www.s2is.org
International Journal on Smart Sensing and Intelligent Systems
ISSN 1178-5608

IMAGE PROCESSING AND RECOGNITION ALGORITHM FOR TARGET TRACKING

Liping Lu[1] and Jinfang Wang[2]

1.School of Computer Science and Engineering, Xi'an Technological University, Xi'an 710021, Shaanxi, China

2.School of Electronic Information Engineering, Xi'an Technological University, Xi'an 710021, Shaanxi, China

Email:llp21@126.com, jinfangwang2014@sina.com

Submitted: Nov. 18, 2015 *Accepted: Jan. 19, 2016* *Published: Mar. 1, 2016*

Abstract- to improve target tracking performance in dynamic target track system, this paper propose the processing method of positive and negative difference image to extract target information; research target image preprocessing algorithm, the separation and segmentation processing algorithm of target and background, target edge detection and extraction based on the collected images; use Laplace operator, Canny operator. Gauss-Laplace operator to gain target information and improved recognition target image effect, analyze the positive and negative difference image measure to solve the background subtraction interference between two sequence images. Through the actual image processing, The results shows the proposed processing method can clear gain target marginal information and target image particle center, control tracking platform can stably track the target, and give the comparison results.

Index terms: Target tracking; OUSU; Canny; difference image.

I. INTRODUCTION

In the aeronautics, astronautics, weapon and control system, dynamic target tracking is important research point and urgent need solve the scientific problems. The intelligent control efficiency of system can be improved effectively by the precise location and real-time tracking[1]. In the field of aeronautics, astronautics and weapon guidance, the instantly changeable characteristics of dynamic target in each stage is a foundation of guided weapon control. Obtaining the information of moving target in real time is benefit to give correct judgments for surveillance of the whole tracking system, also provide the foundation for malfunction diagnosis and weapon system, and is also an important part of achieving automation and intelligence in weapon system [2]. The changeable information of the whole tracking process can be recognized and judged by tracking and measuring dynamic target. At present, various methods of target tracking and detection have been put forward in many literatures. In a word, targets are detected through imaging system and the relevant data are obtained by using the method of image processing or radar tracking[3].

In the dynamic target tracking system, the synchronous control of the tracking control platform, target detection and recognition is the control core and has an influence on the stability of the system. The current target tracking technology has achieved significant development, but due to environmental variety and goal of diversity, all kinds of moving targets tracking are not the only, which has unpredictable difficulties, especially on the dynamic parameter change characteristics of small targets with difficulty on target detection[4]. There is target acceleration, deceleration, background environmental changes and the inconsistent of loading platform, which brings some difficulties to long-distance dynamic targets track. Improvement and research on the tracking and detection of dynamic high-speed moving target can provide the analysis foundation for information acquisition, intelligent control and malfunction diagnosis of dynamic target.

The tracking of measured object is completed through the tracking rotating platform, the optical imaging system and processing algorithms because it is the tracking path target. The target recognition technology in the image is also researched after detecting targets in the optical processing system[5]. How to obtain the ideal target characteristics is the key that ensuring the reliability of the tracking system particularly in the complex environment. Because the environment of the target image recognition is complex, relevant processing methods such as preprocessing of image target, the processing of target separation and target edge detection should be researched to detect the target. This paper research target recognition processing algorithm under the complex background image based on the obtained target image, providing powerful characteristic parameters for the target tracking system.

II. Dynamic target recognition processing method

A. The target image preprocessing algorithm

In the process of dynamic target tracking, in general, there are many noises in the gathered target image. The original image must be preprocessed to obtain the relevant parameters. Image preprocessing is mainly to improve SNR and background suppression of image, reduce pressure of subsequent processing and satisfy the real-time requirements of the image processing system. The image preprocessing will directly affect the feature extraction and matching of projectile burst. In general, there are two image processing methods: spatial domain method and frequency domain method. The spatial domain method mainly calculates the pixel gray value in space domain, such as median filtering, high-pass filtering and so on. The frequency domain method mainly calculates conversion value in some transform domain of image [5-6]. The original image by the frequency domain method is filtered after Fourier transforms, and the filtered image is inversely transformed to the spatial domain to filter out noises and suppress background.

