High Precision Extraction of UAV Tracking Image Information Based on Big Data Technology

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Abstract. The high-precision extraction of UAV tracking image information is of great significance to the development of UAV system, attitude control, real-time flight path planning and correction, accident analysis and payload. In order to improve the precision of UAV tracking image information extraction, a high precision UAV tracking image extraction method based on big data technology is proposed. Collect the tracking image information of UAV, and eliminate the spectral reflectance of ground objects through atmospheric correction; A multi viewpoint dense image matching method is used to generate a feature recognition model of image information; Creatively uses cubic convolution interpolation to establish image matrix; Calculate the world coordinates of the same feature point and the spatial direction of the wing line and symmetry axis to evaluate the image clarity of the UAV; The pyramid image matching strategy is used to automatically match and jointly adjust the points of the same name in each image layer; The size and direction of the key points are determined by fitting the three-dimensional quadratic function, and the gradient and direction of the key points are calculated respectively to achieve high-precision extraction of UAV tracking image information. Finally, the experiment results show that the method improves the precision of UAV tracking image information extraction, has high practicability and meets the requirements of the research.

Keywords: Big data technology · UAV · Image information · Precision improvement

1 Introduction

The 3-D position and attitude of the UAV are the main parameters reflecting its flight status and performance, which are of great significance to the development of UAV system, attitude control, real-time planning and modification of flight path, accident analysis and effective load. Therefore, the precision measurement of UAV image parameters has a strong theoretical research value and broad application prospects [1]. According to the different positions of the measuring sensors, the measuring methods of UAV image

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parameters can be divided into two kinds: image measurement method and image measurement method. The UAV image measurement method based on inertial navigation system is the most widely used one at present. This method has the characteristics of high reliability and high precision, but the UAV image measurement system has the problems of cumulative error, high cost, and unreliable attitude measurement result when the body is weightless, such as spin. The GPS measurement method has high position measurement precision, but the attitude measurement precision is not high because of the limited length and width of the UAV, and the measurement method depends on the GPS. The high-speed aerial camera measurement UAV image needs to set up a large control field on the ground, and the track range and flight attitude of the UAV are limited [2]. The method of external measurement of image refers to the method of collecting the UAV image, extracting the image features and calculating the image parameters by using the measuring equipment installed on the ground, which mainly includes the method of attitude measurement based on model base, the method of monocular motion track intersection, the method of monocular plus distance information image measurement, the method of multi-station UAV attitude measurement based on line feature and the line intersection measurement based on image point feature. The measurement method of monocular motion trajectory can only get the trajectory of the UAV, and the measurement precision is not high. The measurement method of monocular plus distance information image avoids the problem of multi-view matching, but needs additional equipment to measure distance, and in order to get high measurement precision, the range of target attitude is limited. The method of surface rendezvous measurement of UAV attitude can measure high precision pitch angle and yaw angle, but can not get roll angle and position parameters. The method of line rendezvous measurement based on the feature of image point requires that the stable point is extracted to more than three non-collinear points on the UAV, and the reliability is not high, and the measurement precision is not high because of high flight of UAV and small airframe size.

Different from the above measurement methods, innovatively combined with the image features of UAV, this paper presents a UAV image measurement method based on image feature fusion. The multi spectral remote sensing image is normalized by radiation, and the spectral reflectance of ground objects is eliminated by gas correction; A multi viewpoint dense image matching method is used to generate a feature recognition model of image information; The new image is interpolated innovatively by cubic convolution interpolation, and the image matrix is established; The pseudo change is controlled by radiometric correction, and the world coordinates of the same feature point and the spatial directions of the wing line and the symmetry axis are calculated respectively, which realizes the measurement of the UAV image; The combined adjustment method of multiple images is used to preprocess the tilted image; Combined with the pyramid image matching strategy, the same name points of each layer of images are automatically matched and jointly adjusted; The size and direction of key points are determined by fitting three-dimensional quadratic function; The gradients and directions of the key points are calculated by parallel computing to achieve high-precision extraction of UAV tracking image information.. Experimental results show that this method improves the adaptability and reliability of UAV image parameter measurement and image measurement, and has great significance.

