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Image Stitching Algorithm for Drones Based on SURF-GHT

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Abstract. Aiming at the problem that the amount of single remote sensing picture information is limited due to the limited angular range of single drone, this paper proposes SURF-GHT algorithm based on SURF algorithm and generalized Hough transform based on the existing image stitching algorithm. After the feature points are extracted by the SURF algorithm for the pictures to be spliced, the decision tree forest in the generalized Hough transform is used to filter the set of feature points, and then the fading image fusion algorithm is used for image splicing. The experimental results show that the SURF-GHT algorithm improves the quality of image stitching on the basis of higher stitching efficiency, and better satisfies the subsequent identification of remote sensing images of drones.

1. INTRODUCTION

During the flight of the drone, due to the limited flight height, the limited wide-angle of the aerial camera carried, and so on, the single remote sensing photograph contains a small amount of information, which leads to some difficulties and obstacles in the subsequent processing and recognition of the image. In order to obtain image information of a relatively complete shooting area, multiple aerial images are required to be image stitched.

Image stitching is basically divided into several steps, which contains extracting and matching feature points, registering target images, blending images to be stitched and special processing on overlapping borders. Among them, the registration and integration of the target image is more important. In the splicing process, the image splicing algorithm will largely affect the accuracy and speed of the final spliced image.

At present, there are many researches on the image stitching algorithm for drones at home and abroad. The idea of image stitching was originally proposed by computer graphics founder Ivan Futhefland at the 1965 IFIP conference. After decades of development research, by 2004, image stitching processing technology developed rapidly. Specially, Lowe et al. [1] officially proposed image-splicing technology based on Scale-Invariant Feature Transform (SIFT), which made splicing of multiple high resolution images better. Since then, Bay et al. [2] proposed the Speeded Up Robust Features (SURF) based on the SIFI algorithm to improve the matching efficiency.

2. SURF-GHT ALGORITHM STEPS

This paper proposes a SURF-GHT image mosaic algorithm based on SURF algorithm for feature matching and generalized Hough transform. The algorithm flow is as follows:

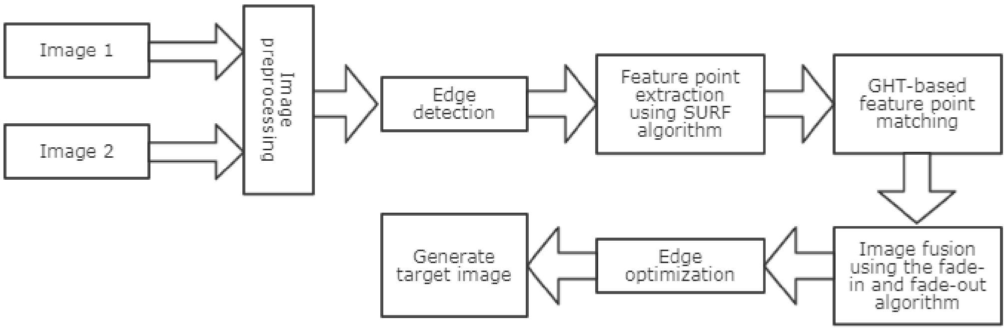

Figure 1 SURF-GHT algorithm flow chart

2.1. Gauss Pyramid Scale Space for Constructing Images

Edge detection of images is performed using a second-order differential operator, Laplacian [3]. There is a Hessian matrix for each pixel in the image, as follows:

$$\mathrm{H}(\mathrm{f}(\mathrm{x},\mathrm{y})) = \begin{bmatrix} \dfrac{\partial^2 \mathrm{f}}{\partial \mathrm{x}^2} & \dfrac{\partial^2 \mathrm{f}}{\partial \mathrm{x}\,\partial \mathrm{y}} \\ \dfrac{\partial^2 \mathrm{f}}{\partial \mathrm{x}\,\partial \mathrm{y}} & \dfrac{\partial^2 \mathrm{f}}{\partial \mathrm{y}^2} \end{bmatrix}$$

Considering that the UAV is affected by factors such as external wind, its own power, and attitude changes during the actual flight aerial photography, it is necessary to perform Gaussian filtering on the image to ensure the scale independence of the feature points. After that, Hessian is calculated [3] as follows:

$$\mathrm{H}(\mathrm{x},\sigma) = \begin{bmatrix} L_{xx}(x,\sigma) & L_{xy}(x,\sigma) \\ L_{xy}(x,\sigma) & L_{yy}(x,\sigma) \end{bmatrix}$$

The approximate value of the Hessian matrix discriminant is calculated as follows [4]:

$$\mathrm{Det}(\mathrm{H}_{\mathrm{approx}}) = \mathrm{D}_{\mathrm{xx}}\mathrm{D}_{\mathrm{yy}} - (0.9\mathrm{D}_{\mathrm{xy}})^2$$

After template calculation, the value of a certain pixel is compared with the value of 26 adjacent pixels in the three-dimensional region of the pixel. If the calculated value of the specific pixel is the maximum, the pixel is identified as a feature point.

