Research on Fast Mosaic Method of UAV Aerial Images Based on Motion Trajectory

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Abstract: An approach for fast stitching of UAV images based on motion trajectory is proposed for high speed aerial photogrammetry in unfamiliar areas with few control points. It uses the method based on images to determine the motion trajectory and rapidly select the UAV trajectory images. The SIFT-based image feature matching algorithm is applied to extract feature matching points. This approach can effectively solve image stitching problems, such as translation, rotation, scaling, illumination, occlusion and different viewing angles.

1. Introduction

At present, Unmanned Aerial Vehicle (UAV) remote sensing technology is one of the important means to obtain near-low-altitude surface information, which is operated by radio remote control equipment and ground control system. It has the advantages of small size, light weight, controllable flight speed, and wide shooting range and so on. Especially in dangerous areas where human cannot enter, it can play a greater role. The obtained ground remote sensing images have two main applications: one is to determine the location of the interested target points on the ground, which is useful for the detection of suspicious targets in unknown areas or for military close fire calibration. The second is to take overlapping continuous photographs of the ground, and generate large-area digital maps through ground software processing. In general, the flight altitude of small UAVs is low, the attitude, yaw, pitch, roll, altitude, speed and other factors change constantly during flight, which will affect the imaging of ground targets and cause distortion. In addition, the focus of the digital camera on the UAV is limited. Although near-low altitude flight improves the resolution of the image, the field of vision of the image is small. In order to get the complete image of the whole flight area, image mosaic and processing must be implemented.

At present, UAV image mosaic technology has developed rapidly. UAVRS-I/II UAV developed by the Chinese Academy of Surveying and Mapping has completed the project of "Key Technologies Research and Verification Test of UAV Marine Monitoring Remote Sensing System" and studied UAV image processing technology. Yang Zhengyin and others discussed the accuracy of aerial photogrammetry topographic map of UAV. It was concluded that the plane and elevation accuracy of 1:2000 topographic map based on UAV image met the mapping requirements of 1:2000 flat land and hills in the "1:500, 1:1000, 1:2000 topographic map Aero-photogrammetry Industry Standard"[6]. Hu Xiaoxi and Zhou Xiaomin have studied the positioning accuracy of UAV image mapping, which shows that the Orthophoto Image Based on UAV image after geometric correction and stitching has high plane position accuracy [7-8]. However, these image mosaic methods generally limit the fixed route, a large number of control points, or use RTK for differential positioning of GPS. When surveying unfamiliar areas, the airline has strong randomness, few control points, and RTK is easily disturbed, these methods of image measurement have some limitations.

In this paper, based on a certain UAV camera platform, the flight trajectory can be determined quickly by combining navigation information with image matching, and the initial image can be stitched synchronously, so that useful images can be quickly screened for stitching. The experimental results show that the method is widely applicable and improves the efficiency of image mosaic. This method is suitable for situations where there are few control points and fast photography processing in unfamiliar areas, which could also assist in screening large-scale photographic images.

2. Fast mosaic method of Unmanned Aerial Vehicle aerial images in unknown areas based on motion trajectory

Because the attitude of UAV in flight, including yaw, pitch, roll, altitude, speed and other factors, changes constantly, the actual trajectory of UAV does not necessarily follow the predetermined route. Therefore, it is difficult to select mosaic photos according to the scheduled route, and this problem can be well solved by using the method of motion trajectory determination based on image correlation.

2.1. Method for determining motion trajectory based on image relevance

As shown in Figure 1, as long as the two adjacent moments are not too far apart, there must be some overlapping areas in the photos taken by UAV cameras. Therefore, the overlapping areas can be calculated by velocity and azimuth, and then the feature points of the overlapping areas of the two pictures can be selected for correlation calculation. If it is below the set threshold, the selected image is not the next locus position of the moving point, and then the calculation is re-selected. The logical calculation block diagram is shown in Figure 2. After these iterations, on the one hand, the trajectory of UAV can be determined, on the other hand, a series of trajectory motion pictures can be screened out to facilitate the subsequent high-precision mosaic processing. Due to the difference of UAV speed, altitude and camera parameters, and the requirement of motion trajectory accuracy, different time intervals T can be set for flexible processing.

