Research and verification of related algorithms based on UAV imaging payload

Huan Tao

Shandong Vocational College of Information Technology, Weifang, Shandong, China

Abstract: In order to effectively process geographic information, the UAV image stitching algorithm and verification algorithm with geographic information regard geographic information data as multi-channel double-precision floating-point matrix data, which can be calculated synchronously using matrix processing algorithms . At the same time, the use of the image stitching algorithm with geographic information based on grouping control can improve the accuracy and speed when performing a large number of image stitching tasks. Experimental results show that the algorithm can effectively process UAV images with geographic information, especially in image stitching.

In order to meet the needs of scouts, this paper proposes an integrated representation method of image and geographic data information, which synchronizes the process of geographic data information processing and image processing, and realizes the integrated fusion processing of image and geographic data[1]. At the same time, combined with image registration, fusion and stitching technologies, geographic information is integrated into the image processing process to achieve synchronous processing of image geographic data, so that reconnaissance intelligence analysts can quickly and directly obtain the geographic location of the target of interest from the image.

1. UAV aerial photography and basic theory of computer vision

1.1 Common coordinate systems

Nowadays, the commonly used coordinate systems in the field of UAV aerial photography include the following four: (1) Digital image coordinate system, which mainly realizes the pixel storage method. Pixels are arranged in rows and columns in each image to realize the entire image pixel. The dots make up the pixel matrix. (2) The image plane coordinate system, which is also in pixel units, cannot represent the physical location of the image point in the photo. (3) The camera coordinate system, which is used as the coordinate system defined by the position of the camera; (4) The world coordinate system is used to describe the position of the camera object[2].

1.2 Camera imaging model and coordinate transformation

The camera is used as a perspective lens, and when the light rays pass through the perspective mirror, the focus point is formed. The distance between the focal point and the center of the perspective mirror is the focal length. The optical imaging model simplifies the obtained camera model. The relationship between the three imaging principles is as follows[3]:

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \qquad (1)$$

In the formula: the object distance is represented by u; the image distance is represented by v; the focal length is represented by f.

The camera is equivalent to a convex lens head. There is a photosensitive element near the focal point of the convex lens. When the focal length is similar to the central photosensitive element of the convex lens, the lens model can be simplified to obtain the pinhole imaging model (see Figure 1). After the pinhole imaging model is successfully converted, a linear relationship is formed between the two coordinates of the image and space. The image point coordinates can be used to

solve the object point coordinate problem, which can be transformed into a linear equation problem. Therefore, for each coordinate system Conversion relationships are critical. In order to facilitate the calculation, it is assumed that there is a virtual imaging plane in reality, and the image distance is formed between the plane and the imaging center, and the virtual imaging is completely equivalent to the real imaging plane in terms of geometric relationship[4]. (See Figure 2) is a schematic diagram of the common coordinate system relationship of the pinhole imaging model.
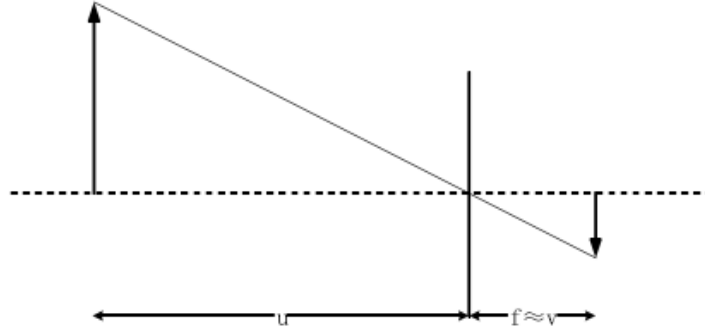

Figure 1 Schematic diagram of the pinhole imaging model

Assuming that in the image plane coordinate system, the pixel in the x direction is represented by dx, and the physical size in the y direction is represented by dy, then the coordinates formed by the origin of the image plane coordinate system in this coordinate system can express the digital image and the image plane. The relationship expression formula between the coordinate systems is as follows:

$$
\begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} \dfrac{1}{dv} & 0 & u_0 \\ 0 & \dfrac{1}{dy} & v_0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \tag{2}
$$

