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Overlap Analysis of the Images from Unmanned Aerial Vehicles

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***Abstract*—Compared with traditional images, high-resolution images obtained by unmanned aerial vehicles (UAV) are superior in many aspects such as low cost, convenience and so on. However, the attitude of unmanned aerial vehicles cannot be determined accurately, which will lead to the decrease of accuracy and efficiency of automatic matching, so image pre-processing should be done to guarantee enough degree of overlap for image mosaicking and mapping. There are some ascendant characteristics of SIFT operator such as invariant to scale, rotation, and lightness, and these characteristics are very useful in increasing the matching accuracy of UAV images. In this paper, the overlap analysis of UAV images has been processed based on the SIFT algorithm, and the steps of overlap analysis are described, and the way of treating wrong matching points is explained. Finally, satisfactory results are obtained.**

Keywords- UAV images; SIFT; degree of overlap; image overlap analysis

I. INTRODUCTION

Real time, rapid and accurate data collection of the change information of land and resources is one of the most important elements of territorial resources monitoring. At present, some methods such as satellite remote sensing, aerial remote sensing are very common ways to collect data [1]. Although these methods are very useful in practice, they are not effective, fast and accurate enough. The cycle of getting satellite remote sensing images is usually long, so the currentness may not be guaranteed, and also the accuracy of discrimination will be affected because of lower resolution of satellite remote sensing images. Higher resolution images can be obtained by aerial remote sensing methods, but there are some limitations to the air planes such as air traffic control, weather condition and high cost. In addition, if the mission is urgent, preparations cannot be done in time.

UAV (Unmanned Aerial Vehicle) based photogrammetry is becoming a popular field recently, because it has some advantages compared with traditional ways of data collection [2]: 1) lower cost of platform building; 2) flexible and rapid response; 3) capacity of obtaining high resolution images and precise positioning data; 4) implementation of high-risk and high-tech missions; 5) no need of permissions for airspace control for low-altitude flights in most countries (e.g. in China). As a result of these advantages, building Earth observation systems based on UAV platforms has become a hot topic throughout the world.

However, there are also some new problems, which have not appeared in traditional methods of data processing [3]: 1) the attitude angles between neighboring UAV images are much larger than those of traditional aerial images, and the forward overlap degree may be very low. Therefore, there are some difficulties in features matching in this case; 2) the image format is smaller than usual, and the number of images is large, so some effective algorithm have to be investigated to improve data processing; 3) The flight routes are curves, and the lateral overlap degree may not be big enough for image mosaicking. So some preparations, which can be called as image overlap analysis, should be done before image processing, and some images which do not meet the overlap requirements will be removed and those areas should be photographed again in time.

Therefore, in order to avoid the problems above and guarantee the images are eligible for mosaicking and mapping, some pretreatments should be done before image processing. In this paper, a method of UAV images overlap analysis is

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described, and some experiments are made to test the method in different situations.

II. IMAGE OVERLAP ANALYSIS

The image overlap analysis is a method which can guarantee that the UAV sequence images can meet the requirements of surveying and mapping and there are enough corresponding feature points to complete image mosaicking or mapping. In the route and lateral directions, the degree of overlap should be at certain range, and if not so, the photos should be photographed again. As the UAV attitude is not easy to control and susceptible to the environment factors, the overlap degree of sequence images may not be within the range threshold. Therefore image availability analysis should be done before image processing.

A. *Degree of overlap*

Aerial images should cover the whole survey area, and the degree of overlap between the images should also be sufficient [4]. Usually, the degree of overlap in the route direction should be between 60% and 65%, and no less than 53%; the overlap degree in the lateral direction should be between 30% and 40%, and no less than 15% [5]. The UAV is not easy to control and sensitive to weather conditions, so the stability of UAV is lower than that of air planes, and the flight strip will become a curve instead of a straight line (the value of strip curvature should be no more than 3%). So it is necessary to compute the degree of overlap firstly, and in order to get enough feature points to compute the transformation matrix between neighboring images, the threshold of degree of overlap should be determined, and here we suggest 55% for route direction and 30% for lateral direction.

B. *SIFT Algorithm*

The first step of calculating the degree of overlap is to extract stable features and match them, and here we choose the SIFT algorithm [6].

In 2004, David Lowe presented an algorithm called SIFT (Scale Invariant Feature Transform) to extract distinctive invariant features from images [6, 7]. The features are invariant to image scale and rotation, and even robust to affine transformation and change in illumination. A large number of features can be extracted from typical images with efficient algorithms. A typical image of size 500x500 pixels will give rise to about 2000 stable features (although this number depends on both image content and choices of various parameters). The major steps of the SIFT algorithm are as follows:

1) Scale-space extrema detection. The first step is to search all scales and image locations. The input image is firstly convolved by a Gaussian function with differet scale factors [8, 9], and it is implemented efficiently by using a difference-of-Gaussian (DoG) function to identify potential keypoints. Points in the DoG images which are local extrema in their own scale and one scale above and below are extracted as keypoints.

