Research on Target Detection and Automatic Extraction of Region of Interest in Infrared Serial Images

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Abstract—**Infrared imaging guidance is a research hotspot in accurate terminal guidance field now. An idea on automatic extraction of region (ROI) of interest in infrared serial images is proposed in order to treat intelligently infrared serial images which are captured. The target detection algorithm of target is researched and the applying scene of the target detection algorithm is confirmed based on analysis for the features of infrared serial images. According to differences of detection algorithm for infrared serial images between static and dynamic scenes, the corresponding detection and extraction algorithm of ROI is discussed respectively. The algorithms are all simulated in real scene. A new stepwise approaching and recurring threshold search algorithm based on two-dimensional maximum entropy principle was proposed by studying recurring formulation optimized of two-dimensional maximum entropy in order to realize to detect target and extract ROI of serial images under complex background. The algorithm above realizes automatic extraction of ROI in Infrared serial images. The results improve the efficiency of accurate terminal guidance and they have good application value by practicing.**

Index Terms—**infrared serial images, ROI, target detection, stepwise approaching and recurring threshold search algorithm, accurate guidance**

I. INTRODUCTION

In modern battles, long-distance attacking missile develops to intelligent, high precision and remote controllability. Midcourse guidance uses GPS/INS with terrain matching. Terminal guidance uses radar, infrared imaging technology or infrared imaging technology with data link. Infrared imaging guidance technology can auto-search, auto-capture, auto-identify target, then can auto-trace target because there are many features such as high precision, good anti-interference, good concealment capability and so on and it has been research hotspot in accurate terminal guidance field [1].

At present, the infrared seekers has been the second products whose type products are AAWS-M in America and Triget belongs to German, France and Britain. The information captured by infrared seekers usually is serial image [2]. To treat infrared serial images intelligently is the precondition for accurate terminal guidance, and we can make infrared seekers have better tracing target ability. From martial application, region of interest (ROI) of target in serial images is the region in moving target. So the process of automatic extraction of ROI in infrared serial images is the process of detecting moving target then extraction moving target region.

It is a hotspot in computer vision fields that to trace target and to extract ROI from serial images with complex background. The technology used in missile guidance, video controller and traffic manager commonly while it also is an important issue for automatic extraction of ROI. There are two methods for extraction ROI: one is human detected regions of inertest (hROI) which is selected according to ROI by human, and another is algorithmically detected regions of inertest (aROI) which is selected according to characters of the image [3]. This paper mainly studied the target detection algorithm in static scenes and dynamic scenes, automatic extraction algorithm of ROI and image segmentation issues. The result can improve the efficiency of accurate guidance.

II. CHARACTERS ANALYSIS OF INFRARED IMAGES

Infrared images can represent space distribution of infrared radiances between the target and its background. The follows are the characters of infrared images [4]:

1. Infrared images represent temperature distribution of the object. They are gray images and there are not colors or hatching. So there is lower resolution for human.

2. There are higher space correlativity and lower contrast for infrared images because of much physical interference.

3. The definition of infrared images is lower than visible images because the space resolution and detection ability of infrared imaging system are not as good as visible CCD array.

doi:10.4304/jsw.6.2.225-232

4. There are many noises in infrared images.

5. There is a little changing range in gray values of infrared image. So there are obvious wave crest in histogram of infrared image compared with histogram of visible image. This paper made experiment using Lena image and Infrared tank image. The result shows in Fig.1.

The bounds between target and its background are very blurry and there are many noises in infrared image because there are more details in infrared image captured in complex environment. There are obvious temperature differences between the target and the background in infrared image while they have different gray ranges in the image. So we should study target detection algorithms in various situations firstly if we'll extract ROI of target automatically.