Median filtering is a common image preprocessing method and process the image by the selected window template to eliminate interference noise and point noise. Median filtering has good inhibition effect on interference noise and point noise. By using median filtering, The edge of image target can be preserved well and edge characteristics and clarity of targets are improved. The median filtering is a nonlinear image enhancement processing algorithm.

In median filtering, firstly a window W template with odd pixel is defined; then, each pixel of window according to the selected template is processed and analyzed. The pixels are arranged in a certain order according to the size of each pixel in the selected window. The pixel value of window center can be replaced with the gray value of intermediate position. Assuming that the image after processing is $g(x,y)$, it can be got by formula (1).

$$g(x,y) = mediam\{f(x-k, y-l),(k,l) \in W\} \quad (1)$$

In (1), the size of the selected template window is set W. The parameters of window are always defined as the size of 5×5, 7×7, 9×9 in the conventional image processing method. According to the size of the selected window and formula (1) the smooth image can be obtained.

In the window of two-dimensional median filtering, the template can be defined as square, cross and circle according to the requirements and all the templates are sliding window. According to the size of the selected window, the gray value of each point in the image is determined to replace the gray value of specified point.

However, the method of conventional median filtering cannot obtain good effects when there were more details and more thin lines in the image. Therefore, it is necessary to make weight processing for function based on the original median filtering method. For example, when the weight of middle pixel is 3 in the one-dimensional window whose size is 1×3, the pixel weight of both sides is 2, then the median weight value is $med\{x_{i-1},x_{i-1},x_i,x_i,x_i,x_{i+1},x_{i+1}\}$, and the gray value is arranged, thus details of the image are protected.

The effect of median filtering is better compared with previous two filters. A part of tiny background edge information can be filtered when noises are filtered. It is beneficial to remove background information and locate target edge by preserving the thick target edge information.

B. the separation processing algorithm of target and background

The image of target and background is obtained by the subtraction operation between the background image before the target appearance and the image after the target appearance. Ideally, the subtraction result of two frame images should be an all-black image when there is no target, the grays of background point in the field of view are zero; when there is a target, and the corresponding pixels in the target area are detected because of the change before target appearance. The distribution of gray values reflects the distribution of target luminance, and the gray values of background area with no targets are zero. There has system random noise and outside air jitter in actual detection, after subtraction operation on background area with no projectile burst target, the pixel gray values of the background area surrounding pixels are not all zero, and the background area is the image with noise distribution.

C. The segmentation processing algorithm of target and background

In the technology of image processing, the segmentation of target and background is the key and premise of image processing and also is the foundation of target information extraction in the complex environment. The principle of threshold segmentation is usually used in the segmentation of target and background, and the target information can be extracted in the complex environment through selecting the proper threshold [6]. But the choice of threshold has an influence on the technology of processing image in the different background environment. How to determine the best threshold to ensure the effect of image segmentation is the problem of the segmentation of target and background.

The accuracy of the segmentation of target and background image in tracking path is a premise for reliable control of the system. The threshold segmentation of target detection is to eliminate the influence of background noise through selecting proper threshold. The spurious signals are eliminated effectively according to the threshold. The choice of threshold has a direct influence on the effect accuracy of image segmentation. The algorithm of threshold segmentation can be divided into global threshold and local threshold. For the global threshold, the threshold is selected only once in the whole process of image segmentation and the whole image is divided into two categories according to the threshold. The common method of global threshold has minimum error method, OTSU method, etc. For the local threshold, the threshold is selected more than once in the whole process of image segmentation and many different thresholds can be selected according to the actual situation. The multi-category segmentation of image is completed according to the selected threshold. The advantages of threshold segmentation are simple calculation, high operation efficiency and fast speed.

