Research on Simulation and Analysis of Monitoring Process of Hail-proof Apple Bagging Four-rotor Aircraft

Xiaoping Gou1,*, Wanjun Zhang2,3,4,b, Jingxuan Zhang2,c, Jingyi Zhang3,d and Jingyan Zhang4,e

1School of Physical Education Longdong University, Qingyang 745000, China
2Qingyang Xinyuan Engineering Company Limited, Gansu 745000, China
3Lanzhou Industry and Equipment Company Limited, Lanzhou 730050, China
4Xi'an Jiaotong University, Shanxi 710049, China

*gouxiaoping12@sohu.com, bgszwj_40@163.com, cgszhangwj40@163.com,
dtszhangwj40@163.com, e116543048@qq.com

Abstract. This bagging method is feasible and can produce strong economic and social benefits, and is recognized by the majority of fruit farmers. With the frequent occurrence of natural disasters in recent years, search and rescue equipment of four-rotor aircraft has been widely used. Firstly, the overall design architecture of the four-axis flight system is introduced. Then the dynamic model of the four-axis aircraft is established for the ground coordinate system and the collective coordinate system. At the same time, the response speed, control stability, and robustness are obtained. The control algorithm of aircraft is designed by using sliding mode variable structure control theory. Finally, the simulation data is used to compare the controller with the controller, and it is proved that the controller's strength and stability meet the requirements of the project.

1. Introduction
The four-rotor drones have been widely used in aerial photography, post-disaster rescue, and agriculture and forestry cultivation due to their small size, flexible operation, vertical take-off and landing, and fixed point suspension [1-3]. The four-rotor drone relies on the rotation of four motors to drive the propeller rotation to generate lift, and to achieve pitch, roll, yaw and other actions by changing the speed of different Motors. Due to the control stability of the aircraft and its own process, the continuous high speed rotation of the motor and propeller makes the probability of failure greatly improved. The four-rotor UAV is a typical nonlinear system with strong coupling characteristics [4-6]. Once the above failure occurs, the flight stability will drop sharply, and even cause the UAV to lose control. How to ensure that the four-rotor UAV can be effectively controlled under the condition of failure is becoming a hot issue in the field of four-rotor UAV [7-9].

Most attitude control algorithms require attitude and angular velocity information. The measurement of this information usually combines a variety of sensors and is obtained by estimation techniques. However, the trend in the construction of micro-small systems (such as micro-four-rotor aircraft, small satellites, et al.) is limited by cost and volume restrictions, and angular velocity measurement equipment is usually removed [10-14].
Apple bagging is a supporting technology to improve the appearance quality of commodities. It must be based on the comprehensive management of orchards, and the results and benefits can be reflected [1-2]. Firstly, it can make the peel delicate and bright, and the fruit dots are sparse, which can significantly improve the appearance quality; Secondly, it can promote the rapid increase of anthocyanins in red fruits, enlarging the coloring area by about 30%, and the color is uniform, bright and beautiful; Thirdly, it can effectively reduce the residue and pollution of pesticides and dust on fruits; Fourth, it can prevent and control diseases, insects, birds, mice, bees and other harmful effects on fruit, reduce fruit rust; Fifth, it can avoid friction between branches and leaves, prevent sunburn and reduce mechanical damage such as hail. Therefore, fruit bagging is still the most direct and effective technology in the production of pollution-free green fruits.

The sliding mode observer uses non-smooth feedback to estimate the state of a system with matching interference. At the same time, compared with the traditional EKF filter, the computational burden of the sliding mode observer is smaller [16-20].

In view of the shortcomings of the above documents, this paper makes the following improvements:
1) The fault-tolerant controller design is directly aimed at the nonlinear attitude dynamics model of the four-rotor drone. There is no need to linearize the model and increase the scope of application of the controller;
2) Considering the influence of unknown external disturbance and actuator failure on the performance of the aircraft, a geometric observer design based on the angular velocity estimation of the four-rotor UAV is designed [21-28].
3) The nonlinear fault-tolerant controller proposed in this paper is verified by real time experiments, and the good attitude control effect is obtained, which ensures the effectiveness and realizability of the algorithm.