2 High Precision Extraction Method of UAV Tracking Image Information

2.1 UAV Tracking Image Information Feature Recognition

In order to make the radiant signals of different images consistent, radiant normalization of TMETM+, ALI and other multi-spectral remote sensing images is carried out, and the DN value of the original image is converted into reflectivity to correct the radiant signals. Normalized remotely sensed images from different sensors can significantly reduce noise from solar, terrain and atmospheric effects [3–5]. Big Data technology introduced the Big Data COST model for atmospheric correction, correction of atmospheric effects and effects caused by differences in solar-terrestrial distances and solar zenith angles [6]. Firstly, the brightness value of the image is converted into the spectral radiation value L of the sensor.

$$L_\lambda = \text{gain}_\lambda \times Q_\lambda + \text{bias}_\lambda \tag{1}$$

In the formula: λ is the band number; L is the spectral radiant value of the pixel at the sensor, the unit is W; Q is the pixel DN value of the band; gain and bias are the scaled gain and offset values of the sensor, both of which are W.

The radiometric correction parameters used in this study are shown in Table 1.

Table 1. Radiometric correction parameters for TM/ETM and ALI (in W/(m^2, ster, μm)

		TM		ETM + (high gain)		ETM + (low gain)		ALI	
Band name	Band serial number	Gain λ	Bias λ	Gain λ	Bias λ	Gain λ	Bias λ	Gain λ	Bias λ
Blu ray	1P	—	—	—	—	—	—	0.046	−3.5
	1	0.76852	−2.28	0.78598	−6.99	1.182658	−7.39	0.045	−4.5
Green light	2	1.458526	−4.38	0.79586	−7.6	1.265896	−7.65	0.029	−1.8
Red light	3	1.065829	−2.23	0.63586	−5.63	0.956283	−5.95	0.019	−1.4
Near infrared	4	0.86289	−2.38	0.63585	−5.76	0.965871	−6.08	0.012	−0.86
	4P	—	—	—	—	—	—	0.0092	0.66
	5P	—	—	—	—	—	—	0.0084	−1.5
Mid infrared	5	0.126365	−0.48	0.12652	−1.15	0.192582	−1.18	0.0027	−0.7
	7	0.062558	−0.23	0.04523	0.38	0.065586	−0.43	0.00092	−0.22

The ESUM values of the images used in the study at the top of the atmosphere are shown in Table 2:

Table 2. Average solar irradiance at the top of the atmosphere (in W/(m^2.μm))

Band name	Band serial number	ESUN λ		
		TM	ETM +	ALI
Blu ray	1P	—	—	1868
	1	1986	1998	1997
Green light	2	1798	1825	1812
Red light	3	1035	1041	1246
Near infrared	4	—	—	453.6
	4P	—	—	465.8
Mid infrared	5	221.2	131.9	235.2
	7	85.65	85.98	83.65

Figure 1 shows the spectral curves of the typical terrain after FLAASH atmospheric correction for Hyperion images.

