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An Improved ORB Algorithm of Extracting and Matching Features

Lei Yu[1], Zhixin Yu[1] and Yan Gong[2]
College of Information and communication Engineering, Harbin Engineering University, Harbin, Heilongjiang, China
260548780@qq.com

Abstract

For feature extraction of image mosaicing, an improved fast extracting algorithm of binary feature points is presented which is based on ORB (Oriented FAST and Rotated BRIEF). In the process of detection using median filter method to detect more accurate feature points. Improving the speed by using the ORB algorithm to extract image binary descriptors and using RANSAC algorithm and homography matrix to eliminate false matching points. In the end, making use of perspective transform to map points for obtaining the target coordinates to correct images and achieve two images matching in the scene. The experiment is under the environment of OpenCV and Visual Studio2010.The result shows that the improved ORB algorithm is faster and more accurate.

Keywords: *ORB, Median filter, RANSAC, SIFT, SURF*

1. Introduction

Image registration is a vital step in image mosaic, the image matching algorithm continuously updated and became mature in recent years. There are a lot of image registration technique is used in many fields in real life, such as space image acquisition, the weather forecast, face recognition, cell detection in medicine, CT, skull restoration and so on, in addition in the military, cartography, graphics and computer vision.

Image registration methods are divided into three categories: one is the image registration based on pixel value; the second is image registration based on transform domain; the last one is based on image features. The first two methods are easily affected by factors such as brightness change, rotation and the computing time is long. So the third method is widely used. In 1999, the SIFT algorithm proposed by David G. Lowe make image mosaic technique have significant improvement [1]. SIFT has the rotational invariance, scale invariance, brightness invariance and good anti-noise ability. It is superior to other methods and has been widely used; now it has become the mainstream algorithm. In 2003, M. Brown used SIFT algorithm to realize the automatic panorama splicing [2]. ASIFT algorithm makes SIFT algorithm be affine invariant which is put forward in 2009 by Morel [3]. In 2006, Bay, *et al.*, proposed a registration algorithm after SIFT algorithm based on fast robust characteristic--SURF algorithm [4]. This method has robustness for the scale and rotation like SIFT algorithm, but it has greatly improvement on the calculation speed. Edward Rosten first put forward the FAST (the Features from Accelerated Segment Test) algorithm in 2006, which greatly improving the speed, but the precision is not high and does not have scale invariance. In order to simplify the calculation, there is a feature points extraction algorithm used binary method in recent years. The ORB algorithm is a typical binary algorithm proposed by Ethan Rublee, *et al.*, in ICCV (IEEE International Conference on Computer Vision) 2001. ORB algorithm is put forward based on FAST and BRIEF algorithm, not only the speed has greatly

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improvement, but also it has the rotational invariance compared with the single BRIEF algorithm.

Firstly this paper uses median filter to eliminate the noise in the image to reduce the interference, then uses the ORB algorithm to extract descriptors. Getting an effective sample combined homography matrix with RANSAC algorithm to weed out the wrong matching points. Perspective transformation is used to correct the image and finally achieves a match. The method improves the speed of matching and obtains more correct points.

2. The Principle of ORB Algorithm

ORB algorithm [5], which is proposed based on FAST algorithm and BRIEF algorithm, is a method to describe feature points by using the binary string. Since the feature point of ORB is detected by the improved FAST feature detection, and which is described using an improved BRIEF feature descriptor, and the speed of FAST and BRIEF are very fast, ORB has an absolute advantage in speed. The greatest feature of this algorithm is fast and having rotational invariance and reducing sensitivity to noise.