Attitude representation is a fundamental issue in attitude and angular velocity estimation systems [29-30]. The smallest coordinate representation of the posture, such as the Euler angle, the Rodriguez parameter, the improved Rodriguez parameter, etc., usually encounters geometric singularity problems (kinematics singularity. The unit quaternion is a widely used attitude representation method in recent years. It is a method that uses a minimum possible number of elements to represent the attitude manifold globally. Compared with the traditional attitude Matrix, the group operation and differential algorithm of unit quaternions are simpler.

2. Dynamic model of four-rotor unmanned vehicle
The four-rotor aircraft can be regarded as a rigid system with a cross fixed structure and four independent Motors driving propellers. The motion of the aircraft is completely controlled by the speed of the four motors, as shown in Fig.1.

The simplified structure of the four-rotor aircraft is shown in Figure 1. The aircraft is considered to be a rigid body. The following assumptions are made:
1) An approximate inertial reference system with a flat and stationary ground;
2) Gravity acceleration g is constant and its direction is perpendicular to the ground;
3) The atmosphere is stationary relative to the earth, and the air density does not change with altitude.

The experiment was conducted in the trial orchard of Apple Quality Cultivation and introduction in Gansu Apple planting area of 4.6 million mu fruit tree base in 2018. The apple varieties tested were 'Red Fuji', which were fruit trees of 8-year-old fruiting period. The experiment was conducted in a completely randomized design. Five apples were used as a test plot and repeated three times. Industrialization of Hail-proof Apple Bagging, as is shown in Fig.1.
Figure 1. Industrialization of Hail-proof Apple Bagging.

Monitoring process of hail-proof apple bagging aircraft, as is shown in Fig.2.

Figure 2. Monitoring process of hail-proof apple bagging aircraft.

Completely controlled by the speed of the four motors, as is shown in Fig.3.

Figure 3. Completely controlled by the speed of the four motors.
Carrier and navigation coordinate systems, as is shown in Figure 4.

![Carrier and navigation coordinate systems](image)

Figure 4. Carrier and navigation coordinate systems.

3. Sliding mode variable structure control algorithm

Here’s how to calculate quaternions:

(1) Initialization of quaternions

Assuming that the current coordinate system is a geographical coordinate system, the quaternion column vector

\[ q = [q_0, q_1, q_2, q_3]^T = [1, 0, 0, 0]^T \]  \hspace{1cm} (1)

(2) Acquisition of carrier acceleration and angular velocity from sensors

The measurement value of the three-axis accelerometer is read from the MPU6050, which is the acceleration \( \text{acc}_x, \text{acc}_y, \text{acc}_z \), and the measurement value of the gyroscope is the angular velocity \( \omega_x, \omega_y, \omega_z \).

(3) Convert the acceleration value \( \text{acc}_x, \text{acc}_y, \text{acc}_z \) of the three axes of the accelerometer to a three-dimensional unit vector to obtain:

\[
\begin{align*}
    a_x &= \frac{\text{acc}_x}{\sqrt{\text{acc}_x^2 + \text{acc}_y^2 + \text{acc}_z^2}} \\
    a_y &= \frac{\text{acc}_y}{\sqrt{\text{acc}_x^2 + \text{acc}_y^2 + \text{acc}_z^2}} \\
    a_z &= \frac{\text{acc}_z}{\sqrt{\text{acc}_x^2 + \text{acc}_y^2 + \text{acc}_z^2}}
\end{align*}
\]  \hspace{1cm} (2)

(4) The heavy force of the three axes can be obtained by converting the gravity vector of the geographical coordinate system to the body coordinate system \( v_x, v_y, v_z \):
5

Convert the geographic coordinate system to the gravitational vector under the carrier coordinate system and the acceleration vector product measured by the carrier coordinate system to obtain the error of the two coordinate systems [10]:

\[
\begin{bmatrix}
    v_x \\
v_y \\
v_z
\end{bmatrix}
= \begin{bmatrix}
    q_0^2 + q_1^2 - q_2^2 - q_3^2 & 2(q_1q_2 - q_0q_3) & 2(q_1q_3 + q_0q_2) \\
    2(q_1q_2 + q_0q_3) & q_0^2 - q_1^2 + q_2^2 - q_3^2 & 2(q_2q_3 - q_0q_1) \\
    2(q_1q_3 - q_0q_2) & 2(q_2q_3 + q_0q_1) & q_0^2 - q_1^2 - q_2^2 + q_3^2
\end{bmatrix}
\begin{bmatrix}
    0 \\
    0 \\
    1
\end{bmatrix}
= \begin{bmatrix}
    2(q_1q_2 - q_0q_3) \\
    2(q_1q_3 + q_0q_2) \\
    2(q_2q_3 - q_0q_1)
\end{bmatrix}
\begin{bmatrix}
    q_0 \\
    q_1 \\
    q_2 \\
    q_3
\end{bmatrix}
\]