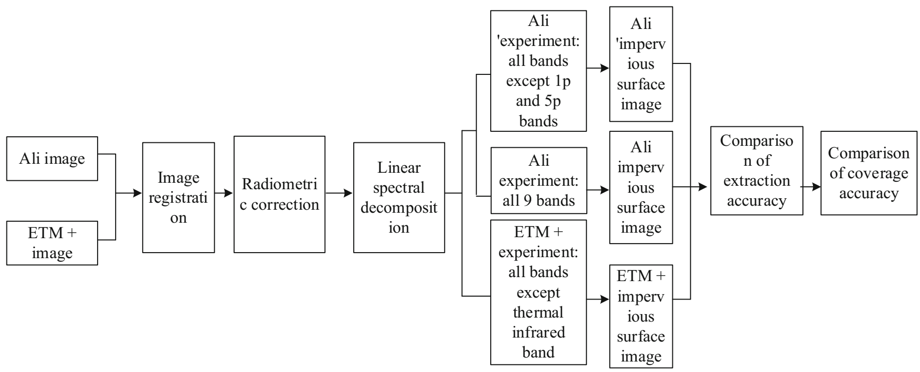

Fig. 1. Technical route of UAV tracking image information comparison

It can be seen from Fig. 1 that, after atmospheric correction, the influence of the atmosphere on the spectral reflectance of various ground objects is obviously eliminated, especially in the range of visible light wavelength, the imaginary high value caused by the elimination of atmospheric Rayleigh scattering and aerosol scattering makes the reflectance in this range obviously decrease, and the spectral curves of various typical ground objects are more close to their real spectral reflectance curves [7]. In order to compare the inversion effect of UAV tracking image information between the ALI and ETM sensors in a more comprehensive way, and to investigate whether the new spectral band added by ALI is helpful to improve the inversion precision of UAV tracking image information, two different schemes are selected to carry out the comparative experiment: one is to participate in the comparative experiment with all 9 wavelengths of ALI, the other is to simulate ALI into ETM+ image for experiment, that is, to remove the new 1p and 5p wavelengths added by ALI, to keep the same wavelength setting as EIM+, and to make the spectral range of ALl and ETM+ wave bands other than thermal infrared one basically consistent. At the same time, in order to compare more objectively, the two aspects of UAV tracking image information extraction and UAV tracking image coverage inversion will be compared respectively.

High precision and resolution digital surface model DSM can be generated by multi-view dense image matching method. The model can express the fluctuation of terrain. This technology has become a new generation of spatial data infrastructure research focus on the object. However, due to the difference of multi-angle tilt images (angle, chromatic aberration, height, etc.), and the serious shadow and occlusion problems in the images, DSM becomes a new difficulty to obtain automatically using tilt images. In order to solve this problem, we can first compute the outer azimuth elements of each image based on automatic aerial triangulation, and then select the appropriate image matching unit to match with the outer azimuth elements, and then introduce the parallel algorithm to improve the computing efficiency.

2.2 Evaluation of UAV Tracking Image Sharpness

After polynomial model is used to transform the coordinate space of the original pixels to be corrected, the repositioned pixels can not be distributed evenly in the original image, but fall among several pixels of the original image. So it is necessary to interpolate each pixel on the new image by resampling, and then a new image matrix is established. Common big data methods include nearest neighbor method, bilinear interpolation and cubic convolution interpolation. The nearest neighbor method assigns the brightness value of the nearest original image pixel near the coordinates of the new pixel to the new pixel. This method can keep the spectral value of the original pixel very well, and the operation is simple and the processing speed is fast. But this method may cause the position deviation of the pixel to be too large, so that the spectral brightness of the new image is discontinuous and the zigzag boundary appears. In bilinear interpolation, the brightness values of the 4 original pixels adjacent to the new pixel are weighted according to the distance between the original pixel and the new pixel, and the weight near the new pixel is higher; then the brightness value of the new pixel is calculated by linear interpolation. The brightness of the image obtained by this method is continuous, which can play the role of smoothing and filtering. But the brightness of the image changes, and the high frequency information in the image is easy to be lost, and the boundary of the ground object becomes fuzzy.

$$x = \sum^{N} \sum^{N-1} a_{ij} X^i Y^j \tag{2}$$

$$y = \sum^{N} \sum^{N-i} b_{ij} X^i Y^j \quad (3)$$

In the formula: (x, y) is the pixel coordinate of the image to be registered; X^i and Y^j are the values of horizontal and vertical coordinates of each pixel in the standard image respectively; a_{ij} and b_{ij} are polynomial coefficients, which can be obtained by least square regression from the original data; N is the degree of polynomial, the size of which mainly depends on the number of GCP, the degree of image deformation and the size of terrain fluctuation. Camera imaging model often refers to pinhole camera model, that is, the projection center is located in the Euclidean coordinates of the origin in the pinhole camera model. Point X with space homogeneous coordinates (X, Y, Z) is mapped to a point x = (x, y, 1)/2 on the image plane, where the line connecting the projection center X with the image plane intersects as shown in Fig. 2.

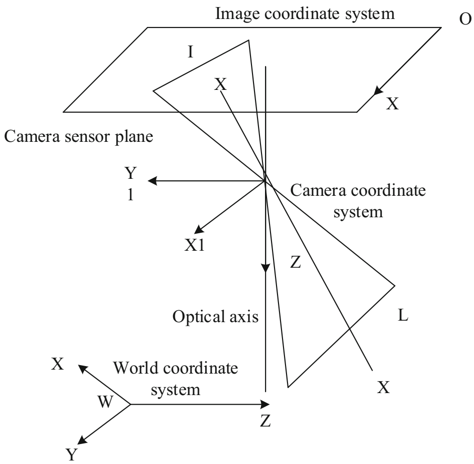

Fig. 2. UAV imaging model

The coordinate system is W-XYZ, the image coordinate system is o-xy, the camera coordinate system is O-XYZ equivalent focal length is f, the rotation matrix from world system to camera system is R, and the center of camera is T. According to the principle of rotation, translation and similar triangle, it is easy to know that the mapping from IR to 2D projective space 2 is IR3 → IR2.