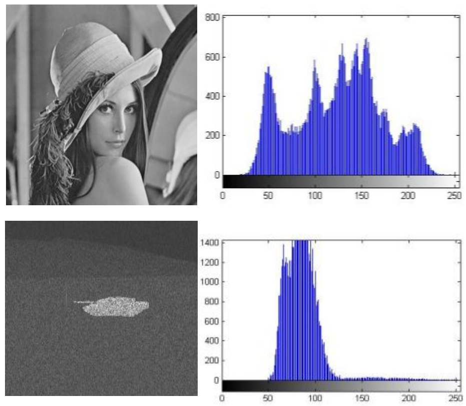


Figure 1. Histogram analysis between Lena and infrared tank.

III. Analysis of the Target Detection Algorithm

There are three methods on moving target tracking currently: optical flow method [5], background difference method [6] and frame difference method [7]. Optical flow method extracts moving target region by using the optical flow feature on target changing over time. The advantage of optical flow method is that it can treat bigger shift between frames because there is little moving restriction between frames of target. The disadvantage of optical flow method is that it is difficult up to real-time if there is not hardware support, and its computing process is very complex and its anti-nosing ability is lower [8]. So this paper is not to discuss this method and is mainly to research target detection algorithm in static and dynamic scenes based on studying background frame difference method and difference method.

A. Principle and Analysis of background difference method

Background difference method is the most direct method to detect target. It detects moving target by computing the difference of current frame with background reference model in image series. Suppose, at t time, the image of background reference model is $f_b(t)$, the image of current frame is $f_c(t)$, then the image of background difference is

$$f(x,y,t) = | f_c(x,y,t) - f_b(x,y,t) | . \qquad (1)$$

Suppose, the segmentation threshold is T, and then the binary difference image is

$$\vec{d}(x,y) = \begin{cases} 1 & f(x,y,t) \geq T \\ 0 & \text{otherwise} \end{cases} . \qquad (2)$$

Background difference method adapts to the situation that the background has small changes. In real application, we should update the background reference model with other methods continually if there are complex situations or uncertain movements. The key of background difference method is that is to establish and update the background reference model [9].

B. Principle and Analysis of frame difference method

The basic principle of frame difference method is to decide various information of moving target such as location and shape by computing gray difference of pixels in adjacent frame images. The common methods are adjacent frame images difference method and symmetrical difference method.

1. Adjacent frame images difference method

The computing process of adjacent frame images difference method is following:

$$d_k(x,y) = | I_k(x,y) - I_{k-1}(x,y) | = \begin{cases} 0 & d_k(x,y) \geq T \\ 1 & d_k(x,y) < T \end{cases} . \qquad (3)$$

Here, $I_k(x,y)$ and $I_{k-1}(x,y)$ are two sequential frame images, $d_k(x,y)$ is a frame difference image, T is the binary threshold.

2. Symmetrical difference method

Symmetrical difference method also is named difference method of three sequential frame images. That is, we can capture the contour of middle frame target by the difference among three sequential frame images. The method can eliminate background affects brought by moving, and then we can capture the contour of moving target exactly.

Suppose, $I_{k-1}(x,y), I_k(x,y)$ and $I_{k+1}(x,y)$ are three sequential frame images respectively, $d_{k-1,k}(x,y)$ and $d_{k,k+1}(x,y)$ are the binary images after difference by adjacent frame images, and then:

$$d_{k-1,k}(x,y) = \begin{cases} 1 & | \mathrm{I}_k(x,y) - \mathrm{I}_{k-1}(x,y) | \geq T_1 \\ 0 & | \mathrm{I}_k(x,y) - \mathrm{I}_{k-1}(x,y) | < T_1 \end{cases} , \qquad (4)$$

$$d_{k,k+1}(x,y) = \begin{cases} 1 & | \mathrm{I}_{k+1}(x,y) - \mathrm{I}_k(x,y) | \geq T_2 \\ 0 & | \mathrm{I}_{k+1}(x,y) - \mathrm{I}_k(x,y) | < T_2 \end{cases} . \qquad (5)$$

Here, T_1 and T_2 are the binary threshold.