(3)

(5) The gyroscope error is the fundamental cause of the body coordinate system error. Therefore, the gyroscope coordinate system is more accurate by compensating the gyroscope with PI of the two coordinate system error.

\[
\begin{bmatrix}
    e_x \\
e_y \\
e_z
\end{bmatrix}
= \begin{bmatrix}
    a_x \\
    a_y \\
    a_z
\end{bmatrix} \times \begin{bmatrix}
    v_x \\
v_y \\
v_z
\end{bmatrix}
= \begin{bmatrix}
    a_yv_z - a_zv_y \\
a_zv_x - a_xv_z \\
a_xv_y - a_yv_x
\end{bmatrix}
\]

(4)

(6) The gyroscope coordinate system is more accurate by compensating the gyroscope with PI of the two coordinate system error.

\[
\begin{bmatrix}
    \omega_{\text{int}} \\
    \omega_{\text{int}} \\
    \omega_{\text{int}}
\end{bmatrix}
= \begin{bmatrix}
    \omega_x \\
    \omega_y \\
    \omega_z
\end{bmatrix} + kp \begin{bmatrix}
    e_x \\
e_y \\
e_z
\end{bmatrix} + ki\frac{\sum e_x}{\sum e_z}
\]

(5)

Among them: \( kp \) and \( ki \) are adjusting parameters, which are determined in actual debugging. \( ki \) can be equal to 0, \( kp \) can be adjusted step by step with 0 as initial value.

(7) Quaternion attitude updating equation [13].

The Quaternion Differential Equation is:

\[
\dot{Q} = \frac{1}{2} Q \omega
\]

(6)

Among \( Q = q_0 + q_1i + q_2j + q_3k \), \( \omega = \omega_xi + \omega_yj + \omega_zk \)

Write the above formula in matrix form

\[
\begin{bmatrix}
    \dot{q}_0 \\
    \dot{q}_1 \\
    \dot{q}_2 \\
    \dot{q}_3
\end{bmatrix}
= \begin{bmatrix}
    0 & -\omega_z & -\omega_y & -\omega_x \\
    \omega_z & 0 & -\omega_x & \omega_y \\
    \omega_y & \omega_x & 0 & -\omega_z \\
    -\omega_x & \omega_y & \omega_z & 0
\end{bmatrix}
\begin{bmatrix}
    q_0 \\
    q_1 \\
    q_2 \\
    q_3
\end{bmatrix}
\]

(7)

For the first order differential equation of quaternion, the first order Picca algorithm can be obtained.
The quaternion is normalized and the following formula (8) is obtained:

\[
\begin{align*}
q_0 &= q_0 + (-q_0 \omega_{x_{\text{int}}} - q_2 \omega_{y_{\text{int}}} - q_3 \omega_{z_{\text{int}}}) \frac{\Delta t}{2} \\
q_1 &= q_1 + (q_0 \omega_{x_{\text{int}}} + q_2 \omega_{z_{\text{int}}} - q_3 \omega_{y_{\text{int}}}) \frac{\Delta t}{2} \\
q_2 &= q_2 + (q_0 \omega_{y_{\text{int}}} - q_1 \omega_{z_{\text{int}}} + q_3 \omega_{x_{\text{int}}}) \frac{\Delta t}{2} \\
q_3 &= q_3 + (q_0 \omega_{z_{\text{int}}} + q_1 \omega_{y_{\text{int}}} - q_2 \omega_{x_{\text{int}}}) \frac{\Delta t}{2}
\end{align*}
\]

(8) The quaternion is normalized and the following formula (9) is obtained:

\[
\begin{align*}
q_0 &= \frac{q_0}{\sqrt{q_0^2 + q_1^2 + q_2^2 + q_3^2}} \\
q_1 &= \frac{q_1}{\sqrt{q_0^2 + q_1^2 + q_2^2 + q_3^2}} \\
q_2 &= \frac{q_2}{\sqrt{q_0^2 + q_1^2 + q_2^2 + q_3^2}} \\
q_3 &= \frac{q_3}{\sqrt{q_0^2 + q_1^2 + q_2^2 + q_3^2}}
\end{align*}
\]

