Uav Visual Landing Method Based on 5G Technology

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Abstract

In view of the fact that the current drones are prone to damage during landing and the drone navigation control has inaccurate landing position, based on the rapid development of drones in recent years, the demand for safe and accurate landing of drones continues. In this paper, this paper proposes a 5G-based drone visual landing method design to solve the problem of mismanagement caused by manual control landing and the inaccurate positioning of the traditional UAV using GPS system for inaccurate positioning. This paper provides technical support for the landing of drones by using 5G network and visual navigation algorithms, so that the automatic landing of drones is not only safe and accurate, but also enables over-the-horizon landing.

Keywords

5G technology; drone; visual navigation.

1. Introduction

With the rapid development of the UAV industry today, it has been widely used in various fields. In addition to the military field, it also includes unmanned inspection, agricultural plant protection, environmental monitoring, logistics and transportation. There are also many ways to control the drone. The most common ones are the manual remote control and the ground station control. These two control methods have certain defects when controlling the drone to land, and there are some manual control when landing. The drone may be damaged due to improper operation, which will not only cause economic loss, but also may cause personal injury. When the ground station controls the landing, there is often a 1~2m error between the actual dropout of the drone and the target power due to the error in the positioning. Moreover, the existing UAV visual landing methods mostly use Wifi for image transmission, and sometimes the image transmission delay is caused by signal reasons, and the transmission distance is also greatly limited.

This paper proposes a 5G technology-based drone visual landing method, which can be applied to various UAVs. The visual algorithm and the ultrasonic sensor cooperate with each other to make the UAV automatic landing not only safe and accurate, but also realize the over-the-horizon landing. . Therefore, the program can be widely used in the field of drones with the advantages of wide field of view and high precision, and has extremely important application value.

2. General Idea

In order to solve the problem that the UAV is prone to damage during the manual maneuver landing process and the landing position of the UAV is inaccurate, this paper proposes a 5G-based drone visual landing method to make the UAV safe and accurate. landing. The UAV visual landing method based on 5G technology includes at least a drone end device, a ground end system, and a landing beacon:

The drone end device includes: lithium battery, pcduino main control, high-definition camera, 5G network communication module, ultrasonic ranging module. The lithium battery is used for powering the drone; the pcduino main control is used for receiving the control command of the ground end system to control the operation of the relevant module on the drone; the high-definition camera is used for shooting high-definition video; the 5G network communication module It is used to access the 5G network, and realizes the ultra-high-definition real-time video transmission of the UAV by using the 5G network; the ultrasonic ranging module is used to measure the distance from the beacon when the drone is landing. The main structure diagram of the airborne module of the UAV is shown in figure 1 [1,2].

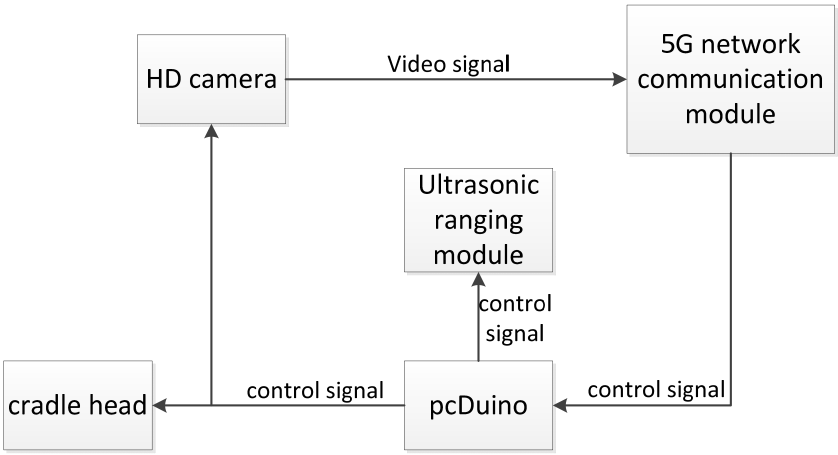

Fig. 1

The ground end system includes: drone ground station software, 5G network communication module, and visual navigation software. The PC end connects to the wireless network through the 5G network communication module to communicate wirelessly with the aircraft; the ground station software is the supporting ground station software of the UAV flight control system, and sends the flight control control command through the 5G network; the visual navigation software adopts python Written with the opencv development environment to provide visual navigation for drone landings.

