Image of Ship Target Matching Algorithm Based on PCA-SIFT in the Complicated Environments with Noise

To cite this article: Min Li et al 2018 J. Phys.: Conf. Ser. 1069 012139

View the article online for updates and enhancements.
Image of Ship Target Matching Algorithm Based on PCA-SIFT in the Complicated Environments with Noise

Min Li, Zhidan Luo, Xianjie Yuan and Yuhang Xing
Xi’an Research Institute of High Technology, Xi’an 710025 China

Abstract. In the complicated environments with noise, the traditional SIFT algorithm has the low matching speed of extracting feature points with the weak real-time performance, this paper proposes a kind of feature point matching algorithm for ship images based on principal component analysis and Scale-Invariant Feature Transform (PCA-SIFT) features. Firstly, the source images are added with the Gauss noise, impulse noise and multiplicative noise to generated the images to be matched; then we extract the feature vector from two images and use principal component analysis to reduce the dimension of feature vectors; the nearest neighbor algorithm to match feature points. The random sample consensus (RANSAC) algorithm can be used to eliminate the error matching. The experimental results show that, in the ship image, the PCA-SIFT algorithm can effectively reduce the number of matching feature points and description vector dimension, accelerate the matching speed and achieve high precision with the good stability, especially in the complicated environments with noise.

1. Introduction
With the research and development of image processing technology, image matching has been widely used in various fields, especially in military fields, such as image matching based on the missile terminal guidance or target detection. In the early stage of target recognition, the ship type was discriminating based on the ship shape features, gray scale feature and texture feature. With further improvement of image matching technology, characteristics of ship target have more clear detail. The rapid and real-time identification of ship targets and the matching of images are of important practical significance for improving the combat effectiveness of weapons.

Many researches have been done on image matching both at home and abroad. At present, the most widely used algorithm is the SIFT algorithm proposed by David Lowe [1]. Some improved algorithms have also appeared, for example, the GLOH algorithm [2], SURF algorithm [3], ASIFT algorithm [4] and SICA-SIFT image matching algorithm [5]. This paper mainly discusses the PCA-SIFT algorithm [6] proposed by Yan Ke and Rahul Sukthankar, by means of principal component analysis to reduce the dimensionality of the feature vector of SIFT descriptors.

This paper puts forward the improvement of the feature descriptions and principal component analysis to reduce the dimension of the extracted points with SIFT algorithm. By adding Gauss noise, impulse noise, multiplicative noise, we can simulate the ship image acquisition in the actual situation, which is affected by various environmental factors. Therefore, we can compare the performance stability of this algorithm and whether there is a good stability of SIFT algorithm to deal with the noise.

2. Image Matching based on PCA-SIFT Feature Extraction Algorithm

2.1. SIFT Feature Extraction
SIFT algorithm is a local-feature extraction and description algorithm based on scale space, image
zoom and rotation invariant [7], whose main idea is the matching between two images into alignment and the image feature point extraction. Using Gauss to check the original image for scale transformation, we obtain the representation sequence of multi-scale images, and extract the features of these sequences in scale space. Its mathematical expressions are as follows:

\[ L(x, y, \sigma) = G(x, y, \sigma) * I(x, y) \]  

\[ G(x, y, \sigma) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \]

In the upper expression, \( I(x, y) \) represents the pixel value corresponding to the input image; \( L(x, y, \sigma) \) shows the image after scale transformation; \( G(x, y, \sigma) \) is used as the Gauss function; \( \sigma \) is the scale space factor, deciding the smoothness of the image. After setting up image Gauss pyramid, and then using differential Gauss function to process image and constructing Gauss difference Pyramid.

\[ D(x, y, \sigma) = (G(x, y, k\sigma) - G(x, y, \sigma)) * I(x, y) = L(x, y, k\sigma) - L(x, y, \sigma) \]

The \( K \) is a constant in the formula, indicating the interval between two adjacent scales. Finding the feature points of images at different scales, that is, the local extremum points of images. The main direction of feature points is calculated by using the gradient distribution feature of neighborhood pixels of feature points, and then the main axis of the image is rotated to the main direction of feature points. The neighborhood of the feature points is divided into 16 4*4 sized sub regions. The 8 histograms of different directions are sorted and a feature vector of 4*4*8=128 dimension is formed. The vector is normalized as a description vector of SIFT features.