(9) The new quaternion obtained above represents the completion of a quaternion operation, returning the quaternion to the beginning, updating the old quaternion to a new quaternion as the initial number of the next quaternion operation, and then starting the next quaternion operation from (1). At the same time, the new quaternion is updated and normalized and transformed into three lower Euler angles (10). The initial calculation of attitude is completed [14]:

\[
\begin{align*}
\theta &= \arcsin(2(q_3 q_0 + q_0 q_1)) \\
\phi &= \arctan(-\frac{2(q_0 q_2 - q_3 q_1)}{q_0^2 - q_1^2 + q_2^2 - q_3^2}) \\
\psi &= \arctan(-\frac{2(q_0 q_3 - q_2 q_1)}{q_0^2 - q_1^2 + q_2^2 - q_3^2})
\end{align*}
\]

4. Matlab / Simulink Implementation and Simulation Analysis of Sliding Mode Control

In order to verify the effectiveness of the proposed algorithm, the experimental verification was carried out using the four-rotor unmanned aerial vehicle platform independently developed by the task group. The experimental platform uses the PC/104 embedded computer as the simulation controller and the xPC target based on the MATLAB RTWI box as the real-time simulation environment. The measurement precision of pitch angle and roll angle is ±0.2, yaw angle is ±0.50. The control frequency of the entire system is 500Hz. The detailed introduction of the platform can be referenced.

4.1. Simulink Design for Sliding Model Control System

Based on the results of the above theories, the paper presents the results shown in Figure 2. Simulation system, the input variables of the system are the desired control height and control posture the main function of the control submodule is to realize the main calculation of sliding mode control method,
the output of the control module iterates as the input of dynamic model Calculate and finally achieve the purpose of control. Simulink general block diagram and control submodule of sliding mode control system, as is shown in Fig.5.

Figure 5. Simulink general block diagram and control submodule of sliding mode control system.

Fourth Rotor UAV Laboratory, as is shown in Figure 6.

Figure 6. Fourth Rotor UAV Laboratory.
4.2. Analysis of Simulation Results

In order to estimate the angular velocity of a four-rotor UAV, a sliding mode observer design frame based on the numerical integration of Liqunfangfa on a manifold is proposed. Height control, as is shown in Fig 7.

![Figure 7. Height control.](image)

Attitude control, as is shown in Fig 8.

![Figure 8. Attitude control.](image)

From the analysis of figures 7 and 8, it can be seen that when the four-rotor UAV is in a stable forward flight state, the longitudinal total distance differential step manipulation is performed, and the lateral velocity, roll angle, and yaw angle corresponding to the optimized speed or standard speed are maintained. Figure 9 shows that only the pitch angle of the four-rotor UAV has gradually increased. In the corresponding figure 10 the forward flight speed has gradually decreased and the reverse flight phenomenon has occurred, while the vertical speed has changed. Thus, the stable bow posture of the aircraft when flying from the front gradually rises.
From the analysis of figures it can be seen that at this time, due to the optimization speed is less than the standard brick speed, the total distance corresponding to the optimization speed is larger than the total distance corresponding to the standard speed. And the rotor blade angle of attack at the optimized speed is in a favorable area with a relatively large lift resistance. The lift resistance ratio in this area tends to be stable with the total distance change. Therefore, the total distance step of the optimized speed is either +1 degrees or -1 degrees. The tension value of the rotor produced is less than that of the total distance step rotor with standard speed. Thus, the pitch moment corresponding to the optimized speed is less than the pitch moment corresponding to the standard speed, so the head rate corresponding to the optimized speed is less than the head rate corresponding to the standard speed, and the reaction rate to the forward speed, Both the preflight speed attenuation at the optimized speed is slower than that corresponding to the standard speed. At the optimal speed, the corresponding time for the aircraft's forward flight speed from 40km/h to 0km/h is about 5.1s. At the standard speed, the aircraft's forward flight speed is reduced from 40km/h to 0km/h. The corresponding time is about 4.6s.

Associate professor Gou Xiaoping, Dr. Zhang Wanjun Professor-level Senior Engineer and Senior Economist (CNC Senior Craftsman, Mechanical Engineer) found that the absolute content and relative ratio of different pigments in the peel were important factors determining the color of the peel.