2.1. FAST Feature Points Detection

FAST（Feature from Accelerated Segment test）algorithm [6] is a common algorithm for the fast feature point's detection. Its basic definition is that when the neighborhood around a pixel A has enough pixels in a different gray area with the pixel A, the point of pixel A is recognized as a FAST corner. Applying it to the grayscale images, FAST corner's neighborhood has enough pixels, and these pixels' gray values is greater or less than the point of pixel A's gray values. Generally, choosing an arbitrary pixel point as center to form a circular area, and considering the circular area as the pixel point's neighborhood. The Figure1 show a discrete Bresenham circle, whose radius is 3, central pixel is P and the peripheral pixels are numbered clockwise from 1 to 16. If in the 16 pixels, there are consecutive n pixels satisfy the equation (1), we can consider P as a candidate feature point.

$$\left|I_x - I_p\right| > t \tag{1}$$

t is a given threshold, Ix is the gray value of consecutive n pixels, Iy is the gray value of point P. In order to achieve fast, generally, we choose n as 12 or 9, *etc.*, it depends on the specific requirements, and the value of n is 9 in ORB algorithm.

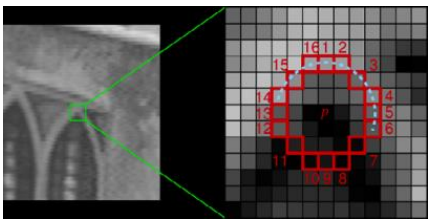


Figure 1. FAST Feature Point Detection Template

We can calculate the four points 1,9,5,13 firstly, if in the four points, there are at least three points satisfy this point, this point can be considered as a candidate corner point, and than continue to compare the other points. But both FAST algorithm and BRIEF algorithm that will be introduced next do not have scale invariance, so we can use the scale pyramid to resolve this problem. To obtain the candidate feature points, we should carry on FAST testing in each layer.

ORB algorithm use Harris algorithm [7] to detect the interesting points in the feature points which have been detected, sort the detected point and take the N points which are most suitable.

FAST algorithm has the features of translational and rotational invariance, not sensitive to noise, high reliability for the feature points, calculating conveniently, but the feature points do not have directionality. Therefore ORB algorithm uses the oFAST algorithm to detect the feature points, which is the FAST operator that has direction. Using the method of intensity centroid to calculate the direction of the corner and achieving a feature point which has a direction. The concrete operation will be described in the next section.

2.2.Description of BRIEF Algorithm Feather

After obtaining the feature point with direction, descriptors has been built using BRIEF (Binary Robust Independent Elementary Features) descriptor ideas [8]. BRIEF extracts descriptors around feature points by binary coding method. The descriptor is simpler and storage space is smaller than SIFT and SURF. Specific methods are as follows:

The image spot P is S*S around the feature point, randomly selecting nd pairs of pixel point and defining it as τ

$$\tau(p;x,y) := \begin{cases} 1 & if \quad p(x) < p(y) \\ 0 & otherwise \end{cases} \tag{2}$$

P(x) is the pixel intensity at the point of the x=(u ,v)T which is in the image spot P after filtering process. A set of points can uniquely identify one binary detection τ. So it defines nd -dimensional binary string just as equation (3) as the BRIEF descriptor.

$$f_{n_d}(p) := \sum_{1 \le i \le n} 2^{i-1} \tau(p;x_i,y_i) \tag{3}$$

nd Can be 1 28, 256 and so on, setting one according to the specific requirements.

BRIEF algorithm mentioned before do not have the scale invariance. In addition, there are some shortcomings such as the sensitivity to noise and not having the rotational invariance. First, solving the problem of sensitivity to noise, BRIEF algorithm is to randomly select nd pairs of points for comparison around the feature point in the 31 * 31 pixel spots while the ORB makes the point comparison equivalent to the sum of pixels of small window .The small window of 5*5 pixels takes the place of the original single point, The ORB makes the image blocks pre-smooth and improves the stability and repetition of the descriptor. Accelerate it by integral image, so this step will not be much loss in performance.