The landing beacon is a marker of visual navigation during the landing of the drone. as shown in figure 2.5

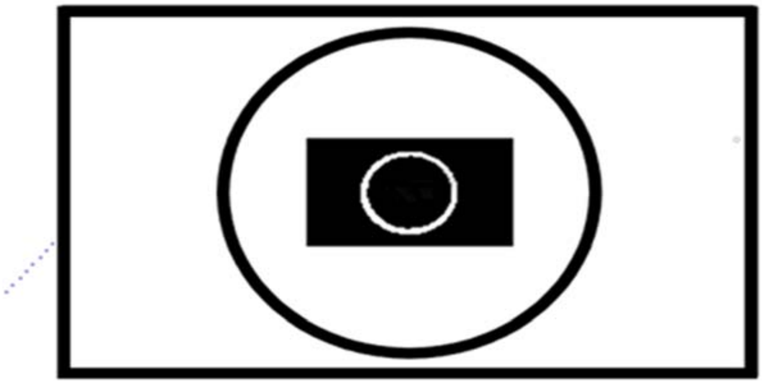

Fig. 2

The visual algorithm mainly includes image graying processing on the image captured by the camera, image edge detection to detect the characteristics of the landing beacon, and estimation and solution of the relative position of the drone and the landing beacon.

The 5G-based drone visual landing method proposed in this paper specifically includes the following steps:

The first step: the ground end system sends a landing command to the drone.

Step 2: Perform image recognition on the image captured by the high-definition camera and transmitted to the ground through the 5G network to detect the landing beacon.

Step 3: When detecting the landing beacon, the visual algorithm calculates the relative position of the drone and the landing beacon.

Step 4: The drone master adjusts the position of the drone until the camera's optical center coincides with the landing beacon center.

Step 5: The drone slowly descends, and the ultrasonic module is used to measure the vertical distance from the landing beacon. When the distance between the drone and the landing beacon is less than the specified value, the drone motor stops running and the landing is completed.

3. Visual Navigation and Its Algorithm

The visual navigation landing process is shown in Figure 3. The visual navigation system uses the high-definition camera installed directly under the drone to obtain the image information of the ground, and then sends the image to the ground through the 5G network. The background computer uses the visual algorithm to identify the characteristics of the previously set landing beacon, and then uses the design. The determined coordinate system determines the relative position of the inspection drone and the landing beacon and adjusts their relative positions, so that the inspection drone center coincides with the landing beacon center in the vertical direction, and then combines the ultrasonic module to determine that there is no The man-machine and the landing beacon distance, and then achieve a safe and accurate landing.

