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I. INTRODUCTION

With the continuous development of economy, science and technology, the circulation of goods and information is accelerating, so the logistics industry occupies a broad market space. Logistics UAV plays an increasingly important role in urban transportation [1-2]. UAV have also received increasing attention in recent years due to their applications in prospect, logistics, photography and communications [3]. These UAV are usually easy to control, even though WIFI smart phones and tablets [4]. Due to the development of low altitude UAV control policy and technology, the practical application of UAV is more and more [5]. Based on the development of mobile communication network, UAV further breaks through the limitation of information transmission distance. At present, the application demand of UAV in cities is increasing. Nowadays, with the rapid development of e-commerce, the volume of logistics business will continue to increase in the future. Logistics UAV can improve the delivery efficiency of e- commerce logistics and reduce the delivery cost [6-7]. Especially in the era of rapid development of the Internet, logistics industry needs to use informatization and technology to promote its development [8].

In June 2013, Matternet of the United States tested a network of drones in Haiti and the Dominican Republic. UAV were able to carry 1.9km of 2kg objects. The company hopes to build a large international drone transport network and a global supply system for drone accessories. At the same time, a charging base station is also established, so that the drone can be landed along the way for charging. Meanwhile, it can also ease the contradiction between express delivery requirements and express delivery capabilities.

Due to the complex imaging conditions on the UAV platform, such as jitter, frequent undefined motion, viewpoint changes and illumination changes [9], the problem of the logistics drones being blurred and unclear when shooting the pick-up image Therefore, it is necessary to clear and identify the image [10]. In the paper, L. Meng et al. proposed a new method for real-time face recognition in video, which has been implemented in MATLAB [11]. In recent years, wavelets have become increasingly important for signal and image processing [12]. In the past literature, it has been studied to use different methods to sharpen blurred images, such as constrained least squares (CLS) and Wiener filters, which often lead to noise amplification or excessively smooth artifacts. In addition, advanced fuzzy image restoration techniques such as iterative regularization, Fourier domain threshold filtering and wavelet domain threshold filtering are not suitable for processing real-time problems due to the large amount of computation. In order to overcome these problems, S. Kim et al. proposed a fuzzy wavelet decomposition (VWD) method based on frequency adaptive contraction and directional wavelet basis, which can be used for real-time, space-frequency adaptive image restoration [13]. As early as 2012, Z. J. Xiang and P. J. Ramadge have studied a core issue: how to control edge retention in image denoising. They solved this problem from a machine learning perspective, using a tree classifier to support a new image regularizer [14]. Using this new regularizer, it provides a theoretical basis for the optimal selection of data-driven Dyadic wavelet decomposition structure. This proposed method proves to be superior to existing haar wavelet threshold algorithms that do not use adaptive trees. The choice of wavelet transform is determined by the symmetry and anti-symmetry of decomposition wavelet. Symmetry is considered an ideal property of wavelet, especially in image processing [15]. In the research of S. R. Dubey et al., a medical CT image feature description method based on local wavelet mode (LWP) is proposed. It also applies the symmetry of wavelet, has high recognition rate and efficiency, and can be effectively used in medicine CT image diagnosis [16]. Another advantage of wavelets is that they do not have a unique base like the Fourier transform, so a wavelet base with a given signal match is required at design time [17]. After a lot of literature research, the wavelet transform method has high value and advantage for the research of digital images. In addition, MATLAB and image processing algorithms have the advantages of compatibility and accuracy [18]. MATLAB can combine the Raspberry Pi embedded image processing technology to track and recognize faces [19].

Therefore, we have studied a logistics UAV, that is, an unmanned Low altitude aircraft operated by radio remote control equipment and its own program control device to carry packages while loading an image processing system. We embed the Raspberry Pi into the image processing technology, combined with wavelet transform to realize the contrast recognition of the picker on the MATLAB platform, and finally achieve safe and accurate delivery. The structure of this paper is as follows. In the second part, the system architecture of the logistics drone is proposed. The third part introduces related methodology, including PID - based flight control theory, wavelet transform and emergency system. In the fourth part, the principles and flow charts of UAV communication control, landing obstacle avoidance and image processing are described. The fifth and sixth parts compare and analyze different methodologies to give experimental and simulation results. Finally, the conclusion is drawn.

II. SYSTEM ARCHITECTURE

Nowadays, the research on intelligent control has begun to turn from the ground to the air. Subsequently, UAV technology has become an important research direction of automatic control. However, since the birth of quad-rotor aircraft, due to poor control, low safety performance and other problems, it has reached a bottleneck state. This paper studies a four-rotor aircraft equipped with ultrasonic obstacle avoidance system. The aircraft architecture is shown in Figure 1, which mainly includes the following aspects:

