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Non - overlapping horizon multi - target recognition based on multi - source information fusion

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Abstract. Aiming at the complexity and diversity of real-time target tracking in complex electromagnetic environment, a method of target recognition and tracking based on scale invariant feature is proposed by using image registration technique, which effectively reflects the feature distribution of the target image and improves the reliability of the tracking and recognition system. Experiments show that the method can effectively reduce the target tracking error, accurately identify the target position and improve the target tracking accuracy when the target changes its angle greatly and the background changes drastically.

Key words. Feature extraction, Target recognition, Multi-source information, Feature fu-sion .

1. Introduction

With the increasing diversity of war styles and the integrated use of various electronic warfare methods, the future battlefield situation is changing rapidly; how to effectively learn about the location and movement of the battlefield target in real time, to distinguish the target type, to judge the threat degree of the hostile target and to track the attack has been the decisive factor of restricting the military situation assessment system performance and has caused high attention in academia and engineering technology field[1]. With the development of computer hardware, image registration has been widely used as the key technology of target recognition and tracking in military, traffic control, intelligent monitoring, GPS navigation, etc., and the relevant algorithm research increasingly becomes deep[2–5]. According to matching idea, the image registration algorithm can be roughly divided into two kinds based on the matching method of image gray scale and image feature: gray scale matching is based on a certain similarity measure to search and compare

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the gray array of the image to achieve the image registration, which has the main drawback of being too sensitive to image scale and affine changes and is difficult to maintain good accuracy and matching efficiency in the practical application; image feature matching is a more successful method in current application, which can effectively extract the characteristic data of the target image and high matching accuracy, but is complicated in the algorithm and limited in application scope. Therefore, to improve the self-adaption ability and matching efficiency of image registration algorithm has become the important issue to be researched and solved in realize the target recognition and intelligentized tracking system.

2. Algorithm principle of scale invariant feature

The basic algorithm principle of the scale invariant feature is: firstly, to continually filter and down-sample the input images by Gaussian kernel functions in different scales to form the Gaussian pyramid image, next, to subtract two adjacent Gaussian images in scale and use pyramid multi-scale space to refer to the result; then to compare the points in the scale space with the points in adjacent scale and position one by one to get the local extremum position, that is, the position and scale of the key point. It mainly includes several key steps as follows:

2.1. Feature extraction

In order to make the feature have scale invariance, the detection of the feature point is done in the multi-scale space, and the dimension space of a two-dimensional image can be defined as:

$$L(x, y, \sigma) = G(x, y, \sigma) * I(x, y)\,. \tag{1}$$

Where, $G(x, y, \sigma) = (2\pi\sigma^2)^{-1}e^{-(x^2+y^2)/2\sigma^2}$ represents Scale variable Gaussian function; "*" represents convolution symbol; $I(x, y)$ represents grey scale value when the image is on the pixel point (x, y); σ represents the scale space factor. In order to detect stable and unique feature points more efficiently, the Gaussian difference equations in different scales can be convoluted with the image to obtain Gaussian difference scale space:

$$\begin{aligned} D(x, y, \sigma) &= (D(x, y, k\sigma) - G(x, y, \sigma)) * I(x, y) \\ &= L(x, y, k\sigma) - L(x, y, \sigma)\,. \end{aligned} \tag{2}$$

Where, k represents the constant factor.

2.2. Feature description

Scale invariant feature transformation theory is to establish a descriptor for each feature point so that it does not change with a variety of changes, and each descriptor has a high uniqueness so that the probability of correct matching can be improved constantly. Therefore, use the gradient distribution of the feature point neighborhood pixels to assign the direction of each feature point so that the descriptor has the rotation invariance:

$$m(x,y) = [(L(x+1,y)-L(x-1,y))^2 + (L(x,y+1)-L(x,y-1))^2]^{1/2}\,. \tag{3}$$

$$\theta(x,y) = \tan^{-1}[\frac{L(x,y+1)-L(x,y-1)}{L(x+1,y)-L(x-1,y)}] \tag{4}$$

Where, the scales of $L(x,y+1)$, $L(x,y-1)$, $L(x-1,y)$, $L(x+1,y)$ respectively refer to the scale values of pixels of key point(x, y) in the position of the up, down, left and right. The key points have three parameters of location, size and direction.

