Research on UAV Visual Recognition and Positioning Method Based on GIS

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Abstract. Regarding the positioning and tracking of the target object by the UAV, the GPS signal in the actual flight is unstable and inaccurate. From this, the GIS visual identification and positioning method is found; the binocular stereo vision technology is proposed. This optical physics theory, as well as binocular cameras and specific calculation methods for positioning; found a way to accurately locate and track UAVs through GIS; accurate enough to calculate the UAV's positioning operation process and calculations through the RSS positioning and tracking method. The wording simulation experiment proves that this visual recognition positioning method has the advantages of higher accuracy and strong adaptability.

Keywords: Uav, Autonomous Three-dimensional Positioning, Gis, Rss Positioning

1. Introduction

Unmanned Aerial Vehicle (UAV) is abbreviated as unmanned aerial vehicle. Unlike a manned aircraft, it is an autonomous aerial vehicle that can control the flight system at a long distance without pilot control [1-3]. Due to its small size, low cost, strong mobility, better concealment and other outstanding advantages, it has been increasingly used in military reconnaissance, target tracking, terrain reconnaissance and other fields in the 21st century. From a technical point of view, UAVs can be classified, but no matter what type of UAVs, the prerequisite for completing military reconnaissance, target tracking, and terrain reconnaissance is to obtain their own precise positioning [4-6]. At present, high-altitude and high-speed UAVs mostly use the combined navigation of precision inertial navigation and GPS to obtain the real-time position of the UAV. Although the accuracy of integrated navigation is already very high, it can only obtain the two-dimensional position information of the UAV.

The GIS-based autonomous positioning method for drones can not only provide more accurate three-dimensional navigation information for drones flying in different scenarios, it is also the basis of passive positioning; at the same time, in today's military warfare, concealment is increasingly emphasized. Under the current trend, research on the three-dimensional autonomous positioning of UAVs has broad application prospects in UAVs used in military warfare.

2. GIS principle

GIS technology is one of the important technologies of computer vision. Because of its artificial
intelligence, GIS technology is widely used in many fields, such as: applying GIS technology to surgical robots, by observing the movement state and posture of surgical equipment in vitro, So as to complete the precise control of surgical equipment; the application of GIS technology in the car can detect road information and feed back to the driver real-time road conditions and dangers that may occur at any time; GIS technology can also be applied to assist blind navigation, thus replacing guide dogs Helping blind people who are walking out more effectively. GIS technology uses a computer to simulate human eyes to perceive the world. Two pictures are collected from different angles at the same time through a fixed binocular camera, and the matching point of the target on the picture and the parallax of each point are obtained through the stereo matching technology, that is, the difference between the projection points of the target in the scene and the binocular camera, The depth information of the target in the 3D scene can be recovered from the obtained disparity value.

In the binocular stereo vision system, two fixed cameras are used as the image signal acquisition equipment, and the image capture card transmits the image and video signals to the computer or signal processing equipment after processing.

3. GIS-based visual recognition positioning

3.1. Realization of Binocular Ranging for UAV
The visual recognition positioning method is to install a binocular camera on the fuselage of the drone. By collecting and processing images, the depth information between the point to be measured on the drone and the fixed point with known coordinates is obtained, and then calculated by the positioning algorithm. The three-dimensional coordinate value of the drone.

The binocular camera is fixed on the bottom of the UAV (this origin is the reference origin and has no effect on the positioning accuracy). Place 3 fixed-point markers on the ground that are not on the same straight line. They have different shapes (or 3 houses, buildings, etc., with known coordinates). The selection standard is that they can be anywhere within the range of the drone. Captured by binocular cameras. The coordinates of the known fixed point are \( P_1(x_1, y_1, z_1) \), \( P_2(x_2, y_2, z_2) \), \( P_3(x_3, y_3, z_3) \).

Before the three-dimensional autonomous positioning of the UAV, the two cameras are first self-calibrated to obtain the camera’s internal parameters (focal length \( f \), imaging origin, distortion coefficient) and the relative position of the binocular lens (rotation matrix and translation constant).

As shown in Figure 1, when the drone is flying in the air, the drone observed on the ground is a point small enough to ignore the size, so the binocular camera can be abstracted as being in the optical center line. The mass point M of the point. In the figure, \( P_1 \), \( P_2 \), \( P_3 \) are the points with known coordinates among the three markers, and \( h_1 \), \( h_2 \), and \( h_3 \) are the distances from points \( P_1 \), \( P_2 \), and \( P_3 \) to the node M to be located.

