Application of UAV Photogrammetry in Digital City Geographic Information Navigation and Positioning

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Abstract: In order to solve the problem of asynchronous measurement data in UAV passive target location and tracking, the time correction algorithm of multi UAV airborne sensors is studied. This paper describes the basic principle and application scope of time correction, analyzes the time factors affecting the positioning accuracy of multi UAV passive target positioning and tracking system, and proposes a time drift correction algorithm based on interpolation idea, which realizes the time registration of multi UAV observation data and reduces the positioning error caused by time synchronization.

Keywords: UAV; Photogrammetry; Digital city; Geographic information; Navigation and positioning

1. Introduction

There is a positive correlation between UAV's self positioning and target positioning. How to use the platform to track accurately after the self positioning reaches a certain precision is also a key problem. In the UAV target positioning system, distance information is one of the commonly used parameters in target positioning. The ranging and positioning method based on laser rangefinder is a widely used positioning method in recent years. It is the simplest positioning method, and the accuracy can meet the requirements. However, the active positioning method is easy to be attacked by the enemy when performing military tasks due to its strong electromagnetic radiation to the outside world Scholars at home and abroad attach great importance to it. In recent years, there have been successful cases of four rotor UAV vision sensor navigation and positioning at home and abroad, but the application of positioning target on UAV is still rare [1]. As a supplement of active positioning technology, the application demand of passive positioning technology is growing, which provides a new solution for UAV target positioning. Because the positioning accuracy of UAV satellite integrated navigation system is limited by the accuracy of inertial device, and the satellite navigation information is affected by human or natural interference, the reliability is not high. Therefore, the UAV satellite integrated navigation system simply uses the UAV satellite navigation system to locate the UAV, which is limited by the precision of the inertial device UAV airborne navigation system can not work normally and can not meet the needs of high-precision target positioning [2]. Therefore, it is urgent to solve the positioning accuracy problem of UAV integrated navigation system. In this case, the on-line calibration technology of high-precision inertial navigation system is an important technical means to solve this problem. When the accuracy of the inertial navigation system reaches a certain level, the inertial navigation system error can be effectively excited by dynamic trajectory excitation, and the error can be calibrated and compensated online. It has important theoretical significance.

2. UAV Photogrammetry Navigation and Positioning

2.1. High precision target determination algorithm for UAV

There is a positive correlation between UAV high-precision positioning and target positioning. How to use it for accurate tracking is an important problem to be solved after the self positioning reaches a certain accuracy. In the UAV target positioning system, distance information is one of the commonly used parameters in target location. In recent years, the positioning method based on laser ranging has been widely used [3]. Its positioning is the most simple and the accuracy can meet the requirements. However, due to its strong electromagnetic radiation to the outside world, it is easy to be attacked by the enemy when carrying out military tasks. Scholars at home and abroad attach great importance to this. In recent years, there have been successful cases of vision sensor navigation and positioning for quadrotor UAV at home and abroad, but its application in UAV target positioning is still rare [4]. As a supplement of active positioning technology, passive positioning technology has an increasing demand in military and civil fields, which provides a new solution for UAV target positioning. The positioning accuracy of UAV satellite integrated navigation system is limited by the accuracy of inertial devices. The influence of man-made or natural interference on satellite navigation information makes its reliability low and cannot meet the requirements of high-precision target positioning. It is urgent to improve the positioning accuracy of UAV satellite navigation system, which also brings difficulties to the normal operation of UAV airborne navigation system [5]. The on-line calibration technology of high-precision inertial navigation system is an important technical means to solve this problem. When the system calibration accuracy reaches a certain level, the dynamic trajectory excitation can effectively stimulate the system error and compensate the calibration error online. It has important theoretical significance.