Set $\vec{d}(x,y)$ is symmetrical difference image, and then:

$$\vec{d}(x,y) = \begin{cases} 1 & d_{k-1,k}(x,y) \cap d_{k,k+1}(x,y) = 1 \\ 0 & d_{k-1,k}(x,y) \cap d_{k,k+1}(x,y) = 0 \end{cases} . \qquad (6)$$

C. Application of target detection algorithm

The background difference method is of high and accurate tracking speed, but it must estimate background by establishing background reference model. If we detect moving target in complex battle environments, usually, to establish a reasonable background reference model is difficult because the background of infrared serial images is very complex. The frame difference method is of high computing speed and can fit dynamic background immediately, so it is adapted to the infrared serial images in there are more blurry details. There is good detecting affect using frame difference method while motionless background. But, it is difficult to detect target effectively if there are complex moving backgrounds in imaging system and targets [10-11].

IV. TARGET DETECTION OF INFRARED SERIAL IMAGE IN STATIC SCENES

For serial images that are in static scenes, we can detect moving target by background difference whose background model can be established by background modeling. But we should analyze many frame images through the whole background modeling process and the background model is difficult to adapt to background changing. In this paper, we studied target detection algorithm based on difference fusion.

A. Target detection algorithm based on difference fusion and study online

In order to resolve the updating puzzle of background model for background difference, we designed a target detection algorithm based on difference fusion and study online by combining frame difference method with background difference method according to correlative ideas mentioned in reference [12]. The flow chart follows in Fig.2.

This algorithm supposes every background pixels in serial image satisfy with Gaussian distribution. First, we complete background model by study and update online. Second, we do difference between two adjacent frame images by using the frame difference method, we can distinguish background point from changing region, and we fit changing region with corresponding region in background by using background difference method, and then we can distinguish exposure region from moving object. Last, we can segment moving target from infrared serial images.

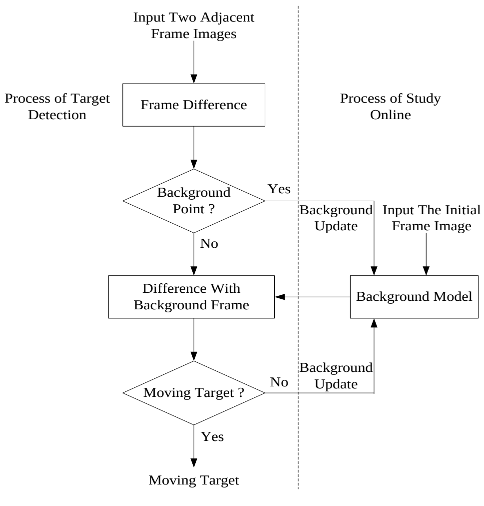


Figure 2. Process of target detection algorithm based on difference fusion and study online

B. Experiment and analysis of target detection algorithm for serial images in static scenes

We select infrared serial images of battle plane (There are 110 frames, the size of every frame image is 256*200, the size of battle plane image is from small to big.) as experiments object. We found that there was little change of the background from the 31st frame image to the 70th frame image and it was similar from the 71st frame image to the 101st frame image by analyzing the serial images carefully. Here, the battle plane is facing target. So we considered it as our experiment object. According to Fig.2, the follows are the experiment steps:

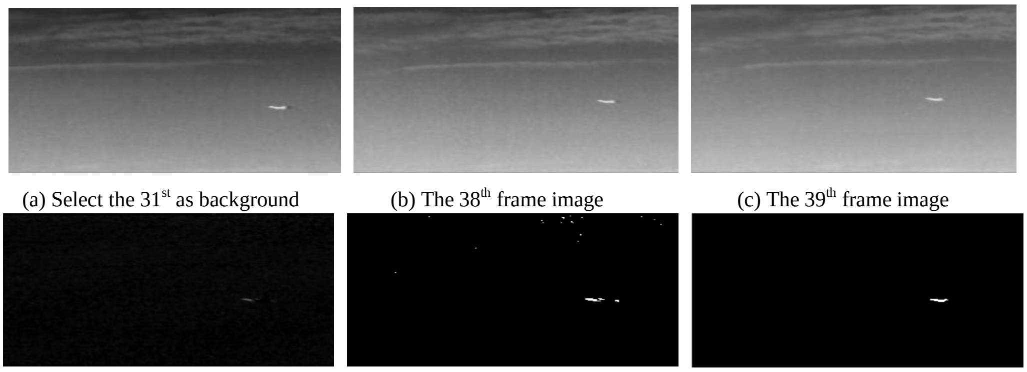
1. To select the 1st frame as initial background image and to initialize background model.
2. To do difference between adjacent frame image selected then to detect changing region.
3. To detect target from difference image by using background model then to update background model.
4. To do binary difference image then to do morphology filtering.
5. Not to detect moving target until return step 3.