5. Summary
In this paper, a fault-tolerant controller based on adaptive sliding mode control is designed for the attitude control problem of a four-rotor drone with actuator failure and unknown external disturbance.
The proposed algorithm has good fault tolerance for actuator faults and good robustness to unknown external disturbances.

There are still some shortcomings in the proposed algorithm: the higher requirements for the prior knowledge of the model and the lack of consideration of the position of the ring error tolerance control are the problems that the author needs to solve in the next work.

The fruit is bagged. Firstly, it can make the peel delicate and bright, and significantly improve the appearance quality. Secondly, it can increase the anthocyanin content of red fruits, and the color is gorgeous and beautiful. Thirdly, it can reduce the residues and pollution caused by pesticides and dust [31-34]. Fourth, it can prevent and control diseases, insects, birds, rats, bees and other hazards, reduce fruit rust.

Acknowledgements
The authors thank the financial supports from National Natural Science Foundation of China (Grant no. 51165024), National key basic research development project (973 project) (2009CB724405) and New century talent support program of Ministry of Education (NCET-04-0935).

Author: Gou Xiaoping, male, born in 1978 with a bachelor's degree, Qingyang Science and Technology Commissioner, Patent Commissioner, and Venture Tutor of Longdong University, has obtained more than 580 authorized patents, three papers published by EI and one monograph published.

Second Author: Zhangwanjun, male, born in 1986, doctoral student in engineering(bachelor's degree in law and management), professorial senior engineer, senior economist (mechanical engineer, CNC senior craftsman), Senior member of China Society of Mechanical Engineering, Senior member of China Agricultural Machinery Society, Senior member of the China Agricultural Machinery Engineering Society, senior member of the China Instrument Instrument Society, member of the China Invention Society, director of the China Invention Society, director of the Gansu Invention Society, member of the Standing Committee of the Committee of Experts of the Modern Manufacturing Engineering (Chinese Core, Science and Technology Core), member, and review expert. Mainly engaged in numerical control technology equipment, new energy research and electromechanical transmission control work. We have authorized more than 250 patents for invention and utility models as the first applicant (patentee) and inventor, and nearly 200 patents for design as the first applicant (patentee) and inventor, and published more than 60 academic papers in core or above journals. SCI/EI/ISTP has more than 40 searches papers, including more than EI 40 papers, SCI 5 papers. Email: gszwj_40@163.com.

6. References
[1] Sun Dongmei, Tian Zengshan, Han Lingjun. Simulating simulation of attitude angle using four-element method in strapdown inertial navigation system [J]. Journal of Missile and Guidance, 2009, 29(1):51-60.
[2] Hu Qiyi. Attitude Estimation and Optimal Control of Four-Rotor Vehicle [D]. Hangzhou: Hangzhou University of Electronic Science and Technology. 2014.
[3] Zhao Jianjun, Chen Bin, Yang Libin. Geodetic coordinate transformation algorithm based on quaternion and its implementation [J]. Computer Engineering and Application, 2013, 49 (4): 202-205.
[4] Jiang Chengping. Design and implementation of a Four-rotor UAV control system [D]. Harbin University of Technology. 2014.
[5] Ma Yuanchao. Research on Navigation and Control Technology of Four-Rotor Aircraft [D]. Harbin University of Engineering, 2013.
[6] Jia Hongguang, Chen Tao, Zhang Yue and Zhang Ronghui. Attitude Solution of Strapdown Inertial Navigation System Based on Quaternion Method [J]. Optical Precision Engineering, 2008, 16 (10): 1963-1970.
[7] Song Yinglin, Xianbin, Rubinchao, Cao Meihui. Data Processing of Miniature Attitude and
Heading System for UAV [J]. Journal of Central South University. 2013.

[8] Huang Pengyu, Zeng Lurong, Yang Chuan, Peng Yuanyuan, Yu Chengbo. Design of a new four-axis aerial photographic aircraft for disaster relief [J]. Sichuan Military Engineering Journal. 2014.

[9] Zhang Jing, Liu Heng, Zheng Zewei. Application of cascade PID control in attitude control of miniature UAV [J] Electronic World. 2014.

[10] Zhang WanJun, Zhang Feng, Zhang Guohua. Research on modification algorithm of Cubic B-spline curve interpolation technology [J]. Applied Mechanics and Materials, Vol. 687-691, pp.1596-1599, December 2014.