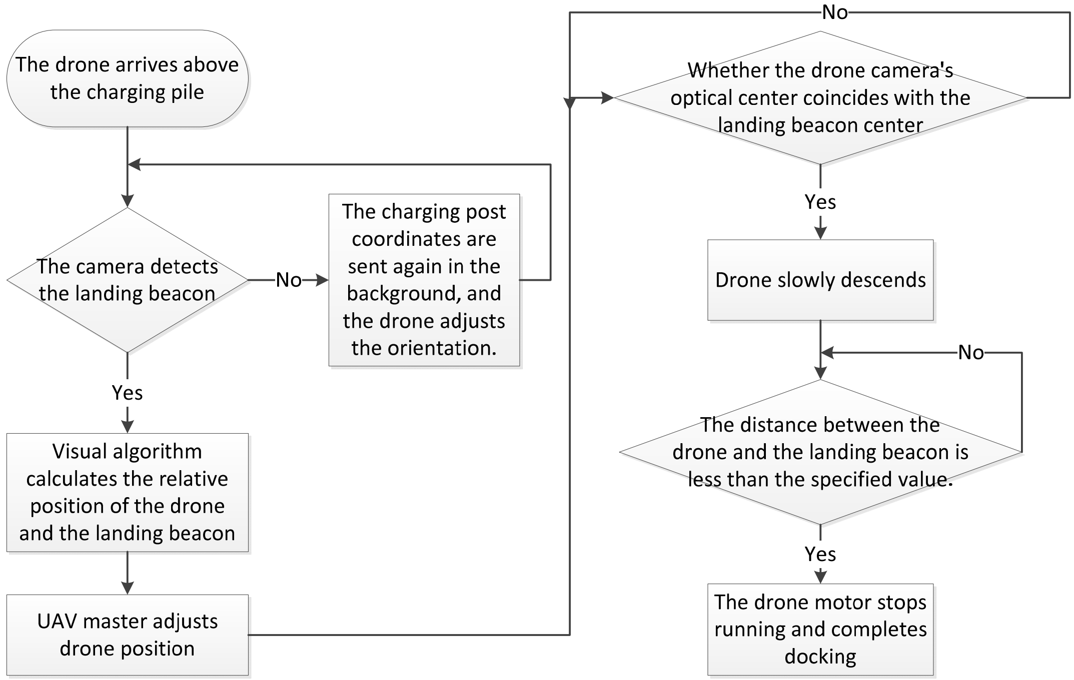

Fig. 3

The visual algorithm flow is shown in Figure 4. The visual algorithm mainly includes image graying processing and image edge detection on the image captured by the high-definition camera to detect the characteristics of the landing beacon, and estimation and solution of the relative position of the drone and the landing beacon. The result is transmitted to the flight control system, and then the flight control system adjusts the drone according to the result, so that the drone center coincides with the landing beacon center in the vertical direction.

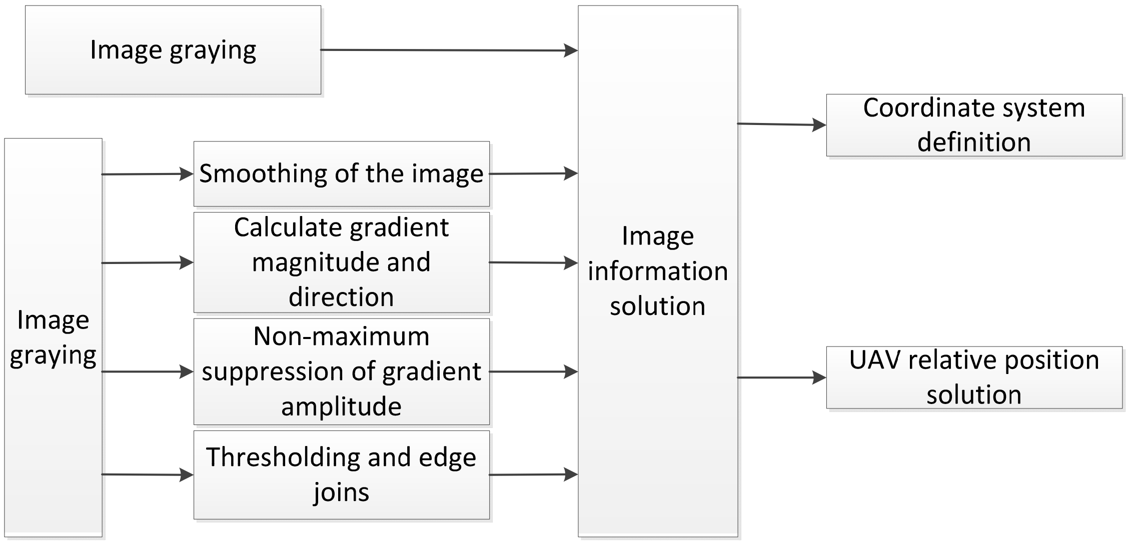

Fig. 4

Specific steps are as follows:

① Image graying processing: The images captured by the high-definition camera are generally color images, and the color images need to be grayed out when further processing the images. In this scheme, the image is grayscaled by the weighted average method. The weighted average method weights and averages the three components with different weights according to importance and other indicators. Since the human eye is most sensitive to green and the least sensitive to blue, the weighted average of the RGB three components can be used to obtain a more reasonable grayscale image, as shown in Equation 1 below.

$$f(i,j) = 0.30R(i,j) + 0.59G(i,j) + 0.11B(i,j) \tag{1}$$

② Image edge detection: This scheme uses the Canny algorithm to perform edge detection on the grayed image [3,4]. The method firstly smoothes the image, calculates the image gradient amplitude, direction and non-maximum value suppression after denoising, and finally sets the high and low thresholds to remove the false edges and connect the true edges. The specific steps of image edge detection are as follows:

i. Smooth filtering of the image. The image to be detected is smoothed and denoised by row and column using a one-dimensional Gaussian function, wherein the one-dimensional Gaussian filter function is as Equation 2.