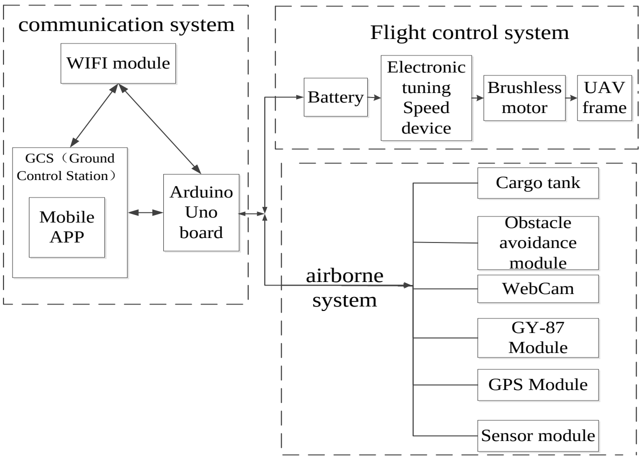


Fig. 1: System architecture diagram

a) *Ground Control Station (GCS):* This android-based mobile APP is designed on the basis of MIT APP Inventor 2 development environment. The operator connects the mobile device with the UAV through the WIFI module, so as to control the take-off, landing and flight direction of the UAV.

b) *Arduino Uno Board:* The flight control board of this system , which can achieve the bidirectional transmission of instructions between the ground control terminal, the flight control system and the airborne system.

c) *WIFI Module (ESP8266):* It is used for two-way communication between mobile phone and Arduino, so as to realize the function of sending and receiving information between mobile phone and UAV [20].

d) *Obstacle Avoidance Module:* It is mainly composed of HC-SR04 ultrasonic wave, SG90 steering gear and tri-color light. The steering gear combined with ultrasonic module can detect whether there are obstacles in the range of 180 degrees ahead [21]; the tricolor light displays different colors to reflect the distance between the quad and the obstacle.

e) *Webcam:* Image taken during a drone flight.

f) *GY-87 Module:* The 10-dof module, which is composed of a three-axis gyro, an accelerometer, a magnetic field and a pneumatic pressure, is used to calculate the current attitude of the four-axis aircraft so as to control its state.

g) *GPS Module* : The NEO-7N UBLOX satellite locator is used to obtain the position of the UAV.

h) *Motor Module:* Drive the brushless motor by Arduino output PWM to the electronic governor.

i) *Sensing Module:* Mainly consists of alarm buzzer, photosensitive resistor and LED lamp, among which the current light intensity is determined by the 5539 -type photosensitive resistor. When the light is dim, the LED light on the wing will be lit.

III. METHODOLOGY

This system proposes three methods: flight control system , wavelet transform and emergency system.

A. Flight Control System

The motor driver is a dc motor driver with current return. The UAV drive system in this paper uses the current control mode of the motor driver. The schematic diagram of the system is shown in Figure 2. The input voltage *ui* (*t*) represents the command value of the current.

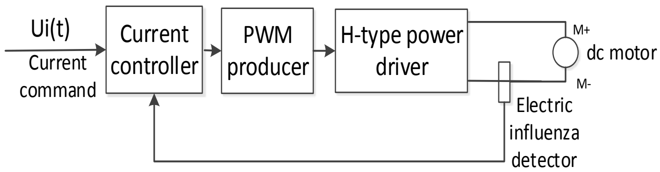


Fig. 2: Current control mode diagram of dc motor driver

The control system of the UAV uses the kinetic energy equation of the motor control system and the closed-loop PID controller to control the balance [22]. Its control input is dc motor current driver input voltage (*t*) and output is the Angle of reversion θ(t) of motor central axis.

We will first to obtain the characteristic equation of the motor linearization system is:

$$\Delta(s) = |sI - A| = s^4 + as^3 - \frac{g}{}s^2 - \frac{g}{}as = 0 \qquad (1)$$

If the state variable is x(t), the input variable is u(t), and the output variable is y(t), then the PID algorithm of the surrounding aircraft is shown in the equation of state (2), where A and B are matrices, and t is the time coefficient.

$$\dot{x}(t) = Ax(t) + Bu(t) \quad (2)$$

$$y(t) = Cx(t) \quad (3)$$

Then, performance indicators were obtained using the optimal control under the LQR (Linear Quadratic Regulator).

The object is the linear system given in the form of state space in the present control theory, and the objective function is the quadratic function of object state and control input. LQR optimal design refers to the state feedback controller K designed to minimize the quadratic objective function J, and K is only determined by the weight matrix Q and R, so the choice of Q and R is particularly important. Let the state equation of the linear-time-varying system be:

$$x(t) = A(t)x(t) + B(t)u(t), x(t) = X0 \quad (4)$$

Performance index:

$$J = \frac{1}{2}\int_0^\infty [x^T(t)Qx(t) + u(t)Ru(t)]dt \quad (5)$$

In the formula, the vector x(t)∈ Rn, u(t)∈ Rm, the matrix A(t) is n x n dimensional time-varying system matrix, B(t) is n x m dimensional gain matrix, Q(t) is the semi-positive definite matrix, which is the weighted state, R(t) is the symmetric positive definite matrix, which is the weighted control input u(t).

