Gou Xiaoping, Zhang Wanjun, Li Bohu, et al. Quality characteristics and feasibility analysis of 5000 mu hail proof plastic bags in Gansu Province [C]//Gansu Modern Thinking cold and Drought Agriculture Development Forum - the second session of Gansu academic annual meeting in 2019.

[28] Gou Xiaoping, Zhang Wanjun, Zhang Feng, et al. Research on Simulation and Analysis of Monitoring Process of Hail-proof Apple Bagging Four-rotor Aircraft [J]. Materials Science and Engineering, 2019, 10, Vol. 612:298-302.

[29] Gou Xiaoping, Zhang Wanjun, Zhang Feng, et al. Study on the Structure Design and Feasibility Analysis of Apple Inhaled Box Bags Based on Hailproof [J]. Earth and Environmental Science, 2018, 12, Vol. 252:3826-3837.

[30] Gou Xiaoping, Zhang Wanjun, Zhang Feng, et al. Study on Quality Characteristics and Feasibility Analysis of Hail-proof Plastic Bagging of 5000 Mu in Gansu [J]. Earth and Environmental Science, 2020, 3, Vol. 612: 2038-2040.

[31] Zhang Wanjun, Gao Shanping, Zhang Sujia. Modification algorithm of Cubic B-spline curve interpolation [J]. Advances in Engineering Research, 2016, 12, Vol. 83. 513-518.

[32] Zhang Wanjun. An intelligent pipeline spraying robot: CN205880549U [P]. 2017.

[33] Zhang Wanjun. A manipulator handling device based on PLC control: CN204473864U [P]. 2017.

[34] Zhang Wanjun. Fruit scissors: CN CN304972251S [P]. 2017.

[35] Zhang Wanjun. Fruit pruning scissors: CN305145790S [P]. 2018.

[36] Zhang Wanjun. Fruit pruning scissors (automatic): CN304984483S [P]. 2019.

[37] Zhang Wanjun. Sugarcane peeler: CN304425040S [P]. 2017.

[38] Gou Xiaoping, Zhang Wanjun, Zhang Feng, et al. Research and Analysis on a transparent anti hail apple bagging shell [J]. Gansu science and technology, 2021, 4, V. 37 (4): 200238-43.

[39] Gou Xiaoping, Zhang Wanjun, Zhang Feng, et al. Research and Analysis on the temperature and humidity performance of fruit guard apple bagging [J]. Gansu science and technology, 2021, 4, V. 37 (4): 200238-43.

[40] Gou Xiaoping, Zhang Wanjun, Zhang Feng, et al. Study and analysis of Bagging Fruit Characteristics Based on apple bagging * - Taking apple bagging in Southeast Gansu Province as an example [J]. Gansu science and technology, 2021, 4, V. 37 (4): 200238-43.