The ORB algorithm can greatly solve the problem of rotational invariance which the BRIEF algorithms don't have, the main way is to add a direction for BRIEF descriptors. First defining the moments of plaque (circular neighborhood) is

$$m_{pq} = \sum_{x,y} x^p y^q I(x,y) \tag{4}$$

x, y is in the position of the FAST feature point ,circular neighborhood radius r, x, y ∈ [-r, r]. Then calculate the center of gravity of the plaque, as shown in equation (5).

$$C = \left(\frac{m_{10}}{m_{00}}, \frac{m_{01}}{m_{00}} \right) \tag{5}$$

The Angle which is formed by feature point and the center of gravity has been defined as for the FAST feature point direction:

$$\theta = \arctan\left(\frac{m_{01}}{m_{10}} \right) = \arctan\left(\frac{\sum_{x,y} yI(x,y)}{\sum_{x,y} xI(x,y)} \right) \tag{6}$$

The ORB algorithm extracts the BRIEF descriptors according to direction provided by the equation (6), Because of the environmental factors and the noise will change the direction of the feature points, the correlation of random pixel blocks of will be relatively large, thus reducing the discrimination of descriptors. The random ORB algorithms take a greedy algorithm [9] to find random pixel block with low correlation, usually select 256 pairs of pixel block with the lowest correlation which forms the 256 bit feature descriptor, which is called rBRIEF.

2.3.The Flow Chart of basic ORB Algorithm

According to the principle of the ORB algorithm, we can get the following flow chart.

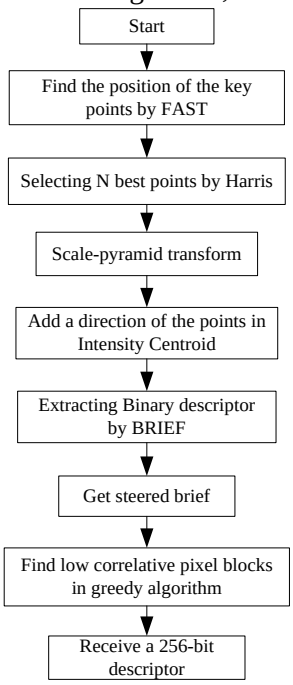


Figure 2. The Flow Chart of ORB

3. The Extraction and Matching of the Features based on Improved ORB Algorithm

In order to improve the calculation speed and correct the images, this paper proposes an improved algorithm based on the ORB algorithm. The process mainly includes: 1. Using median filter to eliminate the noise in the images and reduce interference. 2. Using the ORB algorithm to extract candidates. 3. Adopting RANSAC (random sampling uniformity) algorithm and homography matrix to weed out the wrong matching points 4. Perspective transformation matrix is used to correct the images and ultimately achieving images matching. The basic principle and steps of the ORB algorithm are detailed in section 2. This section introduces the implementation of the rest of the process steps.

3.1. Median Filtering Method to Eliminate Noise

The median filtering method is adopted to remove the noise and gets higher precision matching points. Each pixel's gray value is set the mid-value of all pixels' gray value within certain neighborhood window. The basic principle of Median filter is the value of a point in the digital images which instead by the mid-value, making the surrounding pixels' value closes to the real value for eliminating isolated noise points. Since the median filter is non-linear, it cannot be expressed as a nuclear matrix. However, it also operates around a region to determine the value of the output pixel. The pixel and the region around it make up a set of numbers, just as the name implies, the median filter only calculates the median value, and takes the median value instead of the current pixel value. So the median filter is particularly effective for removing the Salt-and-Pepper noise. Median filtering could keep the edge sharpness at the same time; it will remove the texture in the same area, such as the trees in the background. This method can also be in the RANSAC algorithm when a homography matrix established to provide more correct matching points.

3.2. Extracting the Descriptors

The ORB algorithm is utilized to extract a series of feature points in the first place. As the description is a binary string, so you can use Hamming distance for matching feature points. The hamming distance between two equal length strings is the number of different characters in corresponding position. If the corresponding value of a bit is same, hamming distance is zero or is 1, in other words, the less 1 is, the more similarity of the descriptors. In order to set the threshold to filter matching points, it based on the ratio T of neighbor distance and second neighbor distance, where $T < 0.8$. This algorithm simplifies the calculation.

3.3. Eliminating the False Matching Points

This article eliminates false matching points by RANSAC algorithm combined with homography matrix. RANSAC algorithm is based on a set which contains abnormal data, calculating the mathematical model of the data parameter, getting effective sample. RANSAC algorithm uses less point to estimate model, then verifies the model by the remaining point's. It makes up the defect of the general parameter estimation method, then reducing the influence of abnormal data.