For the time-varying state regulator problem in infinite time, if the matrix pairs {A(t), B(t)} are completely controllable, there exists A unique optimal control.

$$u(t) = -R - 1(t)BT(t)P(t)x(t) = -K(t)x(t) \quad (6)$$

Where the matrix P is the solution of Riccati algebraic equation (7), the matrix Q and the scalar R are the state variables and the proportion of the control input respectively.

$$PbR^{-1}b^TP - Q - PA - A^TP = 0 \quad (7)$$

The optimal performance index is:

$$J^* = \frac{1}{2}x^T(t)P(t)x(t) \quad (8)$$

B. Wavelet Transform

Wavelet transform (WT) is a new transform analysis method. The WT can automatically adapt to the requirements of time-frequency signal analysis, and thus can focus on any detail of the signal. Wavelet transform is mainly divided into two parts, discrete and continuous transform [23].

1) Discrete Wavelet Transform

Like the Fourier series expansion, if the function being developed is discrete (a string of Numbers), the coefficients are known as the discrete wavelet transform (DWT).Continuous wavelet in the treatment of the object will cause theory of coefficient of redundancy, what we need in the practical application in the removal of interference signals while preserving the original low redundancy, as discrete wavelet transform relatively continuous wavelet transform operation more convenient, and in the actual signal processing are discrete information stored on the computer. So the size parameters of the need to a peace shift parameter b discrete processing, the original continuous translational expansion component transform: a=aj0, j as an integer, a > 1 scale step length for a fixed value, including translational component b = kb0a0j , and b0 > 0 and is associated with a form . K is an integer. Discrete wavelet can be defined as:

$$\psi_{j,k}(t) = \frac{1}{\sqrt{a_0^j}}\psi\left(\frac{t-kb_0a_0^m}{a_0^m}\right) = a_0^{-j/2}\psi\left(a_0^{-j}t - kb_0\right) \quad (9)$$

Corresponding discrete wavelet transform:

$$W_f(v,k) = a_0^{-v/2}\int_{-\infty}^{+\infty} f(t)\psi_{v,k}(t)dt \quad (10)$$

The wavelet transform Wf (a, b) can fully present the properties and transformation process of signal function f (t) in the case of a>0 and b∈ (−∞, +∞), and the discrete wavelet can also describe the properties and change process of the function when selecting appropriate parameters a_0 and b_0.

2) Continuous Wavelet Transform

The natural extension of the discrete wavelet transform is the continuous wavelet transform (CWT), which transforms a continuous function into a highly redundant function with two continuous variables (translation and scale). The resulting conversions are easy to interpret and valuable for time-frequency analysis.

A continuous squared integral function *f(x)* converts the continuous wavelet of the real-valued wavelet $\Psi(x)$ to

$$W_\psi(s,\tau)=\int_{-\infty}^{\infty} f(x)\psi_{s,\tau}(x)dx \quad (11)$$

where

$$\psi_{s,\tau}(x)=\frac{1}{\sqrt{s}}\psi\left(\frac{x-\tau}{s}\right) \quad (12),$$

s and τ are called scale and translation parameters respectively.

Given $W_\psi(s,\tau)$, the inverse continuous wavelet transform can be obtained)

$$f(x)=\frac{1}{C_\psi}\int_0^{\infty}\int_{-\infty}^{\infty} W_\psi(s,\tau)\frac{\psi_{s,\tau}(x)}{s^2}d\tau ds \quad (13)$$

where

$$C_\psi=\int_{-\infty}^{\infty}\frac{|\Psi(\mu)|^2}{|\mu|}d\mu \quad (14)$$

$\Psi(\mu)$ is the Fourier transform of. $\Psi(x)$ Equations (11) to (14) define a reversible transformation as long as the so-called permissible conditions are met $C_\psi < \infty$, (Grossman and Morlet [1984]).)

C. Emergency Treatment System

The system consists of three parts: signal emergency plan, electricity emergency plan and power and signal emergency plan.

1) Signal emergency plan

The UAV is allowed to fly only when the transmitter and receiver are successfully connected via WiFi. When the UAV rotor is started, the system records the starting point position through GPS positioning and stores it in the database. In the process of UAV flight, if the UAV signal is insufficient or lost, the control system will make the UAV automatically switch from flight to hover state and try to connect again. The connection time is two minutes. If the connection time-out, the UAV will read the take-off position and plan the path to return to landing.

2) Electricity emergency plan

The UAV is allowed to fly when the power is higher than 40%. When the UAV rotor starts, the system records the starting point position through GPS positioning and stores it in the database. When the UAV battery power is less than 20%, the system will remind the operator to operate the aircraft immediately through the human-computer interaction interface. When the UAV power is less than 10%, no one has the opportunity to read the position of the starting point, and plan the path to force the return, so as to prevent the crash caused by insufficient power supply. When the power of the UAV is less than 5% and the UAV has not returned to the initial position, the UAV will make a forced landing nearby according to the ground area given by the GPS map, so as to avoid the forced landing in the dangerous areas such as rivers and roads. After the forced landing, the unmanned aerial vehicle will send the position to the operator and enter the sleep state after that, so that the operator can find the UAV according to the positioning.