$$k = KR[T|IC - T]L_\lambda - xy \quad (4)$$

In the expression, $K = \begin{bmatrix} f\ 0 f \\ 0 f\ f \\ 0\ 0\ 1 \end{bmatrix}$ is the camera calibration matrix, $I = \begin{bmatrix} 1\ 0\ 0 \\ 0\ 1\ 0 \\ 0\ 0\ 1 \end{bmatrix}$ is the 3 × 3 unit matrix, Y and X are homogeneous coordinates, $C = KR[11 - T] = \begin{bmatrix} r_1 & c_1 & c_n & c_4 \\ c_4 & c_4 & c_3 & c_3 \\ c_{i1} & c_{13} & c_{11} & c_{11} \end{bmatrix}$ is the camera matrix, and K is the distance from space point to projection center. According to the imaging model, a line L in 3D space is projected onto a line I on the image plane. Suppose the equation of the line on the image is by c = 0, and the homogeneous representation of the line is l = (a, b, c), then the set of points in the space mapped to line I by the camera matrix C is a plane, and the plane equation is

$$X^T C^T - K = \theta \tag{5}$$

The homogeneous representation of the plane is C, and the expression (2) is the coplanar equation of projection center, image line and space line.

However, it is difficult to detect the detailed feature information of UAV due to the influence of environment, UAV attitude and high speed in the actual measurement process, and the reliability of the detected feature is worth discussing. Corners, wing lines and symmetry axis are the stable points in the UAV image, which mainly refer to the points where the brightness of the UAV image changes dramatically or the maximum curvature on the edge curve is maximized. These points can be located in the neighborhood with rich information such as rotating invariant, scale invariant and illumination invariant. In remote sensing images with different temporal phases, there are always some features whose spectral values do not change with time, such as undisturbed deep water, residential areas, airport runways, etc. The spectral reflectance of an invariant feature does not change significantly over time without interference from other factors. Even if it does, the change may be caused by different atmospheric and illumination conditions, so it is also called "pseudo-change". For historical images, these pseudo-variations can be controlled or reduced by radiometric correction, so that they can be used in conjunction with measured spectral data over the summer period, with sufficient and stable solar light, cloudless skies and small winds. When all the samples are used to measure the spectrum, the GPS position information, time, description and photo record are recorded synchronously. The flow chart of spectrum measurement is shown in Fig. 3.

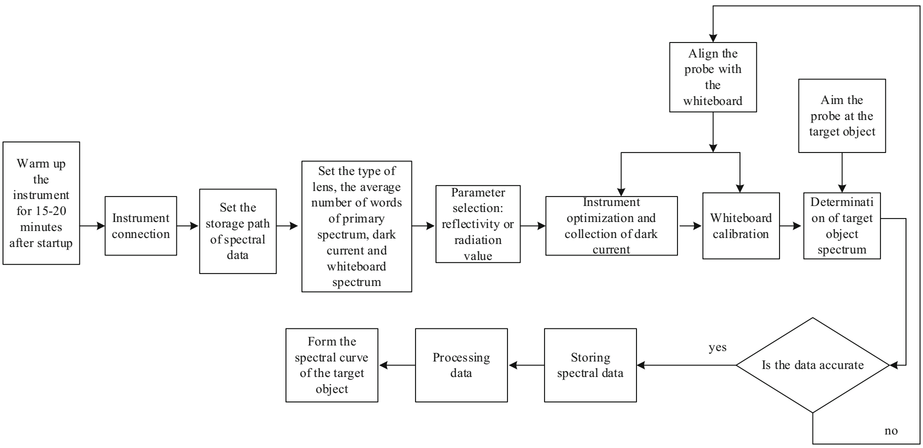

Fig. 3. Flow chart of UAV spectral image information measurement

Wing straight line includes left and right lines. Because of flying altitude and attitude of UAV, the wing line is not easy to be extracted, but the feature of wing line is still valuable. The axis of symmetry is the stable characteristic line of UAV. In most cases, the line of symmetry axis can be extracted from the image of each network camera. The stable extraction of this feature line is also the precondition of high precision image parameters. Based on the above discussion, this paper adopts the method of extracting stable corners, wing lines and symmetry axis to realize the UAV image measurement.