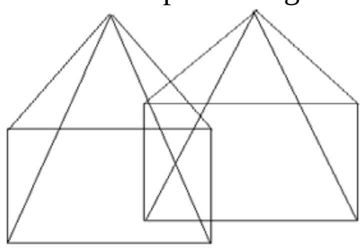

Figure 1. Two adjacent moments' position and photographic relation

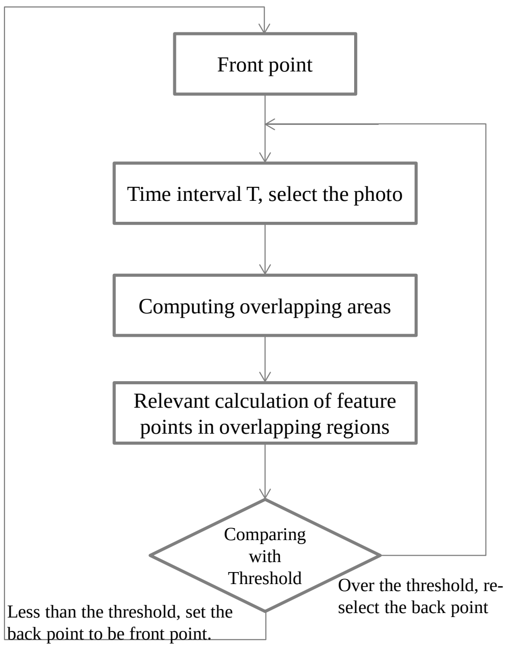

Figure 2. Method for determining motion trajectory based on image relevance

2.2. Image feature matching based on SIFT algorithm

In order to solve the image processing task, image content information should be expressed from the perspective of machine vision, image position should be expressed as pixel coordinates, image distance should be expressed as scale information, and shooting direction should correspond to image rotation direction. SIFT algorithm [9-10] can retain and generalize these image information to a certain extent, and is very suitable for image registration.

Gauss difference function is used to build image scale space, and scale space extremum detection is carried out in the neighbourhood of DoG image pyramid stereo space to eliminate low contrast noise points and unstable edge response points. The key points are located accurately, the statistical histogram of the gradient direction of the neighbourhood of the key points is constructed, the principal direction of the key points is determined, the gradient distribution information of the neighbourhood of the key points is extracted, and the SIFT feature descriptor is generated. Then matching feature points according to a certain similarity measure, using the Euclidean distance between feature point vectors as the similarity measure criterion of feature points in two overlapping images, assuming that point $p_1(x,y)$ and point $p_2(x',y')$ are the feature points in two images, and feature descriptors are Des_{p1} and Des_{p2} respectively. The Euclidean distance between two points is defined as:

$$d = \sqrt{\sum_{i=0,1,\cdots 127} (Des_{p1}(i) - Des_{p2}(i))^2} \tag{1}$$

BBF (Best-Bin-First) query algorithm is used to search and locate feature points $p_1(x,y)$ in the nearest two adjacent feature points p_2' and p_2'' of the image to be matched.

BBF query algorithm is optimized and improved on the basis of k-d tree algorithm, and k-d tree is based on binary search tree. In each layer, space classification is carried out in different dimensions according to a certain threshold, and "retrospective query" is carried out according to "query path" to determine the most approximate points in all regions. This method has low time complexity and high adaptability to different data sets. It is suitable for searching and matching in multi-dimensional space. However, when the data dimension exceeds 20 dimensions, the searching speed of the algorithm will decrease rapidly. BBF algorithm can start "backtracking query" from the nearest node according to the priority of feature points, which is very suitable for query matching of high-dimensional features. According to formula (1), the Euclidean distance between the nearest neighbour point $p_1(x,y)$ and the next nearest neighbour point p_2' and p_2'' is calculated and recorded as D_{NN} and D_{SCN} respectively. The matching success of feature points is judged by Lowe's ratio judgment method. Let the threshold value be t (empirical value is 0.8), and if formula (2) is satisfied, this pair of feature matching points will be accepted.