3) Power and signal emergency plan

If the battery power of the UAV is less than 5% during the process of reconnection or during the process of returning after the connection timeout, the UAV will make a forced landing near the safe range of the map and send positioning by GPS.

IV. SYSTEM SOFTWARE AND HARDWARE DESIGN

The system is divided into three parts: communication control, ultrasonic obstacle avoidance and image processing.

A. Communication Control System

The communication control system of the UAV is mainly to connect to the Internet through WIFI, and then control the UAV to execute commands such as forward, back, left and right steering, takeoff and landing through the APP control interface of the ground control terminal [24]. Figure 3 is the flow chart of flight control system.

The system first initializes the port and the sensor, then detects and reads the remote control command data. The PID is adaptive adjusted through command data and attitude data. The adjusted PID parameters are input to the PID controller to calculate the speed of the corresponding motor. Finally, the PWM signal is adjusted to drive the motor.

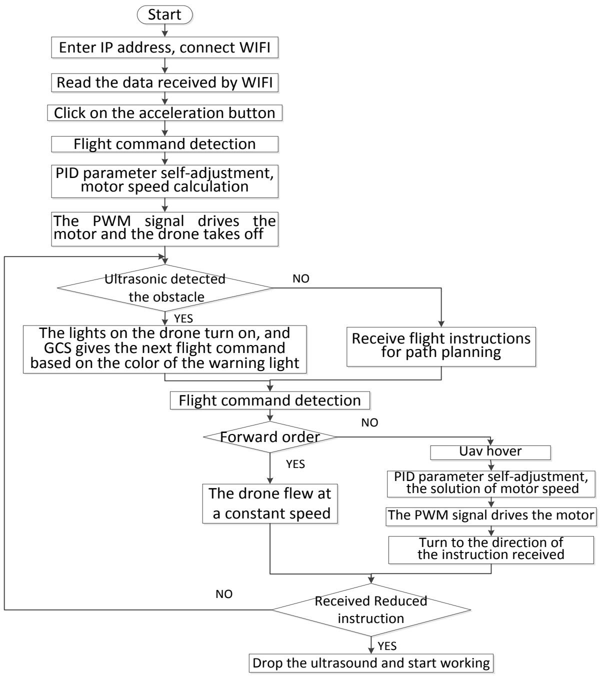


Fig. 3: Flow chart of flight control system

In the process of controlling the UAV flight, ultrasonic detects the surrounding obstacles by rotating the steering gear. If detected, the tri-color LED light on the UAV will be on, and the ground control station will judge the safe direction of the next flight according to the LED light color. If no obstacle is detected, the UAV will point to the next command until the landing command is received, and the ultrasonic wave below starts to work. The landing process is shown in Figure 4.

B. UAV Landing Obstacle Avoidance System

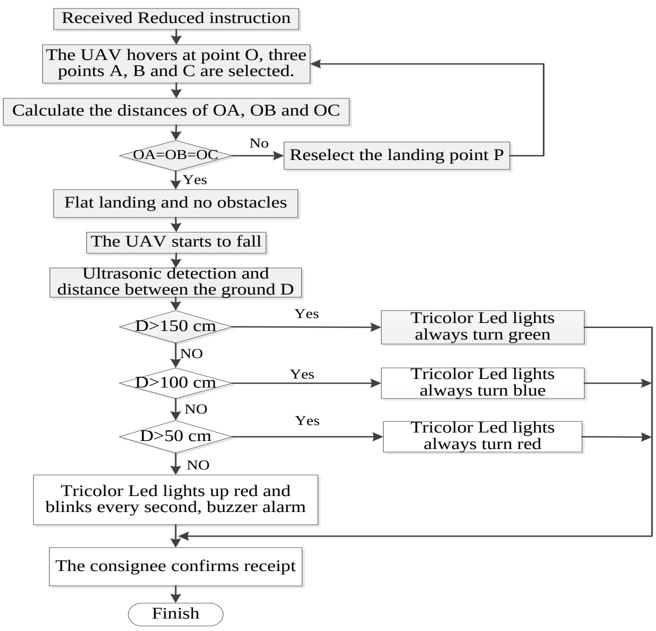


Fig. 4: Flow chart of descending ultrasonic obstacle avoidance system

When the UAV receives the descending command, it is assumed that point P is the pre-landing point on the ground, and point O is the position of the UAV hovering in the air, and OP is perpendicular to the landing surface. Choose A, B and C within the radius of 1m with P as the center of the circle. The height between these three points and the UAV can be determined by calculation. If it is the same, it means that the landing surface is flat, then it begins to fall. At the same time, ultrasonic measure the distance D from the ground to remind the operator to pay attention and ensure a safe landing. If not, then re-select the landing point. After the UAV lands, the receiver confirms receiving the goods, as shown in Figure 5.