$$\begin{cases} x=x_1/x_4 \\ y=x_2/x_4 \\ z=x_3/x_4 \end{cases} \quad (1)$$

The homogeneous coordinates of points in this paper are all defined in the form of (x, y, z). Three rotations involve three orthogonal rotation matrices, which are as follows:

$$\mathbf{R}(x)=\begin{bmatrix} \cos j & -\sin j & 0 \\ \sin j & \cos j & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (2)$$

$$\mathbf{R}(y)=\begin{bmatrix} \cos q & 0 & \sin q \\ 0 & 1 & 0 \\ -\sin q & 0 & \cos q \end{bmatrix} \quad (3)$$

$$\mathbf{R}(z)=\begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos f & \sin f \\ 0 & -\sin f & \cos f \end{bmatrix} \quad (4)$$

Suppose that the position coordinates of the known point P in the Cartesian coordinate system o-xyz are (x, y, z) and the position coordinates of T in o-xyz are (x, y, z), then the corresponding relation UAV between the two can be expressed as:

$$R\begin{bmatrix} x_1 \\ y_1 \\ z_1 \\ o \end{bmatrix} = \begin{bmatrix} l_1 & l_2 & l_3 & r_1 \\ m_1 & m_2 & m_3 & r_2 \\ n_1 & n_2 & n_3 & r_3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (5)$$

Where R is the position of o point in o-xyz coordinate system $l_1, m_1, n_1 \ldots l_3, m_3, n_3$ is the cosine of the direction of the three axes of the o '- XYZ system relative to the three axes of the o-xyz system. From the above analysis, we can see that a linear nonsingular matrix can be used to represent the transformation relation of homogeneous coordinates of the same point in different coordinate systems, and the transformation matrix is T.

$$T=\begin{bmatrix} l_1 & l_2 & l_3 & r_1 \\ m_1 & m_2 & m_3 & r_2 \\ n_1 & n_2 & n_3 & r_3 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad (6)$$

Furthermore, the homogeneous transformation matrix is divided into three parts:

$$E=\begin{bmatrix} L & R \\ 0 & 1 \end{bmatrix} \quad (7)$$

The above formula can express the translation (e.g. matrix R) and rotation (e.g. matrix L) and their combination forms [6]. For the convenience of the follow-up analysis, it is expressed as a combination of these two relations:

$$T=T_r T_a \quad (8)$$

Where tr represents translation and Ta represents rotation, and their matrix forms can be expressed as follows:

$$T_r=\begin{bmatrix} E & R \\ 0 & 1 \end{bmatrix} \quad (9)$$

$$T_a=\begin{bmatrix} L & 0 \\ 0 & 1 \end{bmatrix} \quad (10)$$

Among them, t is the unit matrix of 3X3, and the coordinate transformation such as scaling, translation and rotation can be realized by using homogeneous coordinate transformation method. Using the above calculation process, the longitude and latitude height of the target can be obtained, and the target positioning process can be completed [7]. However, considering that the data selected in the process of target location calculation has certain measurement error, it is necessary to analyze the error source in the process to further improve the target positioning accuracy. Generally speaking, the rotation relationUAV between rectangular coordinate systems can be expressed by orthogonal matrix [8]. Because the transposition matrix of orthogonal matrix is its inverse matrix, it will be more convenient to use homogeneous coordinate transformation method for coordinate transformation.

2.2. Removal of positioning error in geographic information navigation

Due to the influence of environmental factors and its own hardware conditions, in the process of data acquisition, the sensor will produce noise interference signal, which will degrade the signal quality of the system. In order to solve the problem of multi-source data storage, analysis and processing, it is necessary to introduce the geographic positioning database, and use the embedded database SQLite, which is based on the mathematical structure of the distorted signal in the positioning geography [9]. The navigation parameter information such as attitude, position and speed needs to have reference standards. More-over, the information output by the inertial device is relative to the inertial coordinate system, while other transmission Sensor measurement results refer to different reference systems, so it is necessary to define the commonly used navigation coordinate systems and derive the transformation relation UAV between coordinate systems [10]. In this paper, we use the coordinate system of Nen (local coordinate system) as the coordinate transformation of UAV. The specific algorithm is as follows:

$$A_i(y)=\frac{E(x-a^m)}{2T-0.6W^n} \tag{11}$$

$$B_j(\mathrm{x})=\frac{\mathrm{y}-1}{1[T_r-T_a]+0.2W^n} \tag{12}$$

In the above algorithm, W is the spectrum of feature change of geographical location signal, a is the value of input information, and M is the path of feature signal tracking. Furthermore, the prediction distortion selective memory polynomial is designed:

$$g(n)=\sum_{x=1}^{i}\sum_{\substack{a=1\\ odd}}^{j}\lim_{x\to\infty}a_{ij}x\frac{A_i(y)-B_j(x)}{2(w+n)-1} \tag{13}$$