$$\frac{D_{NN}}{D_{SCN}} < t \tag{2}$$

3. Analysis of experimental results

In this paper, a small UAV is used as the test platform, the airborne platform is equipped with satellite and inertial integrated navigation and positioning device, the aerial image camera is equipped with optical axis stabilization system, which is vertical downward. The photograph orientation is the same when shooting, and the camera platform is located at the center of each photograph.

Due to the unstable attitude of UAV, the acquired image will also have a large field of view inclination, and there may be a large rotation angle between the images. In addition, the UAV image itself has problems such as large scale change, large geometric distortion, color and overlap inconsistency. There may also be difficult areas such as duplicate texture areas and haze coverage areas within the coverage area, which leads to poor image quality obtained by UAVs. When extracting and matching image features, it is necessary to experiment and analyze some special images to make sure that image feature extraction and matching can have better adaptability to poor quality images.

Figure 3. Matching results of SIFT operators on large dip images

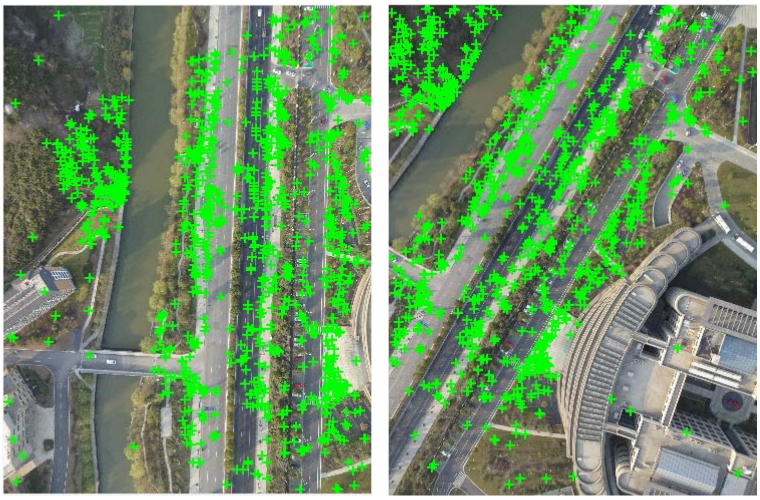

Figure 4. Matching results of SIFT operators on large deviation angles between images