According to this formula and the changing relationship between the two coordinate systems of the digital image and the image plane, the relationship between the two coordinate systems of the plane and the camera can also be determined as follows[5]:

$$
Z_c \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} X_c \\ Y_c \\ Z_c \\ 1 \end{bmatrix} \tag{3}
$$

Combining the above formulas, the conversion relationship between digital image and world coordinate system can be obtained as follows:

$$
Z_c \begin{bmatrix} u \\ v \\ 1 \end{bmatrix} = \begin{bmatrix} f/d_x & 0 & u_0 & 0 \\ 0 & f/d_y & v_0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} R & T \\ 0 & 1 \end{bmatrix} \begin{bmatrix} X_W \\ Y_W \\ Z_W \\ 1 \end{bmatrix} = K[R|T] \begin{bmatrix} X_W \\ Y_W \\ Z_W \\ 1 \end{bmatrix} \tag{4}
$$

2. Representation method of geographic information data

In the field of computer vision, an image can be represented by three channels: red, green, and blue. Because geographic information and image pixels can be one-to-one correspondence, this

paper proposes a method to store and process geographic information data using image storage structure. A digital image can be represented by a multi-channel unsigned char (unsigned char, 0~255) integer matrix. In this paper, double-precision floating-point multi-channel matrix is used to represent the main information of geographic information data, such as longitude (unit is degree (°), -180° (excluding) ~ 180°), latitude (unit is degree (°), -90 °~90°) and height (in m). The geographic information is stored as a double-precision floating-point multi-channel matrix, and the geographic information data can be processed by the matrix processing algorithm[6].

Geographic information data multi-channel double-precision floating-point matrix storage structure (see Figure 2).
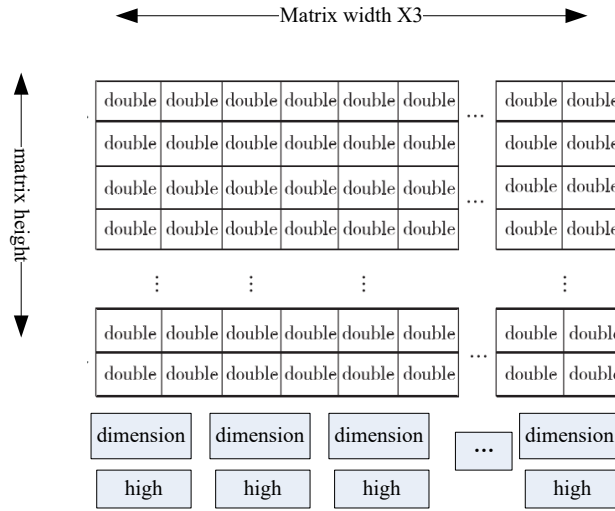
Figure 2 Multi-channel geographic information matrix storage structure

3. Multi-threaded UAV imaging payload stitching algorithm based on ORB with geographic information

3.1 Image mosaic algorithm with geographic information based on group control

In order to solve the problem of long calculation time for a large number of stitching, this paper proposes a multi-threaded UAV image stitching algorithm based on ORB with geographic information, and controls the stitching process of a large number of images through multi-thread grouping, reducing the accumulation of errors in the stitching process of multiple aerial images. It ensures the accuracy of large scene stitching of UAV aerial images.

The UAV image stitching task often faces a large number of images that need to be stitched. Sequential stitching will be time-consuming and labor-intensive, and the stitching effect is not good due to accumulated errors. In order to improve the computing speed and make full use of computing resources, the algorithm in this paper automatically batches the stitched images, and each processor core moves a thread to process a batch of images.

3.2 Image Feature Extraction and Transformation Matrix Calculation

The UAV image processing algorithm with geographic information first needs to extract the image features through the image processing algorithm, and then share the transformation matrix calculated by the image processing process when transforming the geographic information, such as the homography matrix H. This paper takes image stitching as an example to introduce the process of image feature extraction and transformation matrix calculation[7].