*2) Keypoint localization.*The location and scale of each candidate point is determined and keypoints are selected based on measures of stability.

*3) Orientation assignment.*One or more orientations are assigned to each keypoint location based on local image gradient directions. To determine the keypoint orientation, a gradient orientation histogram is computed in the neighborhood of the keypoint (using the Gaussian image at the closest scale to the keypoint's scale).

*4) Keypoint descriptor.*A 128-dimension descriptor is generated for each keypoint from local image gradients information at the scale found in step 2.

C. *Calculation of the degree of overlap*

As the SIFT algorithm detects features in different scales of the image, and the descriptors are 128-dimension vector, there will be a large amount of calculation and the speed of image processing will be very slow. Because the accuracy of feature matching in this stage is not high, the resolution of images can be decreased firstly to increase the speed of SIFT algorithm. In the step of creating descriptors, we can use a window of 2x2 instead of 4x4 to form a descriptor. By doing this, the number of dimension will be decreased, and the matching speed can be increased, but the number of wrong matching points will also be increased.

After matching SIFT features, there are some wrong matching points which can be removed by RANSAC algorithm [10]. However, it is shown that if these outliers are not removed, the statistic result of degree of overlap will not be affected greatly, and the results are listed in the experiment part.

The degree of overlap can be recorded by histogram, and each bin represents a range of 10%, and the ordinates represent the number of matching points. The bin with largest number of matching points describes the degree of overlap between two neighboring images. Figure 1 shows the calculation methods of the degree of overlap. If the weather condition is good enough, the strip curvature will be very small, and in this case the overlap part along y direction can be ignored, and the formula we use can be expressed as

$$\mathbf{O_g\% = (P_x / L_x) * 100\%} \qquad (1)$$

If the weather condition is bad, the strip curvature will be big which may lead to a small overlap area along y direction, and the whole overlap area should be taken into account to calculate the overlap degree, and the formula is

$$\mathbf{O_b\% = [(P_x * P_y) / (L_x * L_y)] * 100\%} \qquad (2)$$

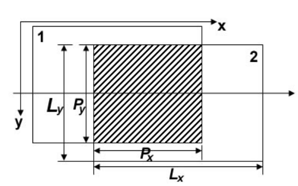

Figure 1. Computation of the degree of overlap

D. Steps of image overlap analysis

The step of image overlap analysis can be expressed as follows:

1) Down-sample the sequence images to increase the speed of SIFT;
2) Extract the SIFT features from each UAV image;
3) Match extracted features;
4) Estimate flight status. This step is used to determine whether the next image should be resampled to calculate the degree of overlap;
5) Compute the degree of overlap for route and lateral direction;
6) Compare the degree of overlap with the given threshold (described in Part II - A) to determine whether the images are eligible or not.

III. EXPERIMENTS AND ANALYSIS

A. Experiments

Two source images are shown in Figure 2 and Figure 3, and the original resolution is 2592×1944. As the SIFT algorithm will take a very long time to process the images, we down-sampled the images firstly to increase the matching speed. In this test, the resolution was decreased to 500×375, and some tests are described as follows:

Figure 2. Image 1 (*Left image*)

Figure 3. Image 2 (*Right image*)

1) Test 1. Firstly, we used the SIFT algorithm to extract features and match them, corresponding points are connected with solid lines (Figure 4). It is obvious that there are some wrong matching points in the images. As a test, we did not do anything with these wrong matching points, and just used all the detected corresponding points to compute the overlap degree, and the result is listed in Table I.

2) Test 2. Firstly, we used the SIFT algorithm to extract features and match them, and the RANSAC algorithm was applied to remove outliers, the result is shown in Figure 5, and the result of the degree overlap shown in Table II was calculated by inliers.

3) Test 3. This test was designed for bad situations which may affect the control of UAV. The UAV is hard to control because of the bad weather condition, and the heading angle would be bigger than usual. In this case, the values of 2 or 3 bins might be very close which would lead to a wrong result of the degree of overlap. Figures 6 and 7 are two source images with bigger heading angles, and Figure 8 shows a resampled image of Image 4. The degree of overlap result is listed in Table III.

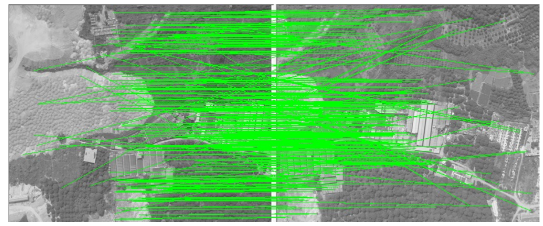

Figure 4. Matching result by using the SIFT (wrong matching points included)