Finding homography matrix [10] between two images and it is a 3 * 3 matrix.

Eliminating false matching points with a threshold to keep good matching points in this paper. In the field of computer vision, two images in the same plane could through homography to link together. For example, an object can be achieved two different photos by rotating camera lens, we can set homography as a two-dimensional matrix M, so picture1 multiply M is picture 2. It has many practical applications, such as image correction, image alignment or calculating the camera motion between two images (rotation and translation), *etc.*, Once the rotation and translation is extracted from estimated homography matrix, then the information will be used to navigate or insert the 3D model to the image or video, making it render according to the right perspective and becoming a part of the original scene.

For each feature point of a picture, may find two candidate matching points in another registration image, we use the threshold to filter out some candidates. The more good matching points are selected, the more possibly that the RANSAC will give a correct matrix, so the median filtering method can improve the accuracy. Specific method is as follows: (1) there is a model adaptes to the assumption of inside points (a selected subset), and all the unknown parameters can be calculated from the hypothesis of inside points. (2) Testing all the other data by the model of step (1), if a point is suitable for the estimation of model and it is also an inside point. (3) If there are enough points classified as inside points, the estimated model is reasonable. (4) Reestimating the model with all the assumptions of inside points. Then you can get a more accurate model, according to this model to screen false matching points.

3.4. The correction and matching of images

This article uses perspective transformation [11] to correct images and ultimately to complete two images matching. Perspective transformation means that making use of perspective center, image points, target points are collinear, then according to the laws of perspective rotation make perspective plane rotate around perspective axis an angle, destroying the light beam of original projection, remained projection geometry transformation on perspective plane. The process can be shown as Figure 3. Image A can transform Image B through a perspective transformation (here it regards as a plane) made of u and v.

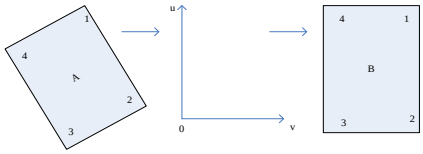


Figure 3. The Schematic of Perspective Transform

Perspective transformation is projective transformation of the projection center, it is often used in image correction. Generally speaking, it will increase the computation time with perspective transformation, while through experiment, matching time has little change, so this paper adopts the perspective transformation to correct pictures. Finally, linked the coordinates of the transformed images to achieve matching results. Figure 4 is the flow chart of the improved ORB algorithm.

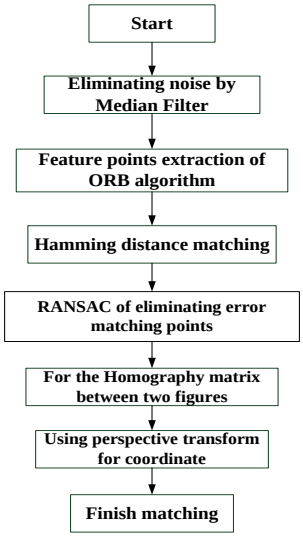
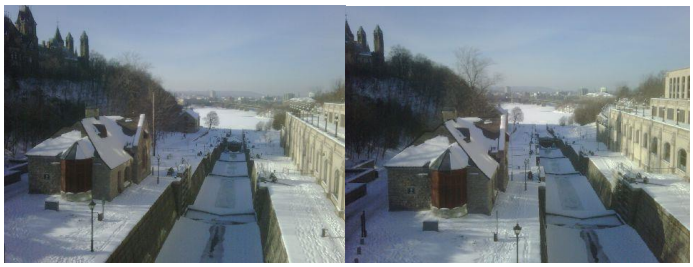