2.3 Realization of High Precision Extraction of UAV Influence Information

Data processing is the core work of UAV low-altitude remote sensing system, which includes image preprocessing, camera high-precision detection, image matching, automatic aerial triangulation, DSMDEM automatic extraction, DOM generation and seamless stitching. The data processing flowchart is shown in Fig. 4.

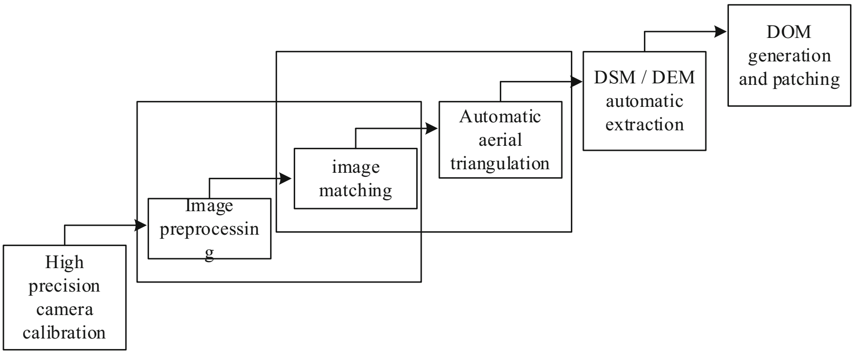

Fig. 4. Low altitude remote sensing data processing flow of UAV

Multi-view images include vertical photography and tilt photography. In the process of processing photographic images, some aerial triangulation systems can not be completed well, so the method of joint adjustment of multiple images is needed to process tilted images. The UAV image information plot steps are shown in Fig. 5.

In the process of joint adjustment of multi-view images, we should pay attention to the following aspects: geometric deformation and occlusion relationship among images, combined with the external azimuth elements of multi-view images provided by the positioning and orientation system, combined with pyramid image matching strategy, automatic matching and joint adjustment of homonymic points on each level of images, so as to get better matching results of homonymic points. When establishing error equation, we should combine the data such as connection point, control point coordinates, GPS/MU auxiliary data with the error equation of self-checking area network adjustment of multi-view images to get high precision adjustment.

Feature extraction is a concept in computer vision and image processing. It refers to the use of a computer to extract the image information of the same name points in the image, which determines the same features in the image. Feature extraction is

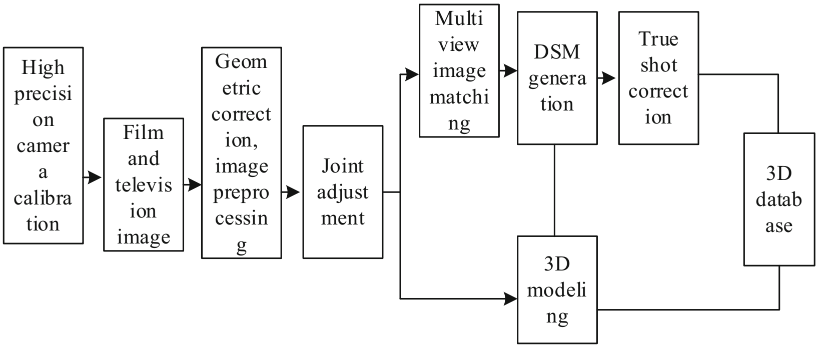

Fig. 5. Step of UAV image information map area

to classify the points on the image into different subsets. These subsets are usually composed of n isolated points, a continuous curve or a continuous region. There are obvious differences and differences between the gray levels of image features and those of surrounding images. Features are usually divided into point features, line features and surface features. The point feature mainly includes the obvious point and line feature in the image, which is the conformation of the edge of the linear object or surface object in the image. The low altitude photogrammetry system of UAV is not easy to operate the UAV under the influence of wind force, and it will deviate from the established flight path. The attitude of a digital camera on an unmanned aerial vehicle cannot remain fixed due to the influence of the wind or the motion of the aircraft, which leads to great changes in the lateral overlaps and heading overlaps between adjacent images. When UAVs fly in urban areas, towering buildings can be distorted in adjacent images, making it impossible to find a matching search area in photographic images. In order to accurately locate the position and scale of the key points, Professor Lowe proposed a method to achieve sub-pixel accuracy, i. e., to fit the 3D quadratic function. This method can remove the key points with low contrast and unstable edge response points, and enhance the matching stability and anti-noise ability.