$$G(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{x^2}{2\sigma^2}} \tag{2}$$

In the one-dimensional Gaussian function, σ is the standard deviation, and the size of σ affects the positioning accuracy and signal-to-noise ratio. The size of σ is important for edge detection. When σ is large, the noise can be smoothed well, but the edge positioning accuracy is low.

ii. Calculate the gradient magnitude and direction. The Canny algorithm obtains the gradient magnitude and direction by finding the partial derivative, and uses the finite difference of the first-order partial derivative in the 2×2 domain to smooth the first-order partial derivative of the filtered image (x, y) as Equation 3 and Equation 4.

$$P_x(x,y) = \frac{[f(x,y+1) - f(x,y)]}{2} + \frac{[f(x+1,y+1) - f(x+1,y)]}{2} \tag{3}$$

$$P_y(x,y) = \frac{[f(x,y) - f(x+1,y)]}{2} + \frac{[f(x,y+1) - f(x+1,y+1)]}{2} \tag{4}$$

Where f(x, y), f(x, y+1), f(x+1, y), f(x+1, y+1) are the gradation values of the pixels at each point of the image. The formula for the gradient magnitude is as Equation 5.

$$P(x,y) = \sqrt{P_x(x,y)^2 + P_y(x,y)^2} \tag{5}$$

The formula for the direction is as Equation 6.

$$\theta(x,y) = -\arctan\left[\frac{P_y(x,y)}{P_x(x,y)}\right] \tag{6}$$

iii. Non-maximum suppression of the gradient magnitude. In order to perform edge positioning more accurately, the Canny algorithm also requires non-maximum suppression of the gradient. After refinement, the position of the edge can be determined by a single pixel, that is, the point where the local variation of the amplitude is the largest, which is the non-maximum suppression processing. In the 3×3 neighborhood, the central pixel is compared with the two pixels adjacent to its periphery. If the central pixel is larger than the adjacent pixel, the point is the edge point, and vice versa.

iv. Thresholding and edge joins. There are still many noise points in the image after non-maximum suppression, and the Canny algorithm uses a double threshold to segment the non-maximum suppressed image. If the gradient magnitude of the point (x, y) is less than the lower bound of the threshold, then the point is not an edge point; if the gradient magnitude of the point (x, y) is greater than the lower bound of the threshold, the point is an edge point; if the gradient magnitude of the point is Between the two, it is found whether there is another point near the point that is greater than the upper threshold of the threshold, and if so, the point is the edge point, otherwise it is not the edge point.

③ After the corresponding image is processed by the high-definition camera, the system needs to solve the image information in the next step, and then use the corresponding coordinate system to find the position of the drone relative to the landing beacon and its own posture, and output it to the main Control, then the main control then controls the flight direction and speed of the drone based on this information, and adjusts the attitude of the drone according to the angle of the camera optical axis and the landing beacon center.

i. Coordinate system definition. In the process of autonomous landing of the drone, three coordinate systems are shared, which are the landing beacon coordinate system, the camera coordinate system and the carrier coordinate system. The origin of the landing beacon coordinate system is the center of the entire landing beacon, that is, the center of the small ring, the X and Y axes are in the landing beacon plane and the X axis is parallel to the upper and lower boundaries. The Y axis is parallel to the left and right boundaries, and the Z axis is perpendicular to the The landing beacon plane is vertically upward; the origin of the camera coordinate system is the optical center of the camera, the X and Y axes are in the camera plane, the X axis points to the right, the Y axis points downward, and the Z axis is perpendicular to the camera plane to point to the shooting direction. Vertically downward; the origin of the carrier coordinate system is the center of mass of the drone, the X-axis and the Y-axis are in the horizontal plane, the X-axis points to the forward direction of the drone, the Y-axis points to the right of the forward direction of the drone, and the Z-axis is vertical It is vertically down on the horizontal plane.

ii. The relative position of the drone is solved. The system identifies and verifies the landing beacon image captured by the camera, and obtains the relative position information of the landing beacon coordinate system and the camera coordinate system and the attitude information of the drone, and then performs coordinate transformation through the rotation matrix S and the translation matrix T. , as Equation 7.