2.2. PCA-SIFT Feature Description

PCA-SIFT algorithm uses the principal component analysis method to reduce the 128 dimensional feature description vector to the appropriate dimension [8] [12]. Process is as follows:

The 128 dimensional SIFT feature descriptor is used to construct the sample matrix. Calculates the difference between the average feature vector and the feature vectors of the entire sample

\[ d_i = x_i - \bar{x}, i = 1, 2, ..., n \]

Constructing covariance matrix

\[ C = \frac{1}{n} \sum_{i=1}^{n} d_i d_i^T \]

Firstly, you should arrange the eigenvalues and eigenvectors of the covariance matrix in the order of largest to smallest. In this paper, a 128×1 matrix is constructed by selecting the eigenvectors corresponding to the maximum eigenvalue of t. By projecting the SIFT descriptor into the n-dimensional subspace, the PCA-SIFT descriptor \( y_{1}, y_{2}, ..., y_{n} \) is obtained [9].

Because \( t=20 \) is selected in the experiment, we can have a 20 dimensional PCA-SIFT descriptor. That is to say, the traditional 128 dimensional SIFT descriptor is reduced to 20 dimensional PCA-SIFT descriptor [10].

2.3. Feature Point Matching

When two matched images are to find their respective feature points and locate accurately, the corresponding feature description vectors are generated. The matching of the two images has been converted to the matching between the eigenvectors of two images. The feature vectors of any feature points in the image to be matched are selected to find the minimum feature points of the source image, i.e., the nearest neighbor points. Calculates the ratio of nearest neighbors to secondary neighbors

\[ d_{ratio} < \frac{d_{min}}{d_{smin}} \]
A threshold distance ratio $T \in (0,1)$, generally the numerical $T \geq 0.8$. If $d_{ratio} < T$, the feature point is the closest distance from another image.

2.4. Eliminating Error Matching

In order to improve the correctness and stability of the matching, RANSAC algorithm [11] is adopted. This is a robust transform estimation algorithm. By using the intrinsic set constraint relation of the feature set, the error matching is further eliminated and the accurate matching results are obtained. The main idea is to randomly select two points determine a straight line and the line within a certain distance of the point is called the line support. After repeated selection, the straight line with a maximum linear support feature set has been identified as fitting sample set. The point within error of fitting is called interior point, otherwise, the exterior point. When the external points are eliminated, then the matching effect is optimized and the registration accuracy is improved. The flow chart of the algorithm for PCA-SIFT is shown below:

![Figure 1. The flow chart of the algorithm for PCA-SIFT](image-url)

3. Experimental Results and Analysis

3.1. Experimental Environment and Design

The experimental environment: CPU Intel(R) Core i5-3230M. The frequency: 2.60GHz. 4G memory. 64 bit operating system. The development tools used are Microsoft Visual Studio 2005 and OpenCV2.0. VC++ language.

In the experiment, four groups were designed. There are thirty the remote sensing images of aircraft carrier which be used as source images.

The first set of experiments is the use of PCA-SIFT algorithm for different sizes of image matching. The different sizes of images are simulated at different resolutions to capture the image effect. Specifically, source image will have a matching operation with images after enlarging 2 times and 7.5 times. The other three groups were respectively adding Gauss noise $\mu = 0, \sigma = 10$, 3% impulse noise, multiplicative noise $\sigma = 0.3$ to generate three matching image. Then using the SIFT algorithm and PCA-SIFT algorithm are to match the source image with three groups of images with noise, which can the strengths and weakness of two algorithms.

3.2. Experimental Results and Analysis

In each group of experiments, a pair of images with an average result is analyzed. In the first set of experiments, the number of feature points in the source image and the matching image was respectively 1239 and 3760. 5287 and 2589 feature points were detected in the source image and the matching images with resolution difference of 7.5 times. As shown in figures 2 below. The common source images in the three groups of experiments had 2080 characteristic points. The second group with Gauss noise had 1604 the feature points. As shown in figures 3 below. The third experiment with impulse noise had 1940 feature points. As shown in figures 4 below. The fourth experiment with
multiplicative noise had 673 feature points. Figures 5 are shown below.

**Figure 2.** The 2 times and 7.5 times difference

**Figure 3.** SIFT and PCA-SIFT with Gaussian noise

**Figure 4.** SIFT and PCA-SIFT with Impulsive noise
Figure 5. SIFT and PCA-SIFT with Multiplicative noise

Matching feature points which are detected and eliminating error matching. In the first group, the image matching effect of PCA-SIFT algorithm to different resolution is tested. In the second groups of experiments, the difference in the number of matching points is 64, the time difference is 1.455s, and the difference of accuracy is 1.1%. In the third groups of experiments, the difference in the number of matching points is 229, the time difference is 1.766s, and the difference of accuracy is 0.9%. In the fourth sets of experiments, the difference of the number of matching points is 22, the difference of the consumption time is 1.793s, the difference of the accuracy rate is 1.2%. The matching results of the four sets of experiments are shown in table 1 and 2 below.