Figure 4. Flow Chart of improved ORB Algorithm

4. The Experiment and Discussion

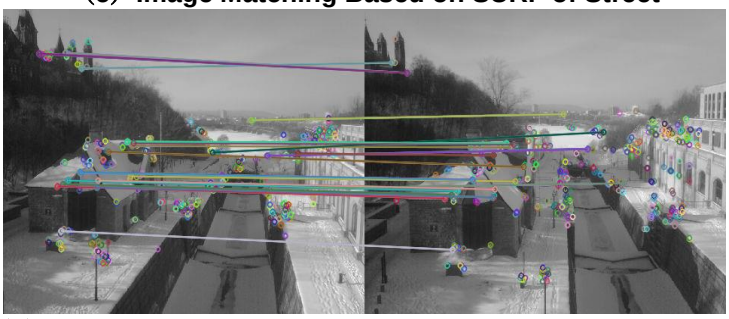
To verify the ORB algorithm is feasible, the paper compare the classical SIFT algorithm and SURF algorithm with ORB algorithm, the threshold is 0.8 which controls the match points the experimental environment is Visual Studio2010 and OpenCV. This paper will take two groups of images for validation. The first set of pictures called street from the typical images, the size is 480 * 360 and with JPG format; the second set of pictures called library captured by digital camera, the size is 608 * 342 and with JPG format.



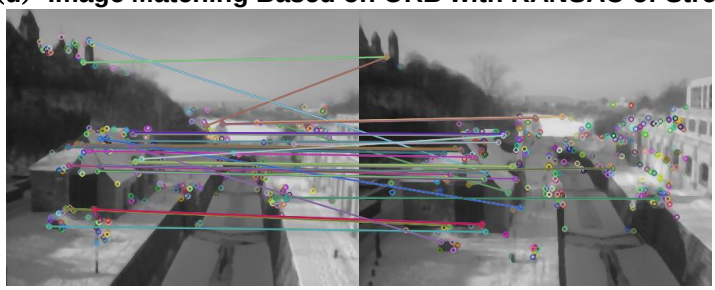
(a) Two Original Images of the Street

(b) Image Matching Based on SIFT of Street

(c) Image Matching Based on SURF of Street



(d) Image Matching Based on ORB with RANSAC of Street



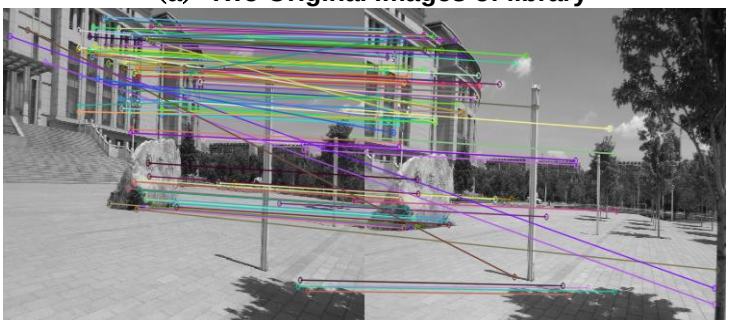
(e) Image Matching Based on Improved Method of Street

Figure 5. The Test of Street

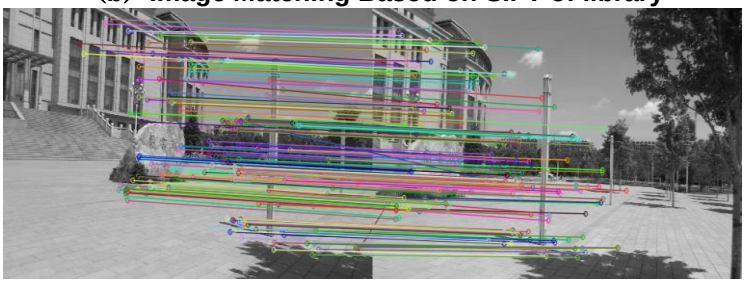
Figure 5 is the testing result of street, Figure 6 is the testing result of library. There are two original images of street in Figure 5 (a), Figure 5 (b) and Figure 5 (c) is the SIFT and SURF algorithm matching result of street respectively, Figure 5 (d) is the result of the RANSAC algorithm combined with the ORB algorithm, Figure 5 (e) shows result of the improved algorithm in this paper.

There are two original images of library in Figure 6 (a), Figure 6 (b) and Figure 6 (c) is the SIFT and SURF algorithm matching result of library respectively, Figure 6 (d) is the result of the RANSAC algorithm combined with the ORB algorithm, Figure 6 (e) shows result of the improved algorithm in this paper.