2.2. Extraction and Matching of Feature Points

After extraction by SURF algorithm, the set of feature points is obtained. At this time, it is necessary to match the homonymous feature points between the target images. In this paper, the generalized Hough transform is introduced. By using multiple decision trees in Hough forest, each leaf node in the decision tree has local feature information and offset to reach the leaf node, and the proportion of the leaf node's feature information category is counted, so that a highly reliable probability vote is obtained, thereby ensuring the screening precision of the feature points.

The SURF-extracted feature vector $\{\mathrm{f_i}\}$ is used as the input sample set of the Hough classification tree, and the class information $\{\mathrm{c_i}\}$ of these feature vectors is used as the supervised information [5].

After the sample set is input into the decision tree, the node splitting dichotomy test is used, that is, when the difference between the components of the two feature vectors that need to be compared in the same dimension is less than a threshold value defined by the implementation, the current node is determined to satisfy the condition of continuing splitting. Then, the same judgment operation is performed on the sub-nodes until the condition of the decision tree continues to grow is satisfied. At this time, the test sample stores relevant information in the leaf nodes to ensure the next probability judgment. In this way, the position of the target center can be roughly judged according to the information in the responding leaf nodes. The bisection test of node splitting is as follows [5]:

$$\mathrm{Test}_{x,y}(Z) = \begin{cases} 0, \text{if } |Z(x) - Z(y)| < C \\ 1, \text{otherwise} \end{cases}$$

Among them, Z (x), Z (y) represent eigenvectors and C represent thresholds.

The decision tree in Hough Forest obtains the image region P(y) centered on y during the training process. A random event in which there is a possibility that the target center position is centered on the position x in the image is denoted as E(x). The offset from the position y to the center of the feature point is denoted as d(y). When the node stops splitting to generate the leaf node, according to the information stored in the leaf node, for a single tree T, the probability estimate of the current feature point of the test sample [6] is:

$$p(E(x)|\, I(y); T) = [\frac{1}{|D_L|}\sum_{d \in D_L} \frac{1}{2\pi\sigma^2} \exp(-\frac{||(y-x)-d\,||^2}{2\sigma^2})] \cdot C_L$$

In the formula, C_L denotes the probability of reaching the target image area of the leaf node, and D_L denotes the distance deviation vector of the target image area. For the whole Hough forest, the average probability of all decision trees is obtained by using this method. The estimated probability is as follows [6]:

$$p(E(x)|\, I(y); \{T\}_{n=1}^{N}) = \frac{1}{N}\sum_{n=1}^{N} p(E(x)|\, I(y); T_n)$$

Finally, in order to simplify the classification and detection process of Hough forest, the maximum probability of all candidate features is selected as the final estimation value, and the actual target location is determined according to the set threshold.

2.3. Image Fusion and Boundary Optimization

After the selection of generalized Hough transform and Hough forest decision tree, the set of feature points with high similarity and good matching degree is obtained. After registration, the set of feature points corresponding to the two images to be stitched is considered for image fusion. Because the UAV will be affected by flight attitude, illumination intensity, air humidity and other factors in the actual aerial photography process, it is necessary to select appropriate image fusion algorithm to ensure that the image gray value to be stitched to a certain extent to maintain continuity, reduce data cliff, so as to avoid obvious stitching gap. The gradual inversion image fusion algorithm [7] is used to make a natural transition to the spliced image, thereby improving the quality of the splicing.

In the overlapping area of two images to be stitched, the gradient-in and gradient-out image fusion algorithm makes the weight W linear with the position change of the independent variable, i.e. the pixels [8]. The change rules are as follows:

$$w = 1 - \frac{\mathrm{line} - L}{R - L}$$

In the formula, line represents the column where the current pixels are located, L represents the left boundary of the overlapping area of the mosaic image, and R represents the right boundary of the overlapping area of the mosaic image. According to the weight w, we can get the formula of the gradual-in and gradual-out image fusion algorithm [9].

$$I(x,y) = \begin{cases} I_1(x,y), (x,y) \in I_1 \\ w_1 I_1(x,y) + w_2 I_2(x,y), (x,y) \in (I_1 \cap I_2) \\ I_2(x,y), (x,y) \in I_2 \end{cases}$$

Where I(x, y) represents the current pixel generated by fusion, $I_1(x,y)$ and $I_2(x,y)$ represent the current pixel of the two images to be stitched, respectively, w_1 and w_2 represent the weight values of the current pixel points of the two pictures to be stitched.