Furthermore, the least square method is used to obtain the solution matrix:

$$W_f(a,b)=\frac{1}{g(n)}\int_{-\infty}^{\infty}f(t)\left(\frac{\mathrm{a}-A_i(y)}{B_j(\mathrm{x})}\right) \tag{14}$$

Among them:

$$f(t)=\frac{1}{k_0}\iint_{-\infty}^{\infty}\mathrm{d}\left(\frac{t-b}{a}\right) \tag{15}$$

In the above algorithm, K is the scale factor of wavelet transform and D is the transform factor. Furthermore, the mathematical model of positioning data link is established, which provides a theoretical basis for the optimal design of control link [11]. The input signal of data link is x (T) and equivalent transformation y (T). Indirect learning method is used to obtain the approximate value of positioning parameters through self recognition calculation, and wavelet analysis method is used to denoise polynomial information.

$$Y(t)=\frac{1}{p}p\int\frac{X(t')}{W_f(a,b)-f(t)}\mathrm{d}t \tag{16}$$

P in the above algorithm is taken as the core control parameter of UAV navigation geographic positioning system. Based on the above algorithm, the interference value in the process of UAV navigation and positioning is effectively eliminated, which can better ensure the smooth transmission of UAV navigation information. Based on the above algorithm, the UAV navigation and positioning technology is optimized and improved, and a large number of multi-source sensors are used to collect positioning information of various formats [12]. The data link transmission control mode and cognitive radio geography are used to improve the geographic positioning function to ensure the smooth positioning of the base station and the control center. In the process of UAV communication processing, due to the influence of uncertain factors, it is easy to produce interference wave frequency, and it is difficult to obtain echo image effectively. In order to ensure the effective operation of UAV positioning, it is necessary to extract the original filtering of UAV navigation and positioning signal to obtain accurate UAV positioning data. The analytic function of geographical transmission control signal is transformed

$$Z(t)=X(t)+iY(t)=a(t)e^{|\,a(a)} \tag{17}$$

Among them:

$$a=\sqrt{X^2(t)+Y(t)}^2 \tag{18}$$

Furthermore, the phase function is obtained by denoising the phase information of the control signal of geographical positioning data

$$g_i(\mathrm{t})=\frac{a}{Z(t)}+Y(t) \tag{19}$$

The distribution density function of noise elimination satisfied by this phase is

$$g(\mathrm{m})=\frac{2a}{g_i(\mathrm{t})+1}*P\left(\frac{g(n)}{A_i(y)+B_j(\mathrm{x})}\right) \tag{20}$$

Unmanned helicopter flight can be divided into the following six degrees of freedom motion, including yaw, roll, pitch, forward and backward motion, left and right motion and up and down motion. The premise of UAV autonomous flight is to perceive the navigation parameter information (position, speed and attitude) of UAV in three-dimensional space, so how to define and calculate the navigation parameter information, as well as the corresponding reference coordinate system definition and reference origin selection, is particularly important [13]. In this paper, the coordinate system, attitude description method and GPS longitude, latitude and altitude data conversion involved in unmanned helicopter navigation and positioning are described in theory. Based on this, the positioning information collection model of UAV remote positioning data positioning node is optimized, and the specific structure is shown in the Figure 1.

Based on the above information acquisition model, the operation format of the collected geographic positioning information is further optimized, and the original echo information of UAV navigation geographic positioning is extracted by edge filtering and format conversion processing, so as to obtain accurate UAV positioning data. Effectively guarantee the reasonable optimization requirements of geographical positioning technology.