To determine the size $m(x, y)$ and orientation $\theta(x, y)$ of the key points, firstly the distribution direction of the key points shall be determined according to the local features of the image, and then the gradient $D(X)$ and direction distribution character $L(x, y)$ of the neighboring pixels of the key points shall be used to calculate the gradient and direction of the key points respectively. The specific formulas are as follows:

$$m(x, y) = \sqrt{(L(x+1, y) - L(x-1, y))^2 + D(X)} \tag{6}$$

$$\theta(x, y) = \tan^{-1} D(X)/(L(x+1, y) - L(x-1, y)) \tag{7}$$

However, the SIFT matching algorithm with invariant features can be divided into two types: the matching based on gray level and the matching based on features. In recent years, many scholars have studied the matching based on image features more than the matching based on gray level.

3 Analysis of Experimental Results

In order to verify the correctness and feasibility of the proposed method, digital simulation is carried out for the method of measuring image parameters using point or line features of UAV and the method of image measurement using feature fusion proposed in this paper. The simulation measurement error of UAV position parameters and pixel classification accuracy are used to evaluate the accuracy of UAV tracking image information extraction. The tilt system used in the experiment is a lightweight, handy five-lens tilt camera called the KG2000 Pm. KG2000Pro Tilt Aerial Camera System is a new tilt camera system based on the development of the Dajiang Genie IV, the camera system light pixel height as shown in Table 3.

Table 3. KG2000 pro camera parameters

Overall dimension	Weight	Sensor	Resolving power	Sensor size	Pixel size	Camera lens	Lens distribution
125 × 97 × 81	35	CMOS	4200	1/1.3	1.5 μ	No displacement	Equidistant 29 mm lens group

The SonyQx100 (9009865) used in the experiment was tested on the spot. The contents and results of the test are shown in Table 4.

Table 4. Sorry QX100 (9009S65) results of machine calibration

Serial number	Calibration content	Calibration value	Remarks
A	Main point x0	−0.00S65S mm	Camera interior orientation element
B	Main point Y0	−0.003652 mm	
C	Focal length	10.65862 mm	
D	Radial distortion coefficient K1	2.13E−11	Radial distortion difference coefficient
E	Radial distortion coefficient K2	−S.12E−2S	
F	Eccentric distortion coefficient Q1	3.15E−8	Tangential distortion difference coefficient
G	Eccentric distortion coefficient Q2	−1.65E−8	

In order to solve the problem of UAV image parameters only using corners, the coordinates of the corners in the world system are obtained by the rendezvous of the binocular lines, and then the image parameters of the UAV are obtained by solving the absolute orientation problem by using the linear least squares. In the simulation, the noise standard deviation increases from 0.1 to 1, and the average measurement error Pmn = Pa − Pa/1000 is calculated for each noise level program. The simulation result is shown in Fig. 6.