![Figure 1. Schematic diagram of 3D positioning geometry.](image-url)
3.2. RSS positioning algorithm distance estimation

RSS (Received Signal Strength) positioning is based on distance. The accuracy of distance estimation indirectly reflects the accuracy of positioning. Assuming that the coordinates of the node M to be located are \((x, y, z)\), the distances from the M point to the three known fixed points measured by GIS are \(h_1, h_2, \text{ and } h_3\) respectively, then:

\[
AX = B \tag{1}
\]

\[
e = B - AX \tag{2}
\]

The square of the residual:

\[
f(X) = e^2 = (B - AX)^2 = (B - AX)\sum_{i=1}^{N} X_i^2 \tag{3}
\]

The solution of \(X\) can be obtained:

\[
X = (A^T A)^{-1} A^T B \tag{4}
\]

The height of the drone can be calculated

\[
z = \sqrt{h_i^2 + x_i^2 + y_i^2 + z_i^2 - x^2 - y^2} \tag{5}
\]

So far, the position coordinates \((x, y, z)\) of the drone are calculated.

4. System simulation and result analysis

4.1. System simulation

To test the effectiveness and superiority of the proposed method, MATLAB simulation will be used to evaluate the performance of the three-dimensional self-location algorithm. Set the UAV to move in the air at a constant speed of 54.43° with the positive semi-axis of \(x\) and 29.74° with the positive semi-axis of \(z\) at a speed of 0.95 m/s. The point \((0.1, 0.2, 0.3)\) is a point in the UAV flying at a constant speed, and it is assumed that the point is the starting position of the UAV at 0s.

Randomly select 3 fixed-point coordinates as \(P_1(0, 0, 0), P_2(0.1, 0.7, 0), P_3(0.3, 0.2, 0)\). The binocular camera has gone through the steps of image acquisition, camera calibration, image preprocessing, and binocular stereo matching to get the drone 0.1s, 0.2s, 0.3s, 0.4s, 0.5s, 0.6s, 0.7s, 0.8s, 0.9s, the distance to a known fixed point at 1.0s. Let the distance between the UAV in the 0.1*i second and the point \(P_i\) be \(h_{ij}\), where \(i=1\sim10, j=1,2,3\), and the data obtained is shown in Table 1.

System simulation of the visual recognition positioning method, input the data in Table 1, and use the RSS positioning calculation method described above to calculate the three-dimensional position coordinates of the UAV at each moment. Connect the three-dimensional position coordinate points of each moment into a smooth curve, and thus obtain the trajectory of the UAV at a constant speed from 0 to 10s. The three-dimensional motion trajectory of the UAV is shown in Figure 2.
Table 1. The distance between the drone and the known fixed point.

| j   | 1   | 2   | 3   |
|-----|-----|-----|-----|
| 1   | 0.4593 | 0.5505 | 0.3782 |
| 2   | 0.5477 | 0.5329 | 0.4171 |
| 3   | 0.6380 | 0.5320 | 0.4722 |
| 4   | 0.7294 | 0.5477 | 0.5320 |
| 5   | 0.8216 | 0.5788 | 0.6124 |
| 6   | 0.9143 | 0.6229 | 0.6914 |
| 7   | 1.0075 | 0.6775 | 0.7740 |
| 8   | 1.1009 | 0.7403 | 0.8591 |
| 9   | 1.1946 | 0.8093 | 0.9460 |
| 10  | 1.2884 | 0.8832 | 1.0344 |

Figure 2. The trajectory of the drone in three-dimensional space.

4.2. Result analysis

Let $M_i$ be the actual position coordinates of the UAV in the $0.1*i$ second. The position of the UAV at each time is known as shown in Table 2.

Table 2. The actual location of the drone.

| t/s | M | x   | y   | z   |
|-----|---|-----|-----|-----|
| 0.1 | M1 | 0.15 | 0.27 | 0.34 |
| 0.2 | M2 | 0.20 | 0.34 | 0.38 |
| 0.3 | M3 | 0.25 | 0.41 | 0.42 |
| 0.4 | M4 | 0.30 | 0.48 | 0.46 |
| 0.5 | M5 | 0.35 | 0.55 | 0.50 |
| 0.6 | M6 | 0.40 | 0.62 | 0.54 |
| 0.7 | M7 | 0.45 | 0.69 | 0.58 |
| 0.8 | M8 | 0.50 | 0.72 | 0.62 |
| 0.9 | M9 | 0.55 | 0.83 | 0.66 |
| 1.0 | M10 | 0.60 | 0.90 | 0.70 |

Comparing the coordinates in Table 2 with the coordinates of the drone in Figure 3 at the
corresponding time, the results show that: the visual recognition positioning method proposed in this paper is almost indistinguishable from the actual three-dimensional position.

5. Conclusion
The GIS-based visual recognition positioning method improves the shortcomings of traditional GPS positioning such as the lack of dimensionality and scene limitations, so that the working scene of drones is no longer limited to outdoor unobstructed environments, and can be applied to indoor, forest and urban areas or a complex environment without GPS signal. Compared with traditional positioning solutions, the binocular camera has the characteristics of low cost, light load, small size, and immunity to electromagnetic interference. It is more suitable for micro-small UAVs for high-precision survey and reconnaissance purposes. The GIS-based visual recognition and positioning method is verified by Mat-lab simulation. The results show that the autonomous positioning method realizes the real-time and accurate positioning of the UAV, which has a high matching degree with the actual position of the UAV and the positioning effect is ideal.

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