C. The Image Processing

First determine if the drone receives a descent command. If a down command is received, the drone arrives at the destination. The image taken by the camera is compared with the image of the pick-up person in the database to verify whether it is the pick-up of the item. Described as follows:

1. *Original image:* The original RGB image captured by the camera.
2. *Grayscale:* The raw RGB image taken is grayed out.
3. *Banalizations:* Binarize the grayscale image [25].
4. *Morphology:* The image after binarization is processed by erosion and expansion to restore the image.

The captured image is compared with the image information of the pick-up person in the database. If the information is the same, the verification is successful, and if the information is different, the verification fails.

After the verification is successful, the pick-up information and image are displayed. At this time, the drone drops and confirms the receipt; the verification fails, the image is displayed, and the information is not recognized.

The landing of the UAV: The process of landing is shown in Figure 4. Confirm receipt or fail to verify the UAV will return.

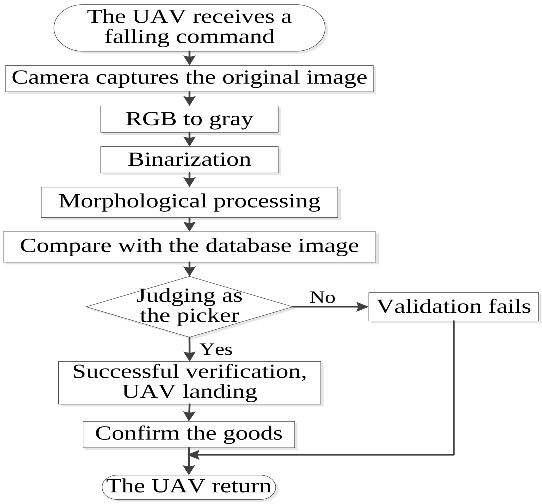


Fig. 5: Flow chart of picture processing

V. SIMULATION COMPARATIVE AND ANALYSIS

The simulation, comparison and analysis are divided into two parts: improved PID and image processing algorithm.

A. *Improved PID Algorithm*

Symbol description:

1. *y(k)* -- discrete value of system response output;
2. *u(k)* -- discrete value of digital PID control output;
3. *r(k)* -- the discrete value of the expected output (known), which in this case is a constant (i.e., step input);
4. e(k)--e(k)=r(k)-y(k), is expected value - actual value, is the error comparison signal with unit negative feedback.

a) Compare and Analyze the Influence of PID Output Parameters

In this paper, in order to study the influence of three PID parameters Kp, , and Kd , we set up an array of PID, Kp, Ki , and Kd take a value of the array each time, and then set a loop function for simulation. Then, all PID effects are output to a graph for comparison, and the output subgraph matrix is shown in Figure 6 (a) ~ (f).

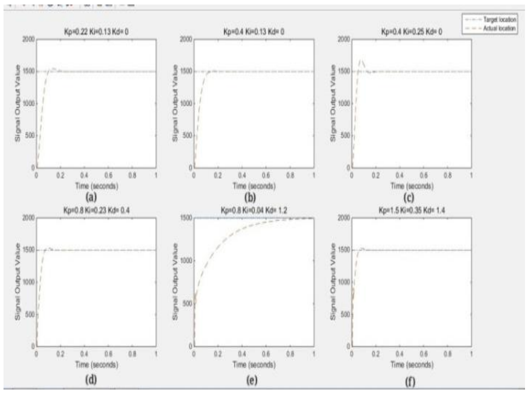


Fig. 6: Comparison diagram of PID parameter influence effect

According to Figure 6 (a) and (b), modification of Kp will shorten the rise time, but may also bring about a large overshoot. Overshoot is not absolute. A small K_p may cause a large overshoot, while a large K_p will cause a small overshoot (for example, in Figure 6, the comparison between Figure (a) and (b)). However, the introduction of integral is also necessary, otherwise it will take a long time to reduce the error e(k) (such as the (e) diagram in Figure 6. The introduction of differential is equivalent to a leading correction, which will reduce overshoot, but the transitional differential is likely to cause tail oscillation, and the system will gradually become unstable. So there's a balance between the differential and the integral, and when that balance is met, the system has almost no oscillations, and the response is fast. It can be known from Figure 6 that (c) overshoot is caused by excessive integration in Figure (d) and (f) are ideal.

b) Improve PID Algorithm

When U(k) > U_{max} , if e(k) > 0 means that the output value has not reached the specified value, or if U(k) < 0, if e(k) < 0 means that the output value exceeds the specified value, the integration will bring a lag, no more integration. $Umax = (k)$ is assumed in this simulation, and the comparison curve of the output of improved PID algorithm is shown in Figure 7.

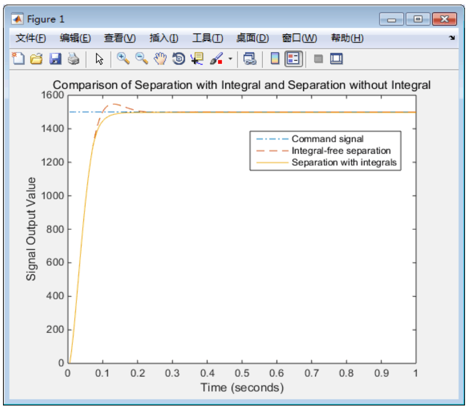


Fig. 7: Improved PID algorithm curve

According to Figure 7, the overshoot of the system is significantly reduced, and the adjustment time is also shortened. This paper proposes an improved PID method, which not only eliminates the steady-state error but also reduces the lag effect brought by the integral link.