3. EXPERIMENTAL RESULTS AND ANALYSIS

3.1. Result Analysis of Feature Point Matching

SURF-GHT algorithm extracts feature points by SURF algorithm, and then introduces generalized Hough transform to classify and count feature information using multiple decision trees in Hough forest, so as to achieve the purpose of screening and matching. In order to compare the performance of several feature matching algorithms, this paper compares the efficiency of feature extraction and matching of SIFT algorithm, SURF algorithm and SURF-GHT algorithm respectively, in order to evaluate the advantages and disadvantages of the algorithm. The experimental environment of this paper is Matlab, in which the SURF algorithm calls the underlying library function of Matlab.

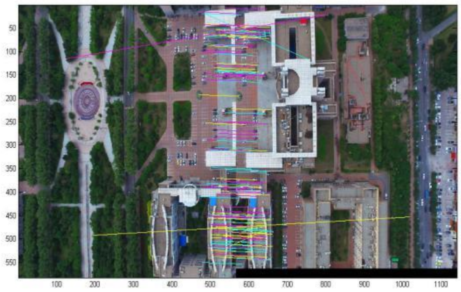

Figure 2 SIFT matching result

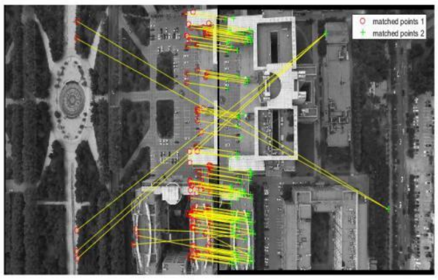

Figure 3 SURF matching results

Table 1 Comparison of Matching Effect

Algorithm type	Number of Characteristic Points in Left Graph	Number of Characteristic Points in Right Graph	Matching point pair	Matching time /s
SIFT	566	1921	157	103.840
SURF	688	808	115	2.233
SURF-GHT	688	808	132	2.304

It can be seen from the above table that the SIFT algorithm matches best when other conditions are consistent, but the matching time is the longest.The SURF matching is slightly worse, and the matching time is shorter. In contrast, the proposed SURF-GHT algorithm guarantees the same feature extraction speed as SURF algorithm and increases the number of matching point pairs.The matching time is almost the same.

3.2. *Image Fusion Results Analysis*

After the decision tree of Hough forest of the generalized Hough transform is used to screen the feature point set, the fading operation is performed by using the fading image fusion algorithm. This experiment uses the Xcode IDE, on the Mac OS system, calls some OpenCV library functions and reads in the two images to be stitched (Figure 4, Figure 5). The stitching results are shown in Fig. 6.

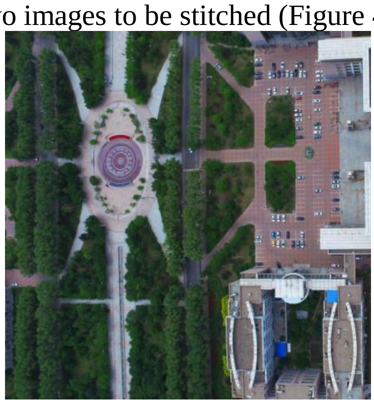

Figure 4 Left to be stitched

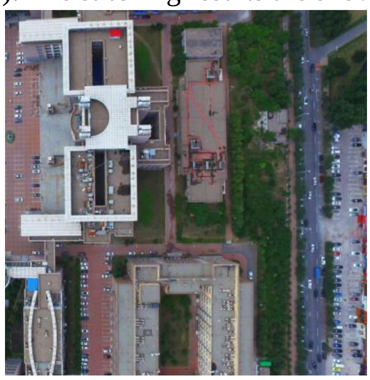

Figure 5 Right to splice

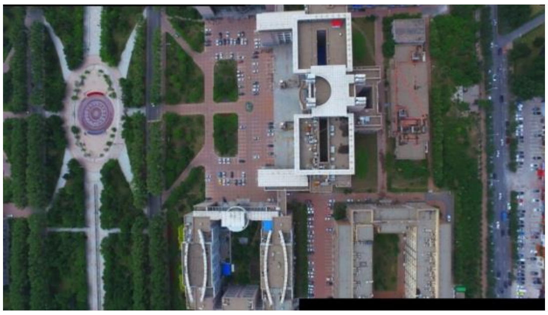

Figure 6 Mosaic results

It can be found that the fusion processing at the boundary is better in the splicing result graph, and there is no significant gradation value of the splicing edge large area blank caused by the gradation value, which also proves that the operation of filtering the feature point using the generalized Hough transform has a positive impact.

4. CONCLUSION

Based on the advantage of SURF algorithm's faster extraction of feature points and the generalized Hough transform, this paper proposes the SURF-GHT unmanned aerial image stitching algorithm. The decision tree of Hough Forest is used to screen the set of feature points, aiming at improving the quality of image stitching. The experimental results show that the SURF-GHT algorithm is used to splice the remote sensing image of UAV, which shows good splicing efficiency and splicing quality, and provides an effective means and method for remote sensing image splicing of UAV.

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