2.3. Feature matching

The feature points are usually matched according to the similarity between features. There are many similarity measures and the nearest neighbor method is commonly used to match the feature points in practical application. For the extracted descriptors, firstly, calculate the Euclidean distance of descriptors between the points to be matched and numerous feature points needed to be matched; next, when the distance ratio between the nearest and next nearest points is smaller than a certain valve value according to the matching criterion, and then the matching is considered successful. The specific process can be described as:

Provided that the images to be matched are A and B, and the feature points' description vectors are respectively: $F_a = \{f_1^{(a)}, f_2^{(a)}, \cdots, f_{N_a}^{(a)}\}$, $F_b = \{f_1^{(b)}, f_2^{(b)}, \cdots, f_{N_b}^{(b)}\}$, Where, N_a and N_b are feature points dimensions. The feature points can be matched through feature matching pairs to complete conversion between images. The initial matching pairs by using Euclidean distance extraction image of the similarity principle:

$$d(F_a,F_b) = \sqrt{\sum_{i=1}^{n}(f_i^{(a)} - f_i^{(a)})^2}\,. \tag{5}$$

Find the nearest distance $d_1$and the nearest distance $d_2$of Euclidean distance in the target image, if $(d_1/d_2) < \varepsilon$, then the matching is successful; otherwise, unsuccessful. Valve value ε is 0.75 in the text. The specific matching algorithm can be expressed as:

Step1: to establish indexes for all elements of F_b;

Step2: to get the approximate k neighbor of each element in Fa from the formula (5) and then return to two nearest neighbor feature points f_1 and f_2.

Step3: to determine whether it is the effective matching for k$_i$according to the matching rule

Step4: to repeat the algorithm of all k$_i$ and get the feature point of F_b, $k_1{\sim}k_{nband}$the collection of all feature point pairs matching with F_a.

3. Dynamic continuous target recognition and tracking algorithm based on scale invariant feature

3.1. Target recognition algorithm

If the image feature of the target is known in advance, then the target recognition is transformed into an image registration process. Provided that the known feature target image is the reference image and the first frame in the dynamic target video is the image to be registered. Since the position, angle and direction of the target in the first frame image are unknown, all kinds of imaging information, namely the reference image information is required to obtain to get better target recognition rate and tracking effect. Target recognition is to use multiple multi-angle reference images and the first frame image to register and seek all target information in the first frame image. The specific recognition algorithm can be expressed as:

Step1: to obtain scale invariant feature points from the reference image and the image to be registered:

Step2: to detect the feature descriptors of feature points from the calculated image;

Step3: to roughly match the reference images and feature points of images to be registered by using feature matching algorithm and remove matching pairs with obvious errors;

Step4: to accurately remove the reserved incorrect matching pairs in step 3 by using intuitionistic fuzzy matching algorithm in literature[16] and get the correct matching point sets from images to be registered matching with reference images.

3.2. Target tracking algorithm

(1) Determining the collection of feature point sets to be matched

Based on the fact that the target tracking algorithm with scale invariant feature is easy to lose when the target changes in shape obviously, the literature [14, 15] conducts continuous robustness tracking of the target by using image targets similarity of the two frames before and after, gaining good effects. However, the tracking results show that if only the constraint relation of adjacent target images is used, the scale invariant feature will become instable strongly, which will directly lead to the fact that feature points in accordance with the image transformation constraint will be less and less. This problem has been solved by constructing dynamic matching feature point sets to be matched in the text. The feature point set $TG\_SET_{all}^{k}$ can be expressed as:

$$TG\_SET_{all}^{k} = TG\_SET_{\det}^{k} + \sum_{i=1}^{m} TG\_SET_{i}k\,. \tag{6}$$

Where, k represents the image number to be matched; $TG\_SET_{\det}^{k}$ represents the correct matching point set of feature points in the k^{th} frame image area to be detected and the feature point set of $(k-1)^{th}$ frame image $TG\_SET_{all}^{k-1}$. Making

$TG\_SET^k_{\det} = \emptyset$ represents that there is no image matching with the first frame image before.

