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A FAST TARGET LOCATION COMPUTING METHOD WITH A SINGLE UAV

Engineering

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ABSTRACT

In order to solve the problem of the fastness and accuracy of UAV target location, a fast target location computing method with a single UAV in the wilderness is provided. This research represents a mathematical method for calculating the coordinates of the target without knowing the angles of view and the heading of the UAV. Target lock is carried out to keep the angle of view, so that the target has the same point in the image. The UAV flies along multi-point specific trajectory where the multi-point position information is acquired by sensors. Then multi-point iterative calculation is performed. Finally the exact position of the wilderness target is obtained. The location computing method of UAV searching in this paper has the advantages of low cost, fast, accurate and simple to calculate.

KEYWORDS

UAV; Target Location; Image Recognition; Positioning Iterative Calculation.

1. Introduction:

Unmanned Aerial Vehicle (UAV) is an unmanned aircraft, and has been widely applied to the occasions or dangerous occasions that people cannot interfere with, such as: traffic monitoring, disaster relief and so on. In recent years, the progress of science and technology and the need of actual warfare have promoted the rapid development of UAV target positioning technology. Some of the tasks of tracking, reconnaissance or transmission of UAVs can be simplified into image detection and target location [1]. At present, the rapidity and accuracy of target positioning are the key problems in the field of UAV search. And the complex terrain conditions have higher requirements for UAV real-time and continuous positioning of moving targets [2].

Over the years, a large number of researches about target positioning or tracking for UAV have been conducted. In [3], a fast target location method for single UAV multi-point observation is proposed. The multiple observation points obtained along the desired trajectory are integrated with the height of the target estimated by the steepest descent method and the Armijo search algorithm to calculate the final position of the target. The proposed system in [4] can detect a moving object with different colors and shapes in front of the camera of the UAV using a simple color-matching algorithm. A customized motion detection algorithm is applied to follow the crowd from the moving camera mounted on the UAV in [5]. In [6], the artificial landmark is set to provide relative localization information as the assistance for UAV. The impact of reflected sunlight is estimated and reduced in [7] when detecting water objects. In order to find the best UAV path, target localization uncertainty covariance is also estimated along feasible UAV paths considering target detectability. In [8], robot-audition-based sound source localization is studied using a microphone array embedded on a UAV to locate people who need assistance in a disaster-stricken area. In [9], the background segmentation and small target detection algorithm is applied in the obstacle detection, and the obstacle localization is achieved by the triangulation method. In [10], the distance between the UAV and the target is calculated using UAV coordinates and the tilt angle of the camera while posing to the target. Then, with knowing the heading of the UAV, it obtains the coordinates of the target. In [11], the mobile ground target in the wild is separated from the background using a Laplacian operator-based method, then located by performing coordinate transformations with the assumption that the altitude of the ground is known. Multiple and cooperative unmanned aerial vehicles are used to locate ground mobile targets in [12][13][14], but the cost is high.

With the promotion of UAV applications, the target position with UAV in the wilderness has gradually become a focus. Especially, the fastness and accuracy of target location are the important issues of target search and positioning. At present, target localization for single UAV is used commonly [15], but the existing of errors in the attitude sensor and GPS positioning system make the single positioning accuracy is not high. Multi-UAV is also used on some occasions, but there is a high cost, waste of resources and other shortcomings. In visual positioning process for multi-machine search, image data is two-dimensional [16]. It's hard to effectively establish a precise angle of view and realize accurate position of the target.

In this paper, a fast positioning method with a single UAV system for search in the wilderness is provided. When flying along the specific vertical, translational, direct trajectory, multi-point angle switching and coordinate positioning are achieved. In the case of the same view of the target lock, iterative positioning calculation is conducted by the data fusion from strapdown inertial navigation information, GPS information, height and view angle information. Consequently, target location in the wilderness is computed quickly and accurately.