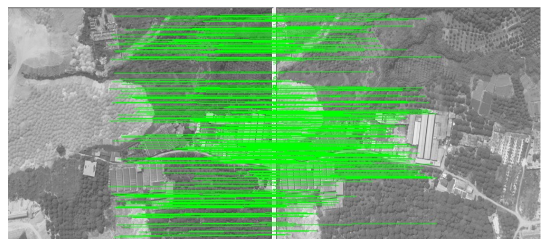

Figure 5. Matching result by using the SIFT and RANSAC

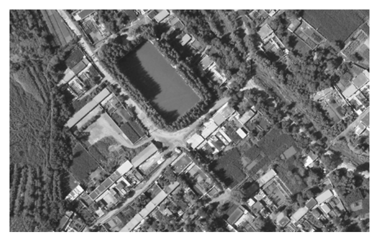

Figure 6. Image 3 (*Left image*)

Figure 7. Image 4 (*Right image*)

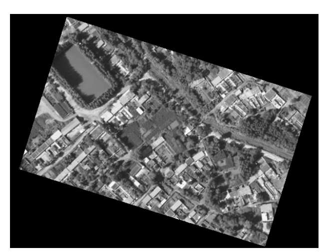

Figure 8. Resampled image of Image 4

B. Analysis

In test 1, nothing had been done with wrong matching points, and it is obvious that some matching results are wrong, and the effect of these wrong matching points can also be found in Table 1. Most results of the degree of overlap calculated by corresponding points are between 61% and 70%, and very few of them fall into other areas. So it was demonstrated that if the number of wrong matching points is small, the final result would not be affected.

In test 2, we used RANSAC to remove outliers, and the result is shown in Figure 5. Here we considered the relationship between neighboring images as perspective projection because the distance from the camera to the objects is far more than the principal distance of the camera [11]. The result of the degree of overlap is calculated by inliers, and is very consistent with the result from test 1.

By comparing test 1 with test 2, we can see that if the wrong matching points are few we can ignore them and just use the matching result to compute the overlap degree. We have done many similar tests like test 1 and test 2, and have reached the same conclusion.

In the case described in test 3, the wrong matching points should be removed by using RANSAC, and the transformation matrix should be computed to resample the right image (Figure 8) to the coordinate system of left image (Figure 7). Then the SIFT algorithm should be applied again to find corresponding points to calculate the overlap degree. The results listed in Table III shows that if we had not resampled the right image, the final result would have been wrong.

The thresholds of the degree of overlap in the route and lateral directions can be set as 55% and 30% respectively.

IV. CONCLUSIONS

In this paper, we have described a UAV image overlap analysis method. The speed of overlap analysis can be increased by down-sampling the image resolution and simplifying the SIFT descriptor, and the way of treating wrong matching points has been described with encouraging results.

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TABLE I. RESULT OF OVERLAP DEGREE (WRONG MATCHING POINTS INCLUDED)

Overlap degree (%)	<=10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>=90
Number of corresponding points	0	0	0	1	2	3	339	3	3	30

TABLE II. RESULT OF OVERLAP DEGREE (NO WRONG MATCHING POINTS INCLUDED)

Overlap degree (%)	0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
Number of corresponding points	0	0	0	0	0	0	301	0	0	0

TABLE III. COMPUTATION RESULT OF OVERLAP DEGREE BEFORE AND AFTER RESAMPLING (NO WRONG MATCHING POINTS INCLUDED)

Overlap degree (%)		0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100
Number of corresponding points	**before**	0	0	0	0	0	0	155	393	70	0
	after	0	0	0	0	0	0	0	0	576	0

REFERENCES

[1] J. Han and Z. Wang, "On the Key Technique of Fast Monitoring System for Land Resourses Unmanned Plane Remote Sensing", Bulletin of Surveying and Mapping, vol. 2, pp. 4-6, 2008.

[2] J. Sun, Principle and Application of Remote Sensing, Wuhan: Wuhan University Press, 2003.

[3] C. Wang, Image data processing methods of UAV low-altitude remote sensing, Doctoral dissertation, Shandong University of Science and Technology, pp. 5-6, 2006.

[4] D. Li, Y. Zhou, and W. Jin, "Introduction on Photogrammetry and Remote Sensing", Beijing: Surveying and Mapping Press, pp. 12-14, 2003.

[5] P. Wang and Y. Xu, "Photogrammetry", Wuhan: Wuhan University Press, pp. 16-17, 2007.

[6] D. G. Lowe, "Object Recognition from Local Scale-Invariant Features", International Conference on Computer Vision. Corfu, pp. 1150-1157, Sept, 1999.

[7] M. A. Brown, "Multi-Image Matching using Invariant Features", Doctoral dissertation, The University of British Columbia, pp. 16-17, 2005.

[8] J. J. Koenderink, "The structure of images", Biological Cybernetics, vol. 50, pp, 363–396, 1984.

[9] T. Lindeberg, "Detecting salient blob-like image structures and their scales with a scale-space primal sketch: A method for focus-of-attention", International Journal of Computer Vision, vol 11, pp. 283–318, Mar, 1993.

[10] M. A. Fishchler, "Random Sample Consensus: a paradigm for model fitting with application to image analysis and automated cartography", Communication Association Machine, vol. 24, pp. 381-395, Jun, 1981.

[11] Z. Li, "On the Theory of Image Mosaicing and Its Related Algorithms", Doctoral dissertation, Nanjing University of Science and Technology, pp. 16-18, 2004.