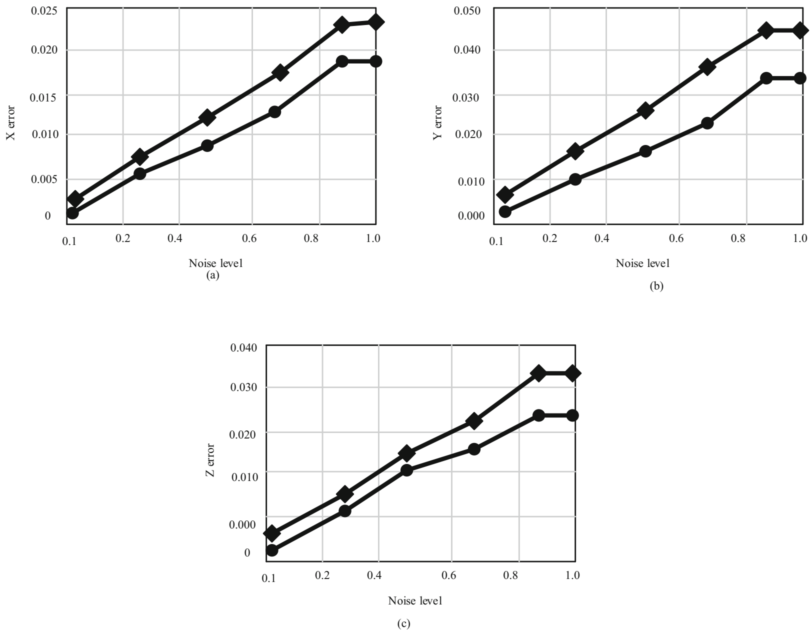

Fig. 6. Simulation measurement error of UAV position parameters

It can be seen from Fig. 6 that the measurement error of each noise level program on the three axes of the simulation results of this method is less than 0.01, which has high anti-interference and improves the accuracy of information extraction of UAV tracking images. This is because in order to improve the image clarity, the method in this paper eliminates the interference of spectral reflectance of ground objects through atmospheric correction, uses multi viewpoint dense image matching method to generate image information feature recognition model, and uses multi image joint adjustment method to preprocess inclined images, so as to obtain low measurement error.

In order to get the relationship between the proposed method and the number of netted cameras, the number of cameras is increased from 1 to 6, and the noise with standard deviation of 1 is added. The same test set samples were used to test the five extracted models respectively. Because the big data technology of this paper is single class extraction model, the results of model extraction need to be merged. In this paper, the classification of each pixel is determined by outputting the probability of each pixel classification, and then the multi-class segmentation is realized. ENVI software is used to extract the conflicting pixels, generate the corresponding position coordinates, compare the corresponding class probabilities, and retain the class values with high probabilities to generate the final confusion matrix, as shown in Table 5. In the confusion matrix, A stands for farmland, B for forest, C for building, D for water, E for road, and F for other land.

Table 5. Confusion matrix of experimental results

Category	A	B	C	D	E	F	Total
A	4125162	213656	12653	16235	5236	782	4373724
B	50256	2068562	126523	596	7652	5688	2259277
C	73652	65856	2008963	11365	15368	2365	2177569
D	1352	1036	625	26521	88	838	30460
E	3652	856	1326	721	72056	1165	89776
F	6253	2156	11355	6253	7523	265861	299401
—	—	—	—	—	—	—	9230207

According to the obfuscation matrix, the precision, average precision and overall precision of each class can be calculated, as shown in Table 6.

Table 6. Table of experimental results

Category	Traditional method extraction accuracy %	Paper method extraction accuracy %
Ploughing pond	76.3	94.1
Forest		91.8
Residential area	87.4	92.5
Waters	77.8	89.5
Road	79.3	91.3
Other land	78.2	89
Overall extraction accuracy	80.6	93.65
Average extraction accuracy	77.8	91.89

As can be seen from Table 6, the overall extraction accuracy is 91.89%. Among them, the main reasons for the higher accuracy of extraction of arable land and forest are the regular shape of arable land and the special texture of forest. But the extraction accuracy of water area and other land is low, mainly because the water area is small, the characteristics are not obvious, other land is complex and diverse, the characteristics of confusion.

Large data method is used to train and extract features from a large number of samples. Finally, the trained model is used to complete information extraction by image classification. Experimental results show that the proposed method can extract the distribution information of objects from the images with high accuracy. Through analysis, the new method combines different objects with model structure reasonably and efficiently, and effectively solves the problem of inaccurate classification of typical objects. This is because the method in this paper normalizes the collected multispectral remote sensing images, eliminates the spectral reflectance of ground objects through gas correction, and provides an accurate data base; The multi viewpoint dense image matching method is creatively used to generate the image information feature recognition model, and the cubic convolution interpolation is used to establish the image matrix, which improves the image information feature recognition accuracy; The accurate measurement of UAV image is realized by controlling the pseudo change through radiation correction; Combined with the pyramid image matching strategy, the same name points of each layer of image are automatically matched, and the size and direction of key points are determined by fitting the three-dimensional quadratic function, which realizes the high-precision extraction of image information.

4 Conclusion

In order to realize the high precision measurement of UAV position and attitude parameters, an image measurement method based on image feature fusion is proposed. In order to solve the problems of the UAV image measurement, the unit-direction vector of the UAV spindle in the world system is calculated by using the stable spindle feature of the UAV, and the image parameters of the UAV are calculated by using the corner feature and wing feature. Compared with the method that solves UAV image parameters by point feature or line feature, the method based on image feature fusion has the advantages of high precision and strong adaptability. High precision extraction of UAV image information based on big data technology is an important means of UAV test and development, attitude control fault analysis and effective payload enhancement. It has important theoretical research significance and broad application prospect. Future research can combine the method in this paper with UAV attitude control, and correct the UAV flight attitude through image information features.

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