We select two groups of images (the 38th frame and the 39th frame, the 99th frame and 100th frame) to verify result in real experiment. The result on the 38th frame and the 39th frame shows in Fig.3 (a)-Fig.3 (f). The result on the 99th frame and the 100th frame shows in Fig.4 (a)-Fig.4 (f).

V. TARGET DETECTION OF INFRARED SERIAL IMAGE IN DYNAMIC SCENES

A. Analysis of Target detection of infrared serial image in dynamic scenes

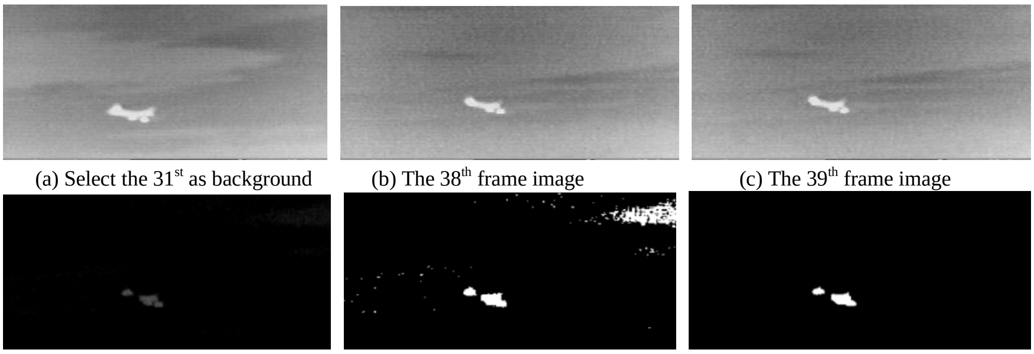
Detection technology on moving target is very important in military reconnaissance and weapon guidance fields. The background of moving target be detected usually is complex background in military applications. Now, there were more problems in the process of detecting moving target if we used the frame difference method simply [13]. Many experts have brought up a plenty of ways to adapt to various situations and these results were all successful [14-16]. Lately, many researchers studied the moving target detection in the side of image matching and image registration. Reference [17] brought up an infrared target detection method based on background matching of adjacent frame images, frame difference and threshold segmentation in complex environment. Reference [18] brought up an infrared target detection method based on Gabor method, feature point matching and image transform. But there are some disadvantages in real time for above-mentioned. Obviously, the method based on feature point matching is very effective if the image is very clear. But, it is very difficult to match the feature points between the adjacent frames if the image is blurry. It will reduce precision greatly if feature points match error. So, this paper proposed a moving target detection algorithm to register image based on QP_TR trust region.



(a) Select the 31st as background (b) The 38th frame image (c) The 39th frame image

(d) The difference image (e) The binary image (f) Morphology filtering

Figure 3. Detection process of moving target based on difference fusion on the 38th frame and the 39th frame.



(a) Select the 31st as background (b) The 38th frame image (c) The 39th frame image

(d) The difference image (e) The binary image (f) Plane target detected

Figure 4. Detection process of moving target based on difference fusion on the 99th frame and the 100th frame.