2. UAV Target Lock Principle:

Target lock of UAV is to make the corresponding points of the target in the UAV images are the same, that is, the same angle of view. So the target lock can be considered as image recognition [17]. Image recognition technology refers to processing, analysis and understanding of the images by a computer based on the main features of the images. The target is described by a small amount of feature information, and identified by detecting these image characteristics. The process of image recognition can be divided into four steps: image information acquisition, image preprocessing, image feature extraction, and image matching.

In this paper, we first obtain the image information by the high-definition camera. Secondly, the image preprocessing is carried out. The purpose of the preprocessing is to improve the image clarity, highlight the key information, and make the contours in the image clearer and the details more prominent. Thirdly, through the transformation of the original data, the appropriate characteristics of the parameters are extracted to identify different types of objects [18]. Commonly image features are: edge and contour features, color features, wavelet features, texture features. Finally, the image matching is carried out. After the target feature template is obtained, the target localization process is to match the target feature vector with the candidate feature vector in the target candidate region. The optimal matching region is selected by optimizing the matching criterion, and the corresponding target area is considered to be the position of the target in the current frame [19].

3. UAV Target Positioning Process:

To handle UAV searching target location, a mathematical method for target location with a single UAV searching in the wilderness is presented. The unmanned aerial vehicle is composed of flight structure, strapdown inertial navigation system(SINS), HD camera, height sensors, GPS, central controller and wireless communication system. The target information is transmitted to the receiving base station by wireless transmission. In the case of completing target lock at the same angle, the receiving base station receives the strapdown inertial navigation information, the height information, the GPS positioning information and the viewing angle of UAV, and control UAV to complete multi-point specific trajectory and positioning. According to multi-point iterative calculation, the final fast and accurate access to target location information can be achieved. As shown in Fig. 1, thinking of the UAV as a point and taking the ground as the reference coordinate frame, the specific target positioning process is described as follows:

(1) In the three-dimensional coordinate system, point T is the target, and point A is starting point of UAV;
(2) GPS positioning information is calibrated by strapdown inertial navigation information to get the GPS positioning information of each point in the UAV specific trajectory.
(3) In the case of target lock, we record the target lock point of view. The corresponding angle of view is $\angle A'AT$ after target lock, where point A' is the location point after target lock for the UAV. The angles of view are corrected through the attitude angle information to ensure that the reference angle of the locked view is the ground three-dimensional coordinate system, and there's no attitude angle deviation. The GPS coordinates and height of A are $A=(x_a, y_a, h_a)$, where x_a, y_a, h_a is the three-dimensional coordinate value of point A;
(4) The sailing angle β is maintained after deflecting a certain angle. Then UAV keeps the same height level of point A moving the distance of l to point B_1. The coordinates and height of B_1 are recorded as $B_1=(x_b, y_b, h_a)$.
(5) UAV drops h_1 vertically from point B_1 to point B. And ensure that the corresponding points of the target in the UAV image are same, that is, the same angle $\angle A'AT=\angle B'BT$. The coordinate of point B is recorded as $B=(x_b, y_b, h_a\text{-}h_1)$;
(6) The navigation angle β is maintained. The UAV moves 1 to point C_1 maintaining the height of B and then drop h_2 vertically to point C, so that the corresponding points of the target in the UAV image are same, that is, the same angle ($\angle A'AT=\angle B'BT=\angle C'CT$). The coordinates of point C is recorded as $C=(x_c, y_c, h_a\text{-}h_1\text{-}h_2)$;
(7) According to the definite points A, B, C, A_1, B_1 and C_1 in the coordinate frame, the GPS positioning coordinates of the target T can be accurately obtained by the triangular projection and triangular similarity. There is no need to acquire the target locking angle $\angle A'AT$, $\angle B'BT$, $\angle C'CT$ and the exact deflection sailing angle β.