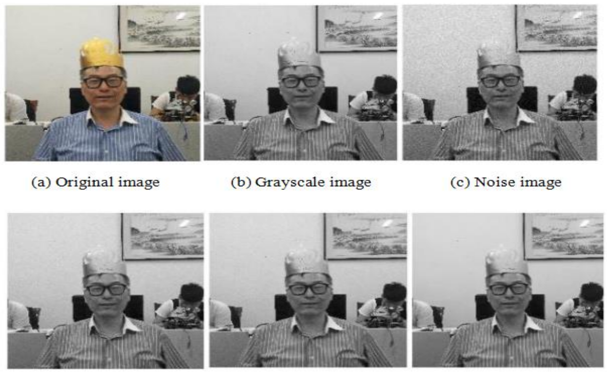
Based on the above, the PID regulation can be summarized into the following two points:

1) When K_p is small, the system is sensitive to the introduction of differential and integral links. Integral will cause overshoot, so should not be too large; Differentials can cause oscillations, and overshoot increases when oscillations are severe.

2) When K_p increases, the overshoot of integral due to lag gradually decreases, but it should not be too small, otherwise the adjustment time will be too long. In this case, if you want to continue to reduce the overshoot, you can introduce the differential appropriately. The system may be unstable if K_p is increased continuously. Therefore, when K_p is increased and Kd is introduced to reduce overshoot, good steady-state characteristics and dynamic performance can be achieved even when K_p is not very large.

B. Image Processing

In order to verify the denoising performance of the wavelet method used in this paper, we add the same mean and variance white Gaussian noise [26] on the basis of the original image. In this experiment, the wavelet decomposition level is set to N=2, and in the selection of wavelet bases, the db8 wavelet decomposition basis function is selected. The simulation results are shown in Figure 8.



(a) Original image (b) Grayscale image (c) Noise image

(d) Median filter image (e) Mean filter image (f) Wavelet Threshold Filtering Image

Fig. 8: Simulated image comparison results

In the simulation experiment, the denoising of the blurred image is simulated by using the traditional filtering function and the wavelet threshold method selected in this paper. The image denoising effect of different methods is judged by quantitative analysis of image contrast. In the quantitative evaluation index, besides the traditional MSE (mean square error) and PSNR (peak signal-to-noise ratio), the latest mean structure similarity (MSSIM) is introduced to evaluate the denoising effect of the filter function. The comparative analysis data are shown in Table 1.

Table 1: Simulated Image Denoising Comparison T Able (Unit Db)

Evaluating indicator / hreshold function	MSE	PSNR	MSSIM
Raw noise image	99.8095	28.1391	0.5087
Median filtering	28.0514	33.6513	0.8159
Mean filtering	25.8242	34.0105	0.8600
Wavelet threshold filtering	24.6278	34.2165	0.8849

In Table 1, the noise removal can be clearly obtained by comparing the indices. The wavelet threshold method used in this paper has a better changer than the original image in both the contrast of Figure 8 (d) ~ (f) and the detail clarity of the image. From the MSE, PSNR and MSSIM in the table, it can be seen that the wavelet threshold method used in this paper is superior to the traditional mean and median filtering for the denoising effect of the simulated image. The results shown that the wavelet threshold denoising method is effective.

VI. EXPERIMENTAL RESULT

The experimental results are divided into two parts: UAV flight test and image processing.

A. UAV Flight Test Result

We flew the drone in a relatively empty playground for safety reasons. Figure 9 (a) ~ (h) refers to the whole process of logistics UAV from delivery to picking up by operators. Among them, figure (a) shows the operator putting a small cargo into the UAV cargo box; Then we connect the phone App to the drone successfully, click the "Faster" button, and the drone takes off. Figure (b) shows the UAV in the process of taking off; During the flight, the front steering engine continuously rotates ultrasonic wave to detect obstacles. If obstacles are not detected, the UAV will point to the next command. If obstacles are detected, as shown in figure (c), the UAV will hover in the air; Meanwhile, the mobile APP of the ground control terminal displayed "Warning: Suggest to turn left", as shown in figure (d). After receiving the obstacle alarm, the operator will send corresponding steering instructions according to the prompt, and the UAV will continue to fly, as shown in figure (e). Fly to the designated place, hover, and identify the cargo picker through webcam, as shown in figure (f), the specific identification process is as shown in part C (image processing); If the authentication is successful, the UAV will dock at an appropriate location, as shown in figure (g). Finally, the pick-up takes out the goods from the cargo box and completes the distribution task, as shown in figure (h); If the authentication fails, as shown in figure (i), the UAV will not dock and continue to fly, as shown in figure (j).