B. Moving target detection algorithm to register image based on QP_TR trust region

Moving target detection algorithm to register image based on QP_TR trust region is designed based on global motion compensation and difference method. This algorithm is similar as other algorithms but the global motion parameters between the adjacent frames in this paper is computed by QP_TR trust region algorithm [19].The framework of the algorithm follows in Fig.5.

Considering our military application, almost equipments are thought as moving rapidly. So suppose the moving model is:

$$u = x + \Delta x \quad (7)$$

$$v = y + \Delta y \quad (8)$$

Here, $\Delta x, \Delta y$ represent global moving parameters of images.

The correct $\Delta x, \Delta y$ will minimize the gray difference of pixels between adjacent two frames, that is,

$$E^2(\Delta x, \Delta y) = \sum_{x,y} [f_{k+1}(u,v) - f_k(x,y)]^2 = \sum_{x,y} [f_{k+1}(x+\Delta x, y+\Delta y) - f_k(x,y)]^2 \quad (9)$$

Equation (9) will be the min-value if $\Delta x, \Delta y$ are correct.

Here, the problem to register image is transformed the problem to optimize parameters, that is, $\min_{(\Delta x, \Delta y) \in R^2} E(\Delta x, \Delta y)$. With that, we should search $(\Delta x, \Delta y)$ to minimize $E(\Delta x, \Delta y)$. This problem to optimize parameters may be resolved by QP_TR trust region algorithm. There are bigger moving distances between adjacent frames because imaging equipments moves with its carrier rapidly. This distance is mapped to bigger $(\Delta x, \Delta y)$. We must use steady strategy layered based on Gaussian pyramid decomposition method in order to avoid QP_TR trust region algorithm running into local infinitesimal, that is, moving parameters computed on higher level will be mapped as initial value on lower level. Set the image is decomposed to *L* levels, the shift parameter computed on the l^{th} level is $(\Delta x, \Delta y)$ then the initial value of shift parameter on the *l-1*th level is $(2\Delta x, 2\Delta y)$.

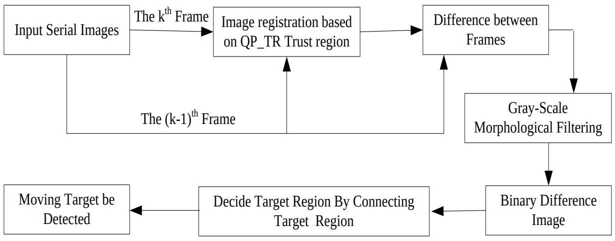


Figure 5. Moving target detection algorithm to register image based on QP_TR trust region.

The follows are that the computing process of moving parameters based on QP_TR trust region algorithm on the l^{th} level:

1. To center as the center of the image on this level, we segment a sub-image as our image to compute whose width and height are 1/S of width and height of original image respectively.

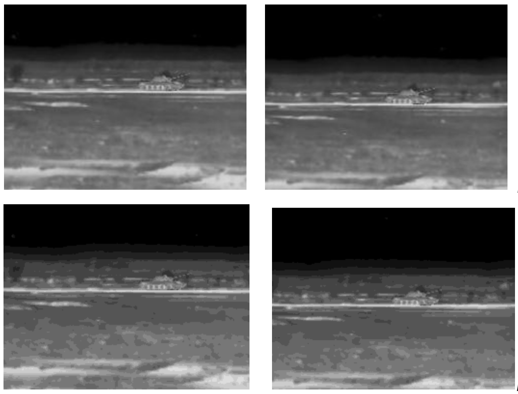
2. If this level is the highest level then to initialize $\Delta x_0 = \Delta y_0 = 1$, else $\Delta x_0 = 2(\Delta x)_{l-1}$ and $\Delta y_0 = 2(\Delta y)_{l-1}$. As same time as, $\Delta_0 = \min(C_{L-1}, R_{L-1})/4, \Delta_{end} = 1, MAX_{ner} = 100$.

3. Consider $f(x) = E^2(\Delta x, \Delta y)$ as target function, we optimize our sub-image above by QP_TR trust region algorithm and then obtain $(\Delta x, \Delta y)_l$ that is the global shift parameter between adjacent frames on this level.