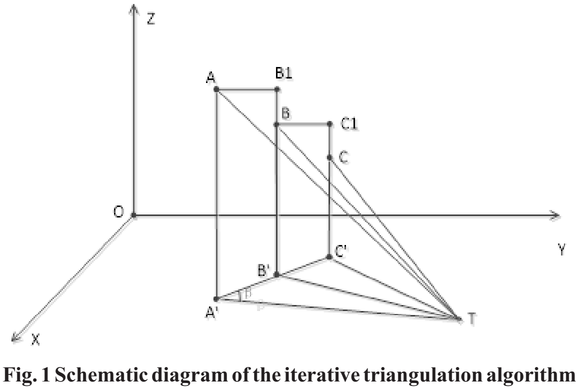

Fig. 1 Schematic diagram of the iterative triangulation algorithm

3. Target Positioning Coordinate Algorithm:

As shown in Fig. 1, according to the triangular projection, we can get:

$$|A'B'| = |AB_1| = 1 \tag{1}$$

$$|B'C'| = |BC_1| = 1 \tag{2}$$

According to $\angle A'AT=\angle B'BT=\angle C'CT$, the right triangle $\varDelta A'AT$ is similar to $\varDelta B'BT$, and the right triangle $\varDelta C'CT$ is similar to $\varDelta B'BT$.

According to the triangular similarity principle, (3) and (4) can be obtained.

$$\frac{|A'T|}{|B'T|} = \frac{|A'A|}{|B'B|} = \frac{h_a}{h_a-h_1} \tag{3}$$

$$\frac{|A'T|}{|C'T|} = \frac{|A'A|}{|C'C|} = \frac{h_a}{h_a-h_1-h_2} \tag{4}$$

In $A'C'T$ and $A'B'T$, we can get (5) according to the cosine theorem.

$$\cos(\beta) = \frac{|A'C'|^2+|A'T|^2-|C'T|^2}{2|A'C'||A'T|} = \frac{|A'B'|^2+|A'T|^2-|B'T|^2}{2|A'B'||A'T|} \tag{5}$$

$$\cos(\alpha) = \frac{|B'C'|^2+|B'T|^2-|C'T|^2}{2|B'C'||B'T|} \tag{6}$$

Owing that l, h_a, h_1 and h_2 are known, we can get $|A'T|$, $|B'T|$, $|C'T|$ and angles b, aby substituting (1), (2), (3) and (4) into (5) and (6).

In the $\triangle A'B'T$ in the plane xoy, let the slope of the line $A'C'$ in the plane xoy be k_a.

$$k_a = \frac{y_c - y_a}{x_c - x_a}$$

And let the slope of the line TA' be k_1, then:

$$k_1 = \frac{k_a - \tan\beta}{1 + k_a \cdot \tan\beta}$$

In $\triangle B'C'T$, the slope of the line $B'C'$ in the plane xoy is also k_a. Let the slope of the line TB' be k_2.

$$k_2 = \frac{k_a - \tan\alpha}{1 + k_a \cdot \tan\alpha}$$

So the equation for the straight line TA' is obtained.

$$y = k_1(x - x_a) + y_a \tag{7}$$

And the line TB' is:

$$y = k_2(x - x_b) + y_b \tag{8}$$

The intersection of the straight line TA' and the straight line TB' is the coordinate of target $T(x_t, y_t)$. By integrating (7) and (8), we can get:

$$x_t = \frac{y_b - y_a + k_1 \cdot x_a - k_2 \cdot x_b}{k_1 - k_2}$$

$$y_t = \frac{k_1 \cdot y_b - k_2 \cdot y_a + k_1 \cdot k_2 \cdot x_a - k_1 \cdot k_2 \cdot x_b}{k_1 - k_2}$$

At this point, the exact coordinate of the target T is determined.

5. Conclusion:

In this paper, a mathematical method is presented for calculating the coordinates of the target when using a single UAV for target localization in the wilderness. The calculation is under the premise of target lock. The UAV flies along multi-point specific trajectory and keep the same angle of view. Then iterative positioning calculation is conducted by the data fusion from strapdown inertial navigation information, GPS information, height and view angle information. There is no need to know the angles of view and the heading of the UAV in the computation. The calculation process of the target coordinates described here is fast, accurate and simple.

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