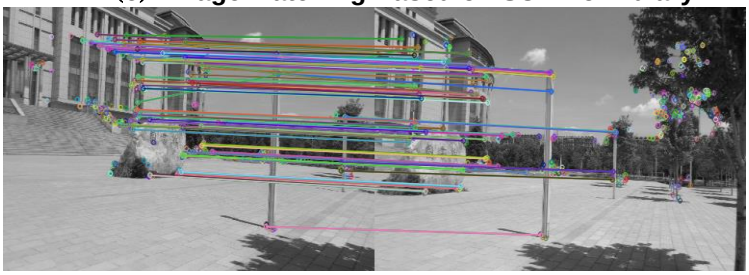
(a) Two Original Images of library



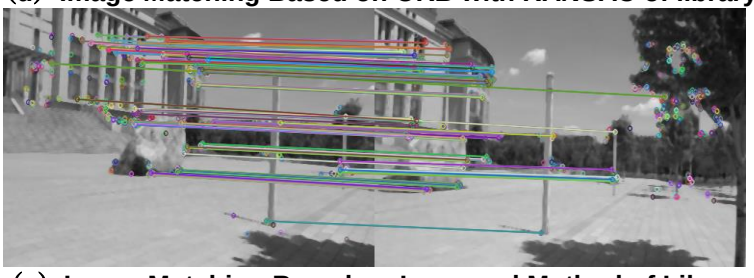
(b) Image Matching Based on SIFT of library



(c) Image Matching Based on SURF of library



(d) Image Matching Based on ORB with RANSAC of library



(e) Image Matching Based on Improved Method of Library

Figure 6. The Test of Library

Table 1. The Results of Different Algorithms of street

Name	Matches	Matching time/ms
SIFT	742	2906
SURF	1496	1985
ORB with RANSAC	280	628
Improved ORB	370	534

By comparing the data of Table 1, it is the results of several kinds of algorithm of street under OpenCV. The matching points of SURF algorithm is SIFT algorithm nearly twice, but the time-consuming of SIFT algorithm is 1.5 times more than SURF, while the time-consuming of the ORB algorithm combined with RANSAC algorithm is nearly three times less than SURF algorithm. The computing speed improved by RANSAC algorithm, and the number of matching points increased 90 by adding the median filtering algorithm while the computing speed accelerated.

Table 2. The Results of Different Algorithms of library

Name	Matches	Matching time/ms
SIFT	1138	3485
SURF	2500	3000
ORB with RANSAC	1080	630
Improved ORB	1160	627

Table 2 shows the results of several kinds of algorithm of library under OpenCV, the result is similar to Table 1, illustrating the universal applicability of the proposed algorithm.

5. Conclusion

This paper proposed a kind of improved extraction algorithm based on ORB. Median filtering method is used to remove noise and using the ORB algorithm to detect feature points, then the hamming distance is adopted to feature points matching. Combined homography matrix with RANSAC algorithm to eliminate false matching points. Finally using the perspective transformation to map point group and obtain the target coordinates in the scene to realize image correction and eventually achieve two images matching. The experimental environment is OpenCV2.3.1 and Visual Studio2010. It shows that the calculating speed has been improved when getting more correct matching points. Median filter and RANSAC algorithm can find more accurate matching points and improves the calculating speed, and the perspective transformation is used in image correction. The universal applicability of the improved algorithm is verified by two groups of different environmental collecting pictures .But this algorithm lost time because of image correcting, so how to compensate the loss of time is the next research.

Acknowledgement

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Authors

Lei Yu, received the Doctor degree in Communication Engineering from Harbin Engineering University (HEU) in China in 2009. She has been serving as an associate professor in HEU since 2008. Her current research interests include image processing and image stabilization.

Zhixin Yu, received the Bachelor degree in Electronics Science and Technology from Northeast Forestry University in 2012 in China. She is now carrying on her master education in Harbin Engineering University (HEU) in China. Her research interest is the area of image processing

Yan Gong, Ph.D. candidate in the Information and Communication Engineering College at the Harbin Engineering University in China, she received the B.S. and M.S. degrees in Computer Science in 2004 and 2008.Her research interests include image processing and computer vision.