C. Experiment and analysis of target detection algorithm for serial images in dynamic scenes

This paper selected two frames images of infrared tank (The size of the image is 256*200.) in a complex background to validate the effect of our algorithm. Suppose that the images are decomposed to *L* layers. First, we done two-layer decomposition on the adjacent frame images based on Gaussian pyramid decomposition method (The decomposition effect follows in Fig.6.).

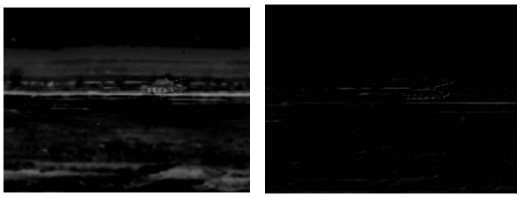
Then, to start from the highest layer *l*=*L*-1, we do not iterate above process until *l*=0. Here, we obtain the last motion parameter $(\Delta x_0, \Delta y_0)$ that is translation vector. Set S=4/3, L=2 and $(\Delta x_0)_1 = (\Delta y_0)_1 = 1$ as initialization. The translation vector is $(\Delta x_1)_1 = 11.3384$ and $(\Delta y_1)_1 = 14.8817$ by QP-TR trust region algorithm on the layer of l=1, the translation vector is $(\Delta x_0)_0 = 22.6768$ and $(\Delta y_0)_0 = 29.7634$ by QP-TR trust region algorithm on the layer of l=0, at last, we can obtain the last translation vector is $(\Delta x)_0 = 22.6772$ and $(\Delta y)_0 = 29.7668$ by iterator in a certain range. In application, we carry on shift correction to the second frame using the translation vector (23, 30) then carry on image registration to the adjacent frame images, and last we use frame difference method to optimize the image after registration. In order to explain the importance of the image registration algorithm based on QP_TR trust region, we compared the image by frame difference method with the image by registration. The effect is followed in Fig.7-(a). From Fig.7-(b), we find that our algorithm can eliminate a majority of backgrounds and can save the basic information of our target.



l=1

l=0

Figure 6. The effect of two-layer decomposition on the adjacent frame images based on Gaussian pyramid decomposition method.



(a) Frame difference (b) Frame difference with image registration

Figure 7. Effect comparison of two differences method.

VI. AUTOMATIC EXTRACTION OF ROI USING STEPWISE APPROACHING AND RECURRING THRESHOLD SEARCH ALGORITHM BASED ON TWO-DIMENSIONAL MAXIMUM ENTROPY PRINCIPLE

The target detection effect is very well by frame difference method with the image registration method. However, there are background noises in the images that can be treated by morphology filtering method. There are only our target and less background noises after morphology filtering, so we can extract target by threshold segmentation method.

Threshold segmentation is the most common method that is a region segmentation technology. This technology adapted to segment the image in which the target and its background hold different gray ranges respectively. The main threshold segmentation methods included OTSU method [20], invariant moment method [21] and two-dimensional maximum entropy method [22]. The main disadvantage above methods is they can not segment the different size target effectively or they can not uniform real-time with effectiveness. OTSU and invariant moment methods ask the size of the target is bigger than 30% [23], and with decrease of relative area of the target, the segmentation efficiency will drop rapidly. The two-dimensional maximum entropy method only extends one-dimensional optimization to two-dimensional optimization simply since it can segment different size target accurately. But the computing speed of the method is so slow as to cost times, and it can not meet real-time. This paper proposes a new stepwise approaching and recurring threshold search algorithm based on two-dimensional maximum entropy principle that will improve the image segmentation speed, so it can meet real-time in application.