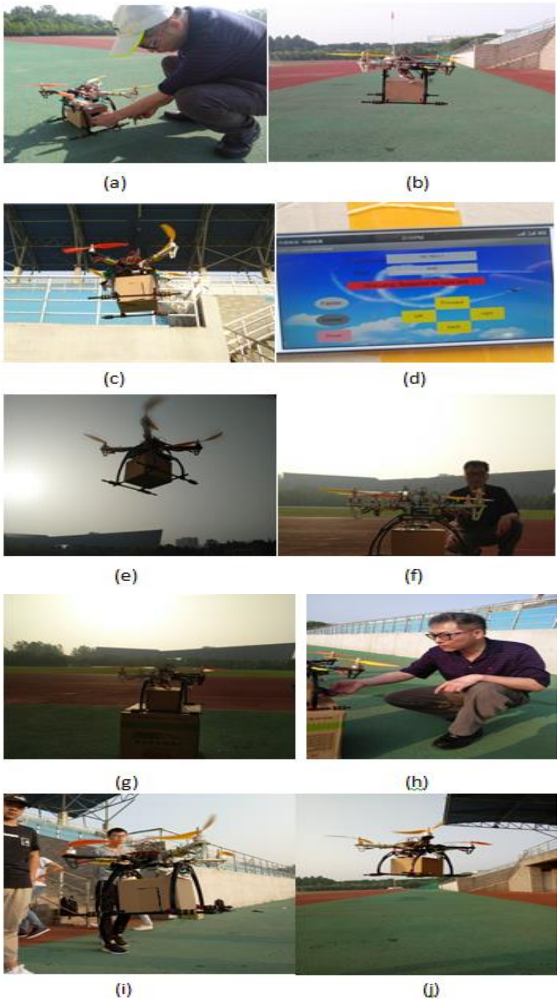


Fig. 9: The process of Logistics UAV Deliverying and Pick-up

B. Image Processing

Face information collection should be the first step in face image detection and recognition. We collected 10 face information from 20 people and established a separate folder for each person to distinguish the information of different people, so we stored 200 face information in the face database. Information of partial face database is shown in Figure 10 (a), (b) and (c).

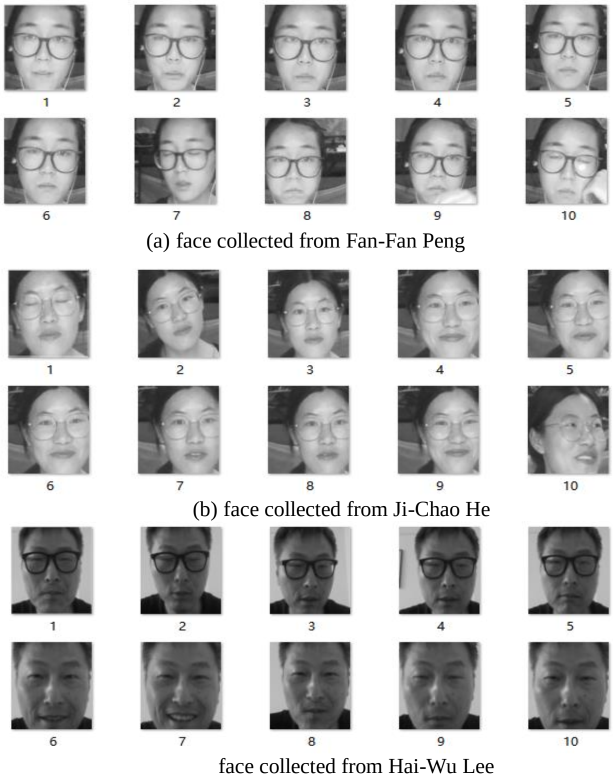
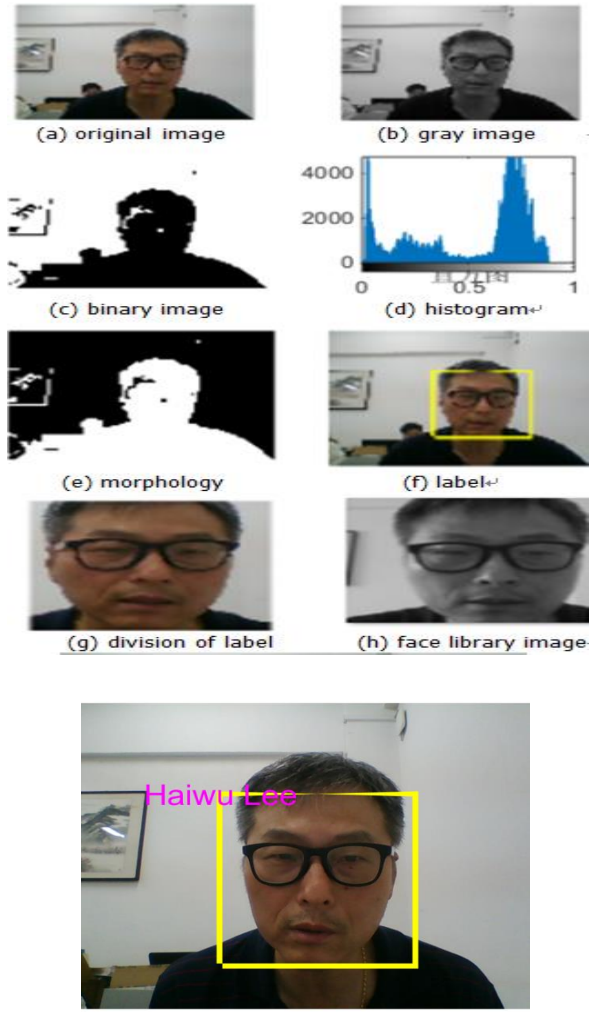