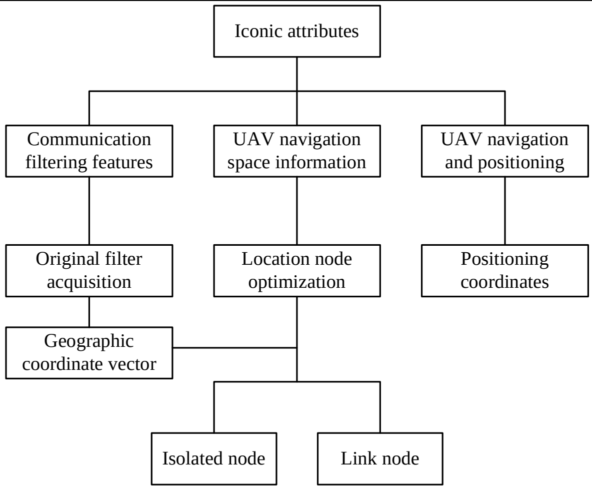

Figure 1. Positioning information acquisition model of UAV navigation system

2.3. Implementation of urban geographic information navigation and positioning

In the multi-point ranging target positioning method, it is similar to the single station angle measurement target positioning method. By improving the positioning accuracy of UAV and the ranging accuracy of UAV relative to the target, the target positioning accuracy can be improved [14]. In addition, since the multi-point ranging target location method requires UAV's track points which are not on a straight line for ranging, and the aircraft maneuvering has a certain impact on the attitude navigation accuracy of UAV integrated navigation system, therefore, UAV mission path design is also an important research content in multi-point ranging target positioning. Taking the inertial / GPS Kalman filter integrated navigation system as an example, this paper analyzes and designs the maneuvering path from the angle of improving the attitude navigation accuracy of UAV. The key to improve the navigation accuracy of UAV inertial integrated navigation system is to improve the accuracy of inertial devices [15]. The installation error, scale factor error and random constant error are the main error sources of inertial sensor due to its component characteristics, structure installation and other engineering related links. In the practical use of strap down inertial unit system, the above inertial sensor error parameters are usually obtained by off-line calibration. However, during the flight of UAV, the high-frequency vibration of the engine and the external airflow interference will lead to the change of the inertial sensor installation error and calibration factor error parameters; In addition, the random constant error parameters will also have a large difference compared with the original calibration value over time. Considering the tedious workload and huge cost of offline calibration, online calibration and compensation of INS error becomes the first choice to improve the navigation accuracy. It is assumed that the parameter error △ x obeys normal distribution, the mean value is 0 and the mean square error is 0 $s_{\Delta X}$. The error data used in the simulation process of single station target positioning are shown in the Table 1.

Table 1. Navigation and positioning error data

Type	Mathematical symbols	Truth value	Error value
Longitude of UAV measurement point	a	110	$2*10^{6}$
UAV measurement point latitude	S	20	$5*10^{-6}$
UAV measurement point height Pitch angle of UAV Roll angle of UAV Yaw angle of UAV	X	15	10mm
Vibration angle of shock absorber (pitch)	N	30	0.4
Damper vibration angle (roll)	I	60	0.2
Damper vibration angle (yaw)	K	45	0.3
Relative azimuth angle between UAV and target	L	10	0.6
Relative pitch angle between UAV and target relative	U	5	0.2
distance between UAV and target	p	15	0.5

Based on the information in the table above, different UAV target positioning methods are selected according to the reliability of UAV position measurement information relative to the target. If the relative distance and attitude information can be obtained, single station angle measurement target positioning method and two-point intersection target positioning method can be used. If only the distance information of UAV relative target is obtained, or the relative attitude information is not Under the reliable condition, the three-point ranging target positioning method can be used. The smaller the distance between the positioning trajectories is, the more similar the positioning trajectories are. By calculating the number of mutual conversion steps between permutations, the distance between positioning trajectories is obtained. Since the selected trajectories can only focus on the relation UAV between geographical blocks, it is necessary to calculate the sorting distance between positioning trajectories. Set the location trajectory as follows:

$$\begin{aligned} w_1[j]&=(2,2,5,5,2,2) \\ w_2[j]&=(2,2,0,0,2,2) \end{aligned} \quad (21)$$