(2) Determining the target area to be detected

The location information of the target in the image to be registered has been basically learned by target recognition. If conduct the scale invariant feature detection in the whole drawing for each frame image, it will take a lot of time and space, and be not conducive to the real-time requirement of the algorithm. In fact, the displacement between the two images before and after of the target on the image is usually small; the purpose of feature detection can only be reached by detecting the target area in the previous frame image and the feature points in the near area. In this text, we begin from improving instantaneity of the algorithm and determine the dynamic regional space of the target area and the area to be detected, which effectively reduces the complexity of the algorithm. Where, the target area is the approximate range of the target image and the area to be detected indicates the feature point detection area of the next frame of the image to be matched.

The target area determined by the specific position of the target in the first frame image and the correct matching point set of the first frame image $TG\_SET^1_{tr}$ can be expressed as:

$$TG\_REG^1_c(x,y) = \{(x,y)|D\|(x,y) - (x^1_c, y^1_c)\| \le r^1_c\}\,. \tag{7}$$

Where, (x^1_c, y^1_c) represents the point set center of correct matching point sets; r^1_c represents radius of the minimum circle centralized by (x^1_c, y^1_c) which can contain the point sets. And the area to be detected of the second frame image can be determined as:

$$\begin{aligned} &TG\_DET\_REG^1_c(x,y) \\ &\qquad = \{(x,y)|D\|(x,y) - (x^1_c, y^1_c)\| \le \sigma r^1_c\}\,. \end{aligned} \tag{8}$$

Where, σ represents the adjustment factor of the area to be detected. When the sampling rate of the target image is low, increase σ to expand the area of the detection area; otherwise, reduce σ to narrow the area.

During the tracking process, the local feature detection area will be updated constantly according to the feature matching result under the restrained conditions of the motion model and the point set to be matched. Therefore, the area to be detected of the k^{th} frame image can be defined as:

$$\begin{aligned} &TG\_DET\_REG^k_c(x,y) \\ &\qquad = \{(x,y)|D\|(x,y) - (x^{k-1}_c, y^{k-1}_c)\| \le \sigma r^{k-1}_c\}\,. \end{aligned} \tag{9}$$

Where (x^{k-1}_c, y^{k-1}_c) and r^{k-1}_c respectively represents the center and the area radius of the $(k\text{-}1)^{th}$ frame image point set to be matched.

In summary, the dynamic continuous target tracking algorithm based on scale invariant feature can be expressed as:

Step1: to determine the feature point set to be matched, the target area center and the radius of the first frame image and the target information of the image to be registered in the area to be detected of the second frame image by using the target recognition algorithm;

Step2: to match the feature points in the area to be detected of the second frame image with the feature point set to be matched of the first frame image and remove incorrect matching points by using feature matching algorithm and determine the feature point set, the target area center and the radius of the second frame image and the area to be detected of the third frame image;

Step3: $k = 3$; to make $k = 3$;

Step4: to detect the scale invariant feature points in the area to be detected of the k^{th}frame image and determine the feature point set, the target area center and the radius of the k^{th}frame image and the area to be detected of the $(k+1)^{th}$frame image;

Step5: $k = k + 1$, to repeat the step 4;

Step6: to repeat the step 5 until the end of the tracking.

4. Example verification

STK (Satellite Tool Kit) is the Satellite simulation toolkit and the leading commercialization analysis software in the aerospace industry, developed by American Analytical Graphics Company, which can quickly and easily give real-time simulation of images in complex environments and provide easy-to-understand analyses of in the form of chart and text. This text generates simulation target sequences with the characteristic of variable scales with the help of the realistic and visual display function of STK to verify the performance of the algorithm.