Table 1. The PCA-SIFT matching results at two kinds of scale space

| scale space | Matching points | False matching | Time(s) | Accuracy rate (%) |
|-------------|-----------------|----------------|--------|-------------------|
| 2 times     | 457             | 0              | 2.043  | 100               |
| 7.5 times   | 74              | 1              | 4.615  | 98.6              |

Table 2. The matching results in three kinds of noise

| Algorithm       | Matching Points | False Matching | Time(s) | Accuracy Rate(%) |
|-----------------|-----------------|----------------|--------|------------------|
| Gauss noise     | SIFT            | 235            | 4      | 2.802            | 98.3             |
|                 | PCA-SIFT        | 171            | 1      | 1.347            | 99.4             |
| impulse noise   | SIFT            | 461            | 6      | 4.053            | 98.7             |
|                 | PCA-SIFT        | 232            | 1      | 2.287            | 99.6             |
| multiplicative noise | SIFT  | 28             | 5      | 3.022            | 82.1             |
|                 | PCA-SIFT        | 6              | 1      | 1.229            | 83.3             |

According to the experimental results, the PCA-SIFT algorithm has the greater matching influence on different resolution images, which can stabilize the ship matching feature points in the image; different types of noise has the different impact on the image, resulting in a number of different feature points matching algorithm. The impulse noise has the minimum effect; Gauss noise affected part of the image information, but still can extract more feature points; multiplicative noise has the majority impact and image information has largely been corrupted by noise. But in the same kind of noise, the SIFT algorithm can better extract the feature information of the image under the influence of noise, and complete the pairing. To sum up, the PCA-SIFT algorithm not only retains the main feature matching points, but reduces the number of redundant matching points about 50%~60% and consumes time, so it also reduces nearly half. Moreover, the number of error matching points dropped significantly, and the error rate was lower.
4. Conclusion
Based on the problem of longer time consuming and higher rate of false matching in traditional image matching algorithm, the feature points of ship targets in images are extracted and matched based on PCA-SIFT algorithm. After the impact of various noises, then we can match two ship image noise. PCA-SIFT algorithm has the advantage of extracting the feature points accurately and matching precision reduces the matching time in the course of consumption. It also can eliminate the error matching points and the matching points with a high degree of consistency. Therefore, the PCA-SIFT algorithm can be used to match the ship target and ship sample to be recognized, so as to realize the fine identification of ship target by image matching. The research of this paper improves the performance of the algorithm on the whole. In the late period, the robustness, timeliness and recognition accuracy of the algorithm are further studied.

5. References
[1] David G Lowe. Object recognition from local scale-invariant features [A]. International Conference on Computer Vision [C]. Corfu, Greece, 1999:1150 -1157.
[2] Guixuan Zhang,Zhi Zeng,Shuwu Zhang,Yuan Zhang,Wanchun Wu. SIFT Matching with CNN Evidences for Particular Object Retrieval [J]. Neurocomputing, 2017, 238.
[3] Qin Xiao,Zhang Yangsong. Comparative research on matching algorithm of SIFTS and SURFS in rock outcrop point cloud acquisition [J]. Site Investigation Scienceand Technology, 2017 (06): 31-34.
[4] Tu Ting, Lu Jixiang. SIFT image matching algorithm based on block and affine invariance [J/OL]. Application Research of Computers, 2018(12):1-2[2018-01-28].
[5] Zhang Xin, Jin Yanxia, Xue Dan. Image matching algorithm based on SICA-SIFT and particle swarm optimization [J].Laser and Optoelectronics Progress, 2017, 54 (09): 091002.
[6] Yu Zhijing, Wang Shaobin. Improvement of PCA-SIFT algorithm for stereo matching system [J]. Laser and Optoelectronics Progress, 2016, 53(03):177-183.
[7] Hou Yimin,Sui Wenxiu,Sun Xiaoxue. Dimensionality reduction method based on SIFT and its application in image retrieval [J].China laser, 2015, 42 (B09): 216-221.
[8] Yan Ke,Rahul Sukthankar, A more distinctive representation for local image descriptors[C]//Proceedings of the 2004 IEEE Computer Society Conference on Computer Vision and Pattern Recognition. Washington, DC: IEEE Computer Society, 2004, 2: 504 -513.
[9] Li Qin,You Xiong, Li Ke,Zhang Yanxi. Research on the matching algorithm of PCA-SIFT [J].Engineering of Surveying and Mapping, 2016, 25 (4): 20 - 24.
[10] Tu Qiujie,Wang xuan. Image classification algorithm based on PCA-SIFT features and Bayesian decision making [J]. Computer Applications and Software, 2016, 33 (06): 215 - 219.
[11] Zhao Ye,Jiang Jianguo,Hong Richang. An Optimized SIFT Matching Based on RANSAC [J]. Opto-Electronic Engineering, 2014, 41(8): 58-65.
[12] Jiang Bo, Zhai Xuping, Image mosaic algorithm based on PCA-SIFT feature matching [J]. Journal of Computer Applications, 2016, 36 (S2):143-145+159.