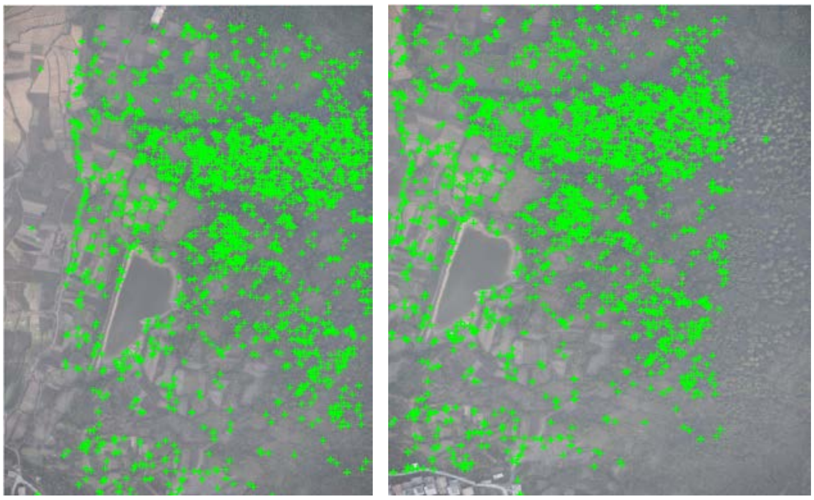

Figure 5. Matching results of haze-covered images by SIFT operators

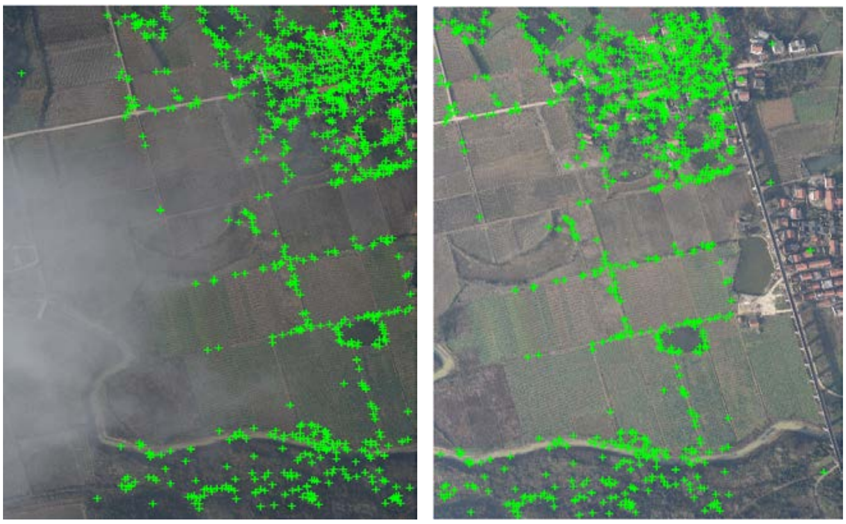

Figure 6. Matching results of SIFT operator on cloud and fog occluded images

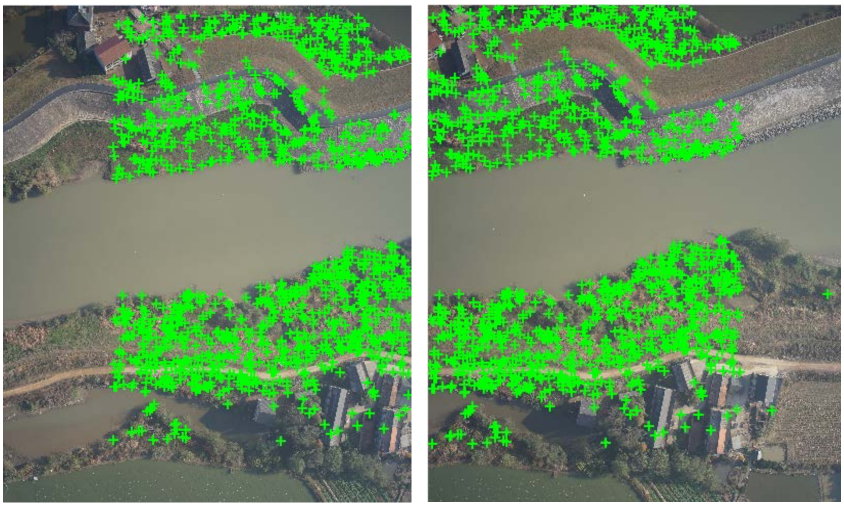

Figure 7. Matching results of SIFT operator on falling water image

In this paper, SIFT feature operator is used to match the special images of UAV. From the experimental results, SIFT operator can also have better adaptability to the low quality image data acquired by UAV, and can achieve good matching effect. After many times of image comparison, the image after stitching is obtained. As shown in Figure 8.

Figure 8. Split joint image of UAV

4. Conclusions

This paper focuses on the fast mosaic method of unknown UAV aerial images based on motion trajectory. The method of determining motion trajectory based on image correlation is used to quickly screen useful image information. The image feature matching based on SIFT algorithm is used for adjacent images, which effectively eliminates the ground deformation in the captured image data. There are also some differences among image sequences, such as translation, rotation, scaling, illumination, occlusion and view angle. Experiments show that this method is a robust image registration algorithm with strong adaptability. This method is suitable for fast photography processing occasions with few control points and unfamiliar areas. It can also assist in mass photography screening.

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