The vector elements are sorted as follows:

$$\begin{aligned} w_1[j]&=(sus_3,\ sus_4,\ sus_1,\ sus_2,\ sus_5,\ sus_6) \\ w_2[j]&=(sus_1,\ sus_2,\ sus_5,\ sus_6,\ sus_3,\ sus_4) \end{aligned} \quad (22)$$

Direct use of the number parameter calculation, greatly affected by the geographical block cycle, can find the relative relation UAV of positioning times in time, which can fully reflect the similarity between positioning tracks. The test cases related to a certain geographical block in the test cases are formed into a set, and the probability of passing the test and failing the test in the set is analyzed. If the proportion of failed test cases in the set is large, it indicates that the geographical block has a high probability of suspicion; otherwise, the probability of doubt is low. According to the coordinates, the geographical blocks are sorted from near to far, and are numbered in turn. The undetermined effect of the system is scored according to the actual defect geographical block number. The higher the score, the higher the positioning accuracy. If the score of the report is more than 90, the programmer can quickly find the defect location in the software only by reviewing 10% of the geographical blocks.

$$s=\frac{s_{\Delta X}(p-q)}{w_1[j]+w_2[j]} \quad (23)$$

Where: P is the total number of geographical blocks; q is the total number of defective geographical blocks. According to the above results, the geographical blocks are arranged in order of size. Considering that the attitude accuracy has a great impact on the target positioning accuracy in the UAV angle measurement and ranging positioning mode, there is no mature direct attitude measurement system in the existing navigation system. In order to improve the target positioning accuracy of UAV when the attitude determination is seriously inaccurate, the working principle of a UAV three-point ranging target positioning method is analyzed. The three-point ranging target positioning process of UAV airborne photoelectric platform is the process of solving the coordinate value of the target geodetic coordinate system only knowing the distance r of the target relative to the photoelectric platform base coordinate system. The schematic diagram of UAV three-point ranging target positioning is shown in the Figure 2.

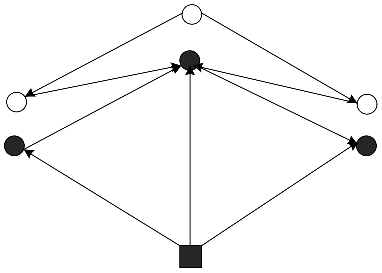

Figure 2. UAV Three point ranging target positioning diagram

Based on the above three-point ranging target positioning structure of UAV, further iterative processing is carried out. With the increase of iteration times, better estimation accuracy can be obtained, but more implementation time is required. Generally, with the increase of the dimension of state vector and measurement vector, more and more iterations are needed, because the higher the dimension of state and measurement vector, the more inaccurate the information involved in the estimation prediction error covariance matrix and measurement noise covariance matrix. Therefore, in practical applications, it is generally recommended to select a large enough value for the iteration times to ensure that the fixed-point iteration converges to the local optimum, based on which the accurate navigation and positioning of urban geographic information can be realized.

3. Analysis of Experimental Results

In order to verify the method in this paper, a single-chip microcomputer with ATmega2560 core control multi-sensor data fusion is selected, and the collected data are read from GPS 1 and GPS 2 channels respectively. According to the actual situation, the wrong data is removed, and then the data fusion is carried out according to the prepared algorithm, and the new data is packaged and sent to the flight control computer. In UAV system, flight control board is the core of aircraft control. It is responsible for balance. It can process data, control motor and cooperate with other components. The main hardware selection of the UAV built in this experiment adopts the hardware equipment described in the previous section. In addition, the propeller selects WST 6045, which means that the propeller length is 6 inches, and 45 is the pitch of the propeller. The longer the propeller is, the lower the Kv value of the motor is. In addition, XBee Pro wireless data transmission is used to establish data communication between PC and UAV. Based on this, the experimental parameters are uniformly set, and the specific experimental parameter information is shown in the Table 2:

Table 2. Experimental parameter setting

Type	Index	Numerical value	Company
Positioning time	Cold boot	26.5	S
	Hot start	<1	S
	Recapture	<1	S
Sensitivity	Cold boot	-132	dBm
	Hot start	-159	dBm
	Recapture	-160	dBm
Accuracy	Horizontal positioning	2.0	m
	Altitude positioning	3.0	m
	Speed	0.1	m/s
Working temperature	-35℃-55℃		

There are two main methods of UAV dynamic positioning: the flight process according to the set route and the hovering process when reaching the set point. In the flight process of UAV, in addition to take-off and landing need remote control operation, when the flight state of UAV reaches stable, it will switch flight state to navigation and positioning mode, and then fly autonomously according to the set trajectory. The four rotor UAV was connected with single GPS and multiple GPS to fly around the campus basketball court for 6 circles respectively. In order to facilitate comparison, a 3-meter wide door is set up on four sides, and GPS is placed at the left and right end points of the door respectively. The GPS positioning data of 5 minutes are measured, and the average value of all positioning points is taken as the real position coordinates of the door. In the flight process, the UAV's longitude, latitude, speed and other information are fed back to the ground station through data transmission for later data analysis. After the data is transformed into coordinates, the positioning curve is shown in the Figure 3.

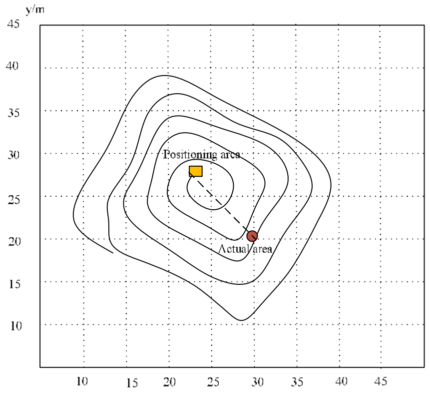

Figure 3. Detection results of traditional positioning curve

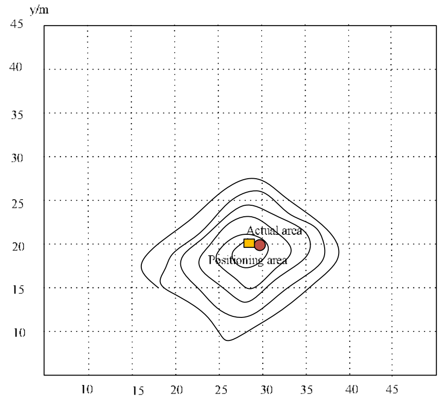

Figure 4. Detection results of positioning curve in this paper

Based on the above detection results, compared with the traditional methods, the UAV Photogrammetry in digital city geographic information navigation positioning effect is relatively more accurate, which can better guarantee the accurate collection of geographic information and standardize the best navigation route.

4. Conclusion

In order to reduce the influence of UAV airborne navigation system error on target positioning accuracy, an online calibration method of high-precision strapdown inertial integrated navigation system is studied in this paper; An on-line calibration Kalman filter model including inertial sensor error as state quantity is designed, and the on-line calibration effect of inertial sensor error under different maneuvering modes is analyzed. The established error online calibration model can effectively calibrate the inertial sensor error, improve the navigation and positioning accuracy of the carrier, and lay a model foundation for the realization of high-precision target positioning Foundation. In order to realize on-line calibration of airborne inertial integrated navigation system with UAV motion characteristics and effectively improve target positioning accuracy, this paper studies a dynamic error excitation method for airborne inertial integrated navigation system (SINS) based on the external excitation input required by the online calibration method of high-precision sins. The relation UAV between the measurement output of inertial sensor and the basic flight parameters of UAV is derived. The excitation relation UAV between UAV's basic maneuver mode and inertial sensor error is established. The observability of inertial integrated navigation system error under different maneuvering modes is analyzed. The simulation results verify the correctness of the error dynamic excitation method, which can be used for UAV's track maneuver in high-precision target positioning It provides a reference for the design.

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