A. Analysis of stepwise approaching and recurring threshold search algorithm based on two-dimensional maximum entropy principle

The image segmentation based on two-dimensional maximum entropy principle is to produce two-dimensional histogram by gray and the adjacent region gray means of every pixel in the image, and then select the best threshold according to this two-dimensional histogram. The two-dimensional histogram shows in Fig.8. Here, the X-coordinate is gray level and the Y-coordinate is local gray means. The element r_{ij} in the two-dimensional histogram represents the number of times one pixel appears. The gray level of the pixel is i and the adjacent region gray means is j. Set threshold vector is (s,t), the histogram is divided to four quadrants. Here, quadrant-A is the background, quadrant-B is out target, quadrant-C and quadrant-D are pixels and noises neighboring the target edge.

The global two-dimensional entropy is defined [22]:

$$H(s,t)=\ln[P_A(1-P_A)]+\frac{H_A}{P_A}+\frac{H_L-H_A}{1-P_A}. \quad (10)$$

Here, $H(A)=-\sum_{i=1}^{s}\sum_{j=1}^{t}(\frac{p_{ij}}{P_A})\ln(\frac{p_{ij}}{P_A})$, $P_A=\sum_{i=1}^{S}\sum_{j=1}^{T}p_{ij}$, $H_L=-\sum_{i=1}^{L}\sum_{j=1}^{L}p_{ij}\ln p_{ij}$.

We can obtain the best (s, t) by maximizing $H(s,t)$.The process of recurring optimization is following:

$$P_A(s+1,t)=P_A(s,t)+\sum_{j=1}^{t}p_{s+1,j}. \quad (11)$$

$$P_A(s,t+1)=\sum_{i=1}^{s}\sum_{j=1}^{t+1}p_{ij}=P_A(s,t)+P_A(s-1,t+1)-P_A(s-1,t)+p_{s,t+1}. \quad (12)$$

$$H_A(s+1,t)=H_A(s,t)-\sum_{j=1}^{t}p_{s+1,j}\lg p_{s+1,j}. \quad (13)$$

$$H_A(s,t+1)=-\sum_{i=1}^{s}\sum_{j=1}^{t+1}p_{i,j}\lg p_{i,j}=H_A(s,t)+H_A(s-1,t+1)-H_A(s-1,t)-p_{s-1,t}\lg p_{s-1,t}. \quad (14)$$

We can reduce the algorithm complexity with image threshold segmentation from $O(L^4)$ to $O(L^2)$ by recurring optimization. The key ideas that improve running efficiency are to reduce times for logarithm computation and iterating. The basic idea of stepwise approaching and recurring search algorithm is that, to search the approximate threshold in two-dimensional histogram with rough-scale then to search the accurate threshold near the approximate threshold. The method improves running efficiency because it avoids iterating and logarithm computing in the gray scales in which no threshold. Two-dimensional histogram with rough-scale is a less scale two-dimensional histogram by combining the corresponding elements in original histogram.

Suppose $f(x, y)$ is a two-dimensional gray image whose size is $M*N$ and whose total gray level is L, $G(s, t)$ is the corresponding two-dimensional histogram defined by $D=\{(s, t) \mid 1\le s\le L, 1\le t\le L\}$, the value of $G(s, t)$ is $g_{s,t}=r_{i,j}/(M*N)$. Suppose the two-dimensional histogram with rough-scale is $G'(s', t')$ defined by $D'=\{(s',t')\mid 1\le s'\le \frac{L}{2^m}, 1\le t'\le \frac{L}{2^m}\}$, the value of $G'(s', t')$ is $g'_{s',t'}=\sum_{s=s'*2^m-(2^m-1)}^{s'*2^m}\sum_{t=t'*2^m-(2^m-1)}^{t'*2^m}g_{s,t}$. The scale of $G(s, t)$ then the scale of $G'(s', t')$ is $\frac{L}{2^m}*\frac{L}{2^m}$, here, 2^m is the gray span in G corresponding every gray level in G'.

Now, we discuss the algorithm in continuous space. Set s, t, s' and t' are continuous variables then:

$$\iint_D G(s,t)dsdt=\iint_{D'}G'(s',t')ds'dt'. \quad (15)$$

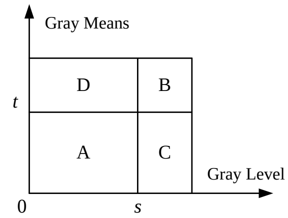


Figure 8. Two-dimensional histogram divided by vector (s,t).