3.2.1 ORB Feature Extraction

ORB algorithm is a new feature extraction algorithm based on keypoint detection oFAST and rotation-sensitive binary Lupin independent basic feature Brief feature detection. Compared with the SIFT algorithm, this algorithm has the characteristics of less computational complexity, and the computational accuracy meets the needs of use. The steps of extracting image ORB features are as

follows:

(1) Build a pyramid for the image;

(2) Use the accelerated segmentation test feature FAST algorithm to detect the position of the key point as a corner point, and the corner point represents the feature points with two main directions in the field;

(3) Using the Harris corner detection algorithm to select the top M best points, the Harris corner detection response function R is defined as: $R = \det J - \alpha(trace J)^2$,where J represents $\sum_w \begin{bmatrix} I_x^2 & I_x I_y \\ I_x I_y & I \end{bmatrix}$.

(4) For the selected M corner points, after calculating the direction of the corner points using the intensity center algorithm, the OFAST feature can be obtained;

(5) Since the Brief algorithm is undirected, rotate the corner direction calculated in (4) as the Brief direction to obtain a directional Brief, and use the greedy learning algorithm to screen out those with high variance and high irrelevance. The directed BRIEF is called rBRIEF.

3.2.2 Feature matching

ORB feature matching uses the k-nearest neighbor algorithm to calculate the feature point distance between any two images, denoted as m, and the secondary distance is m1, and performs feature point matching on any image, and deletes images with low confidence. The minimum sampling consistency algorithm is used for optimization, and the homography matrix is calculated according to the matching points, and then the two images that can be spliced are placed in the splicing geometry, and the set is continuously expanded to form the largest splicing set. The camera parameter matrix K is estimated according to the homography matrix H, the camera parameter matrix K and the world coordinate system, and the transformation W of the camera coordinate system, W is composed of the rotation matrix R0 and the translation column vector[8].

3.2.3 Beam method adjustment

Since multiple homography matrices synthesize panoramic stitched images, it is easy to cause accumulated errors, so it is necessary to add the beam method adjustment value to each image to initialize the images to the same rotation and focal length. All images were corrected for camera parameter K using the beam method adjustment algorithm to improve estimation accuracy. The beam method adjustment is robust, and its objective function is a function of the sum of squares of the mapping errors, that is, each feature point must be mapped to other images to minimize the sum of squares of the errors of the calculated camera parameters.

4. Experimental results and analysis

4.1 Experimental Design

In order to verify the effectiveness of the algorithm in this paper, this paper collects a large number of UAV aerial images in different scenarios, and conducts performance test, stitching result test and stitching result verification on the UAV images with geographic information respectively. Before the experiment, this paper has carried out pixel-by-pixel positioning of the geographic information carried in the UAV image through the non-ranging positioning algorithm, and stored the latitude and longitude information corresponding to each pixel in a multi-channel double-precision floating-point matrix.

4.2 Algorithm Verification Test Results

This paper uses the single-threaded continuous stitching algorithm, the algorithm in this paper (single thread) without multi-threaded grouping control, and the algorithm in this paper with multi-threaded grouping control for comparison, and the image resolution is 720 × 576. According to the test results, it can be seen that the image stitching algorithm with geographic information

based on grouping control greatly improves the speed and accuracy of image stitching. Due to the existence of accumulated errors, the single-thread stitching algorithm will suffer from excessive distortion when stitching more than 50 images. and failed. Single-threaded continuous stitching means that multiple images are stitched one by one in the shooting order. Each time the newly stitched image is only compared with the previous stitching result to calculate the homography matrix H, and the estimated value of the matrix transformation model is different from the actual value. There are always errors between. It is proved that the SIFT algorithm is used in this paper to automatically extract the key points of the images before and after splicing, and the accuracy of the geographic information data of the key points meets the algorithm requirements, indicating that the algorithm proposed in this paper is effective in processing geographic information data.

5. Conclusion

This paper first proposes a UAV image stitching algorithm based on ORB with geographic information. The algorithm utilizes the one-to-one correspondence between geographic information data and image pixels, and stores the longitude, latitude and altitude of geographic information in a multi-channel double-precision floating-point matrix, so that image and matrix processing algorithms can be used to process geographic information. data. At the same time, a multi-thread processing algorithm based on grouping control is applied to improve the execution speed and accuracy of image stitching.

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