4.1. Satellite target recognition tracking experiment

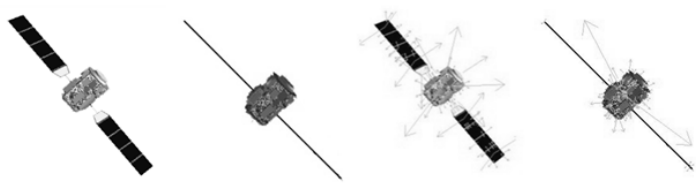
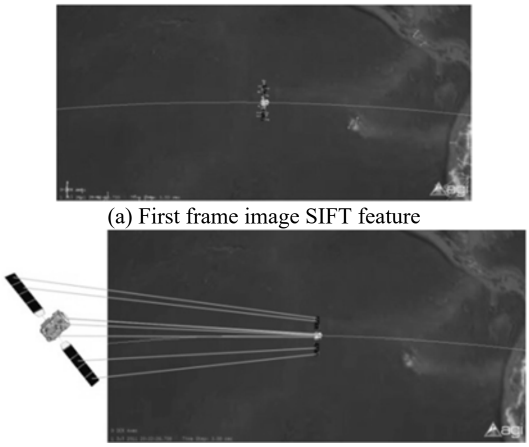


Fig. 1. Satellite image and feature extraction

Fig.1 (a) and (b) are the target images of the satellite in different states, and (c) and (d) are the feature vectors after extracting its scale invariant feature. Fig.2 (a) and (b) are respectively the matching results of the first frame scene image scale invariant feature vector and the target image matching with the first frame scene image. Figure 3 shows the target tracking results with the algorithm in this text under the complex dynamic scene. The light circle around the satellite in the figure is the target area determined by the matching point set. During the tracking process, the terrain, texture and color appearance in the background have undergone



(a) First frame image SIFT feature

(b) Target identification example

Fig. 2. First frame image target identification

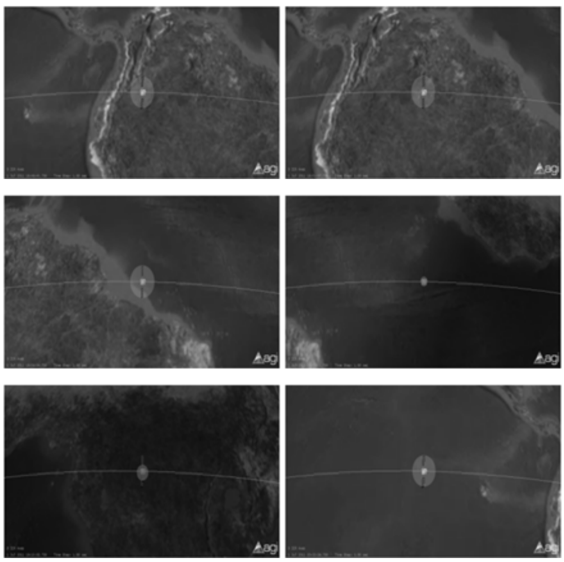


Fig. 3. Identification and tracking process of the satellite target

dramatic changes, especially after the scene is switched from the land to the ocean, not only the background has changed, but the lighting conditions of the whole scene have changed greatly. It can be seen from the experimental results that the algorithm is not affected by the complex background changes to lose its target; good recognition and tracking efficiency have been kept in the whole process; the target area changes dynamically with the change of status and position of the satellite and the entire target detection area can be determined quickly. The algorithm has a strong self-adaption function.

4.2. Fighter target recognition tracking experiment

In order to further verify the effectiveness of the algorithm, make the fighter with complex moving postures as the identification and tracking target.

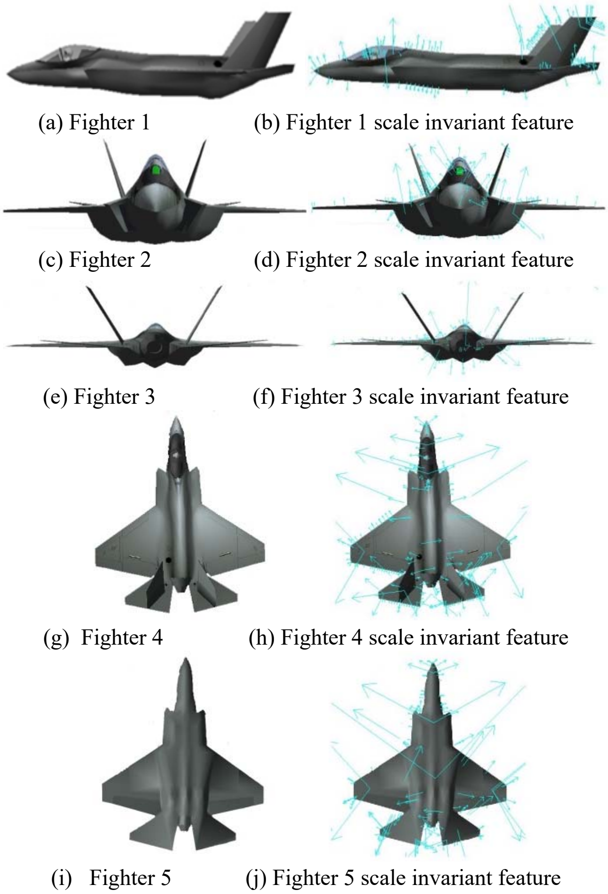
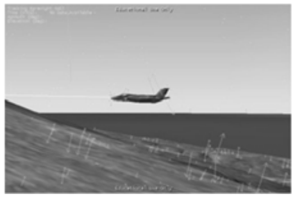