[11] Zhang WanJun, Zhang Feng, Zhang Wan-liang. Research on high-grade CNC machines tools CNC system for B-Spline curve method of High-speed real-time interpolation arithmetic [J]. Chinese Journal of Manufacturing Technology & Machine Tool, 8(8), pp.172-176, August 2015.

[12] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et,al. Research on cross coupled contour error compensation technology in CNC multi axis linkage of Machine tool [J]. Chinese Journal of Manufacturing Technology & Machine Tool, June. pp.154-159, 2018.

[13] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et,al. Cross coupled contour error compensation technology [J]. Marerials Science and Engineering, 2018, 8, Vol. 394. 032031:1-5.

[14] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et,al. Research on the vector control system based on the difference frequency of wind turbine generator [J]. Marelials Science and Engineering, 2018, 8, Vol. 394. 042020:1-9.

[15] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et,al. Curved Measurement Theory of Honing Pneumatic Measurement System and Optimization of Measurement Parameters [J]. Journal of Physics, 2018, 8, Vol. 1064. 012028:1-14.

[16] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et,al. Flow field analysis and parameter optimization of main and measured nozzles of differential pressure type gas momentum instrument based on CFD [J]. Journal of Physics, 2018, 8, Vol. 1064. 012028:1-12.

[17] Zhang Wanjun, Zhang Feng, Zhang Wanliang, et al. Fuzzy Control of Wind Turbine Based on Directional Power Conversion [J]. Electric Power Construction, 2014, 10, 35(10): 13-16.

[18] Zhang Wanjun, Zhang Feng, Zhang Guohua. Research on a algorithm of adaptive interpolation for NURBS curve [J]. Applied Mechanics and Materials, Vol. 687-691, pp.1600-1603, December 2014.

[19] Zhang Wan-Jun, Zhang Feng, Zhang Guohua. Research on modification algorithm of Cubic B-spline curve interpolation technology [J]. Applied Mechanics and Materials, Vol. 687-691, pp.1596-1599, December 2014.

[20] Zhang Wan-Jun, Zhang Feng, Zhang Wan-liang. Research on high-grade CNC machines tools CNC system for B-Spline curve method of High-speed real-time interpolation arithmetic [J]. Chinese Journal of Manufacturing Technology & Machine Tool, 8(8), pp.172-176, August 2015.

[21] 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.

[22] 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.

[23] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et,al. Research on a Kind of Adaptive Fuzzy Control Method and Its Application in Feeding System of CNC Honing Machine [J]. Materials Science and Engineering, 2018, 8, Vol. 452. 042076:1-8.

[24] 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.

[25] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et al. Research and Analysis on the Identification Model of Multivariate Economic System [J]. Materials Science and Engineering, 2018, 8, Vol. 452. 022061:1-11.

[26] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et al. Identification and Analysis of Economic Model Based on Longnan Southeast [J]. Materials Science and Engineering, 2018, 8, Vol. 452. 032058:1-8.

[27] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et al. Based on Brushless DC Motor of Fuzzy and PID Control System [J]. Materials Science and Engineering, 2018, 8, Vol. 452. 042075:1-10.

[28] Zhang Wanjun, Zhang Feng, Zhang Jingxuan, et al. Modeling and identification of system model parameters based on information granularity method [C] // Proceedings of the IEEE International Conference on Computers, Signals and systems. Dalian, 2018:114−118.

[29] 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.

[30] Sun Dongmei, Tian Zengshan, Han Lingjun. Simulated simulation of attitude angle using four-element method in strapdown inertial navigation system [J]. Journal of Missile and Guidance, 2009, 29(1):51-60.

[31] Gou Xiaoping, Gou Heping, Hou Er'long, et al. Hail-proof bagging [P]. Gansu: CN107041263A, 2017-08-15.

[32] Li Tong, Duke Fei, Gou Xiaolong, et al. Apple bagging (6) [P]. Gansu: CN303803464S, 2016-08-17.

[33] Zhang Rongtong, Liu Xiaohui, Yang Huanhuan, et al. Apple bagging (can prevent small hail) [P]. Gansu: CN303904139S, 2016-11-09.

[34] Li Tong, Duke Fei, Gou Xiaolong, et al. Apple bagging (8) [P]. Gansu: CN303838139S, 2016-09-07.