Fig. 10: Partial Face Information Graph Collected from Face Database

After the preparation of face collection, face detection and recognition are carried out. The experimental results are divided into the following three situations:

In the first case, there is only one person in the image and that person is the consignee. Experimental results as shown in Figure 11 (a) to (i), as shown in Figure (a) as the original Figure, Figure (b) as the original Figure turned gray, Figure (c) to turn gray image binarization, Figure (d) show the grayscale histogram, Figure (e) for binary image morphology processing, make the face more clearly, Figure (f) for label, Figure divided label (g), Figure (h) as the garage face Figure, matching with the Figure (i), according to identify the identity of the information, and landing UAV as shown in Figure 9 (g).



(i) face detection and recognition result image

Fig. 11: Image of Experimental Results in the First Case

In the second case, there are three people in the image at this time, two of them are in the face database, and the other one is not in the face database. Figure 12 (c) is the receiver after matching with Figure 12 (d) of the face database. The same is shown in Figure 11 (i).

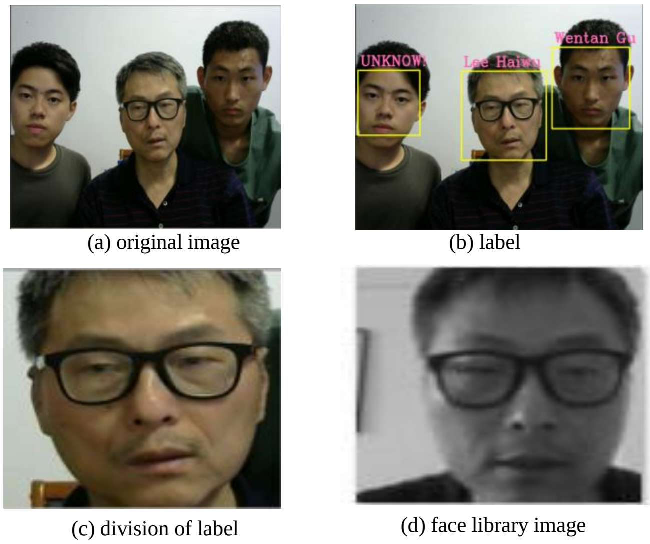


Fig. 12: Image of Experimental Results in the Second Case

In the third case, three people in the experimental images are not pickers, and the information of three people is stored in the face database. Similarly, Figure 12(c) and Figure 12(d) are non-cargo pickers. The experimental results are shown in Figure 13, and the UAV directly returns without landing, as shown in Figure 9(j).

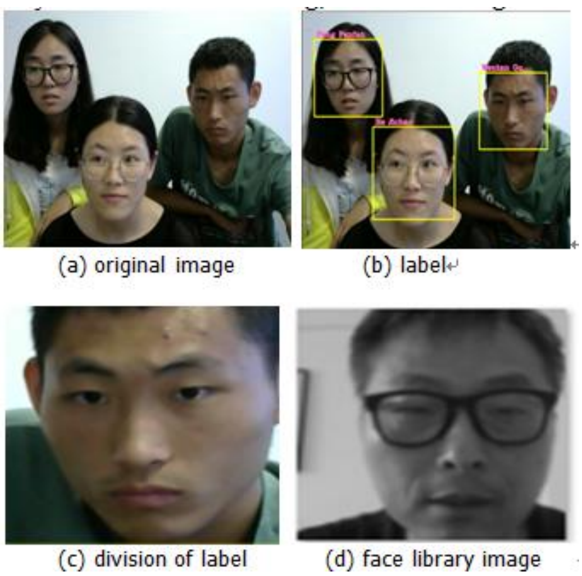


Fig. 13: Image of Experimental Results in the Third Case

VII. CONCLUSION

In this paper, an improved intelligent UAV flight control system is proposed for the environmental adaptability of four-rotor logistics UAV, and hardware design, attitude calculation, software simulation and test flight test are carried out for the system. The system delivers goods to the destination through GPS positioning system. At the same time, the wavelet algorithm is used to clear the fuzzy image taken by the UAV, so as to identify the identity of the consignee and ensure the safe and accurate delivery of the goods. Therefore, the advantages of this logistics UAV mainly lie in solving the distribution problem of small packages, improving work efficiency and reducing labor costs. The experimental results show that the system is feasible.

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