Fig. 4. Fighter target and feature extraction

The experiment sets five target reference images, fig. 4 represents the reference target image of the fighter at different angles and its corresponding scale invariant feature vector; fig. (5a) represents the scale invariant feature vector of the first frame scene image, (b) represents the matching result the target image and the first frame scene image; fig 6 represents the fighter's tracking process when the terrain, texture and color appearance in the background change rapidly. Therefore, the scale invariant feature can describe the scene information very well, and can accurately identify the target from the first frame scene image, and when the target fighter conducts movements, such as pulling up, side fly, overturning, etc., the algorithm in the text always keeps good tracking status.



(a) First frame image SIFT feature

(b) Fighter target identification example

Fig. 5. First frame image target identification

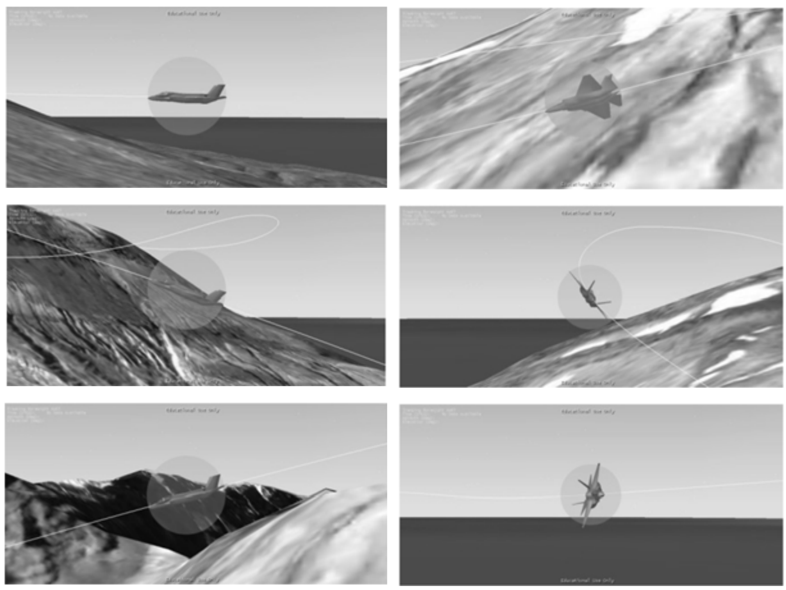


Fig. 6. Fighter target tracking process

5. Conclusion

This text aims to the problem of target losing easily when the target background changing obviously with the target recognition and tracking algorithm based on the image registration and puts forwards the target recognition and tracking algorithm based on the scale invariant feature. Make use of the multi-angle target reference image and the point set to be matched in the current frame image to determine the point set to be matched in the next frame image so that the feature points can be distributed on the target surface continuously and evenly and will not be lost gradually over time; the detection scope of the target with dynamic determined image reduces the complexity of the algorithm and is conducive to the real-time identification and tracking of the target. Experiments show that the algorithm in the text can not only identify all targets quickly and accurately, but also maintain the stable tracking efficiency when the displacement, rotation, scale and illumination of the target change obviously. How to further improve the real-time accuracy of target recognition and tracking will be the research focus in the next step.

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