$$\lambda \begin{pmatrix} u \\ v \\ 1 \end{pmatrix} = K \begin{pmatrix} X_c \\ Y_c \\ Z_c \end{pmatrix} = K[S \quad T] \begin{pmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{pmatrix} \tag{7}$$

(u, v) is the pixel coordinate of the image after the image has been transformed by the contents of Sections 2.2.3.1 and 2.2.3.2, $\begin{pmatrix} X_c \\ Y_c \\ Z_c \end{pmatrix}$ is the coordinates of the point in the camera coordinate system, $\begin{pmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{pmatrix}$ is the coordinates of the point in the landing beacon coordinate system. λ=zc is the Z-axis coordinate of the point on the camera coordinate system. K is the internal parameter of the camera and can be obtained according to the camera calibration. T is a translation matrix, which is a three-dimensional column vector, indicating the position of the origin of the landing beacon coordinate system in the camera coordinate system. The translation matrix T is obtained by the pixel coordinates (u, v) and the landing beacon coordinates $\begin{pmatrix} X_w \\ Y_w \\ Z_w \end{pmatrix}$ of the feature points of the landing beacon image, that is, the landing target position required for the autonomous landing. Then, Harris corner detection and contour detection are performed on the landing beacon image that has completed the above processing. As shown in Fig. 5, after the landing beacon passes Harris corner detection and contour detection, there are 12 corner points and a central center as feature points, because the coordinates of the feature points on the landing beacon coordinate system are known, and the passing angle is Point detection can obtain the pixel coordinates of the image plane, so the translation matrix T can be obtained by singular value decomposition and least squares method, that is, the origin of the landing beacon coordinate system is located in the three-dimensional coordinates of the camera coordinate system $\begin{pmatrix} x_c \\ y_c \\ z_c \end{pmatrix}$. At the same time, assuming that the camera coordinate system is approximately equal to the carrier coordinate system, the coordinates of the landing beacon in the carrier coordinate system $\begin{pmatrix} x_d \\ y_d \\ z_d \end{pmatrix} = \begin{pmatrix} x_c \\ y_c \\ z_c \end{pmatrix}$. Then, the positional relationship of the camera with respect to the landing beacon can be expressed as the following equation 8, where θpt is the pan/tilt angle.

$$\begin{pmatrix} x_d \\ y_d \\ z_d \end{pmatrix} = \begin{pmatrix} \cos\theta_{pt} & 0 & -\sin\theta_{pt} \\ 0 & 1 & 0 \\ \sin\theta_{pt} & 0 & \cos\theta_{pt} \end{pmatrix} \begin{pmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \\ 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} x_c \\ y_c \\ z_c \end{pmatrix} \tag{8}$$

After solving the relative position of the drone and the landing beacon, the drone master adjusts the position of the drone according to the positional deviation, so that the drone camera center of light and the landing beacon center coincide in the vertical direction.

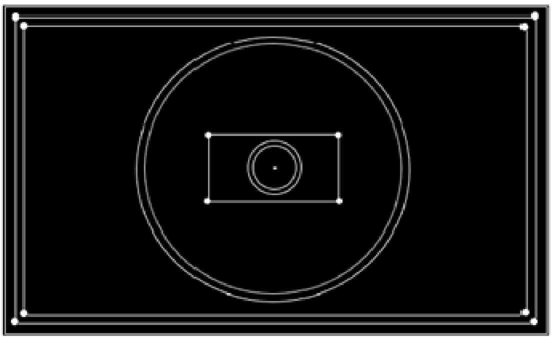

Fig. 5

4. Drone Landing

After using the visual navigation to make the drone successfully hover over the landing beacon, the drone uses the ultrasonic ranging module to measure the relative distance between the drone and the landing beacon, and sends instructions to the drone master, the main control The drone is controlled to slowly descend. When the distance between the drone and the landing beacon is less than the set threshold, the main control controls the four motors to stop rotating, and the entire landing process is completed.

5. Conclusion

In the visual landing method of the UAV based on 5G technology proposed in this paper, by using 5G network for high-definition image transmission, the landing beacon can be detected more quickly, and the delay of transmission instruction is reduced, and the visual navigation technology is adopted. The visual navigation support is provided when the drone is landing, so that the drone can land on the landing beacon accurately and safely.

Acknowledgements

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