And $G'(s',t')=2^m*2^m*G(2^m s',2^m t')$ because of $s=2^m*s'$ and $t=2^m*t$. Both histograms are similar. Only is the two-dimensional entropy of the image maximum while the gray corresponding one point is segmentation threshold. The two-dimensional entropy of the image is smaller deviation the point farther. So we can obtain the approximate threshold from G'. According to above definition, we'll compute the accurate threshold after searching the approximate threshold.

B. Automatic extraction ROI of infrared images

There are more pixels and better region connection in ROI relative to the background. We'll obtain a binary image including target and discrete noises after we segment infrared serial images using threshold method. In order to extract ROI automatically, we should eliminate false alarm points with that recover the connection of target region, exact search binary image, and then extract the accurate target farthest by various technologies. In this paper, the main extraction steps are order statistics filtering, mathematical morphology filtering and extraction rectangle ROI.

C. Analysis of Result

In this paper, we extracted ROI automatically in three infrared images whose sizes were all 768*576. The images are showed in Fig.9. Here, the first image is the first infrared image that is a tank distance of 100m and there is not noise in the image. The second infrared image is a warship distance of 1000m and the third infrared image also is a warship distance of 3500m, there are noises in the second and third images. The segmentation effect based on OTSU method shows in Fig.10. The segmentation effect based no invariant moment method shows in Fig.11. The segmentation effect based on this paper shows in Fig.12. Mask based on ROI automatic detection shows in Fig.13. Obviously, OTSU method and invariant moment method are all size-sensitive while the segmentation effect is the best based on our algorithm.

The image segmentation times based on various method shows in Table I. The time of searching threshold method based on our algorithm can be reduced rapidly compared with other methods. The searching efficiency improved 17.8% compared with the method mentioned in reference [24].

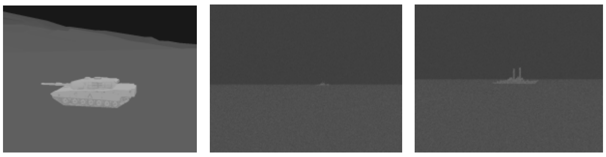


Figure 9. Infrared target image.

Figure 10. Segmentation results based on OTSU.

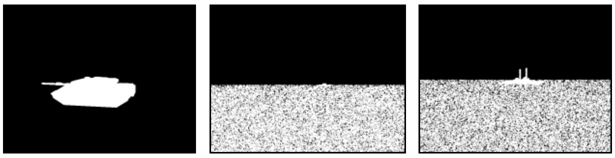


Figure 11. Segmentation results based on invariable moment method.

Figure 12. Segmentation results based on 2-D maximum entropy searching algorithm.

Figure 13. Mask based on ROI automatic detection.

TABLE I.
RUN TIME OF IMAGE SEGMENTATION ALGORITHMS

Run time (s)	Common method	Method in reference [24]	Our method
100m Tank	260. 83	0. 739 0	0. 593 4
3500m Warship	305. 66	0. 723 3	0. 563 0
1000m Warship	324. 64	0. 676 9	0. 609 0

VII. CONCLUSION

With updating for various weapon equipments continually, we should continue to set up the perfect schedules for target detection and extraction automatically in order to realize guidance accurately to infrared serial images. In order adapting the real scenes in modern battle, this paper proposed a target detection algorithm based on difference fusion and study online in static scenes and a moving target detection algorithm to register image based on QP_TR trust region. In addition, considering the features of infrared serial images, this paper proposed a new stepwise approaching and recurring threshold search algorithm based on two-dimensional maximum entropy principle and realized to extract ROI of infrared serial images automatically. All experiments were conducted in order to validate above algorithms. They are proved that our studying can not only meet common requirement for accurate guidance in modern battle but also is reliable and effective, which has significant utility value.

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