The segmentation principle of the OTSU method is that the image is divided into two categories and the threshold is selected according to the probability of gray in the categories [7]. The gray value with the largest inter-class variance will be as the best threshold of the segmentation of target and background if intra-class variance is smallest. Its calculation method is: assuming that the size of obtained image is $m \times n$, then the total pixels of the whole image is $N = m \times n$. According to the theorem, the obtained image is divided into two categories C_0 and C_1 with the threshold. The gray ranges of two categories of images are selected as $G = \{0,1,...,L-1\}$, if the gray value of pixel i is t, then $C_0 = \{0,1,...,t\}$, $C_1 = \{t+1, t+2,..., L-1\}$. If the probability of each gray under the threshold is p_i, then formula (2) can be got.

$$P_i = n_i / N \quad , \qquad (2)$$

The probability of category C_0 is:

$$p_0 = \sum_{i=0}^{t} p_i = \omega(t) \qquad (3)$$

Its mean is:

$$\mu_0 = \sum_{i=0}^{t} ip_i / \omega_0 = \mu(t)/\omega(t) \tag{4}$$

The probability of category C_1 is:

$$p_1 = \sum_{i=i+1}^{L-1} p_i = 1 - \omega(t) \tag{5}$$

Its mean is:

$$\mu_l = \sum_{i=0}^{L-1} ip_i / \omega_0 = [\mu - \mu(t)]/[1 - \omega(t)] \tag{6}$$

In (5), μ is the overall gray mean value. Combined category C_0 with category C_1, the overall gray statistical mean of the image can be analyzed by the mean and the probability of two categories and formula (7) can be got.

$$\mu = \omega_0\mu_0 + \omega_1\mu_1 \tag{7}$$

Their standard variance is:

$$\sigma_{\mathrm{B}}^2 = \omega_0(\mu_0 - \mu)^2 + \omega_1(\mu_1 - \mu)^2 \tag{8}$$

In (8), the best segmentation threshold of target and background can be got when σ_B^2 the largest is˙

$$T = \max_{0 \le l \le l-1} \sigma_B^2 = \max_{0 \le l \le l-1}\left[\omega_0(\mu_0 - \mu)^2 + \omega_1(\mu_1 - \mu)^2\right] \tag{9}$$

It can be found that the variance is a measure standard of gray distribution uniformity of image from formula (8) and (9). It means that the change of gray between the target image and background is smaller if the variance is larger. Parts of backgrounds will be identified wrongly as targets and parts of targets will be identified wrongly as backgrounds, which have an influence on the effect of detection and recognition for targets. The false detection rate was reduced with the segmentation method of the largest inter-class variance by calculating gray standard equations of two categories of images. The segmentation threshold of target and background is determined by the value of t when the variance $\sigma^2(t)$ is the largest and this threshold is the best threshold.

For the target recognition, the OTSU method is mainly to search the best threshold in the whole gray of image after the image preprocessing. This global search takes much time and the processing speed is reduced accordingly. In the recognition processing of this paper, the proportion that the gray value of detection target is smaller than the gray value of background is a measure standard. This threshold is the best threshold if the proportion of measured target is larger than the proportion of background in the image and the search speed of best threshold is improved accordingly.

D. Target edge detection and extraction algorithm

The shape of target can be obtained after the segmentation of target image. In order to determine the target outer contour, it is necessary to make edge detection and extraction for the segmentation image [8-9]. Image segmentation, shape feature extraction and texture feature extraction are the important link and basis of edge feature extraction in the complex background image. And they are also important to analyze the target tracking in the image.

Edge is the basic feature of image. Edge is the set of pixels which gray has step change in the image. It commonly appears in background and target, target and target, area and area. Edge is the step edge and the line edge because it is related with the image brightness or the discontinuities of the first derivative of the image brightness.

Step edges behave that pixel gray values on both sides of discontinuities of the image brightness have significant difference. This difference is the transition from the light background to the dark background or from the dark background to the light background in aspect of vision. So the amplitude of the first derivative of the image brightness is very large on step edge and zero on the non-edge. Figure 1 is sectional view of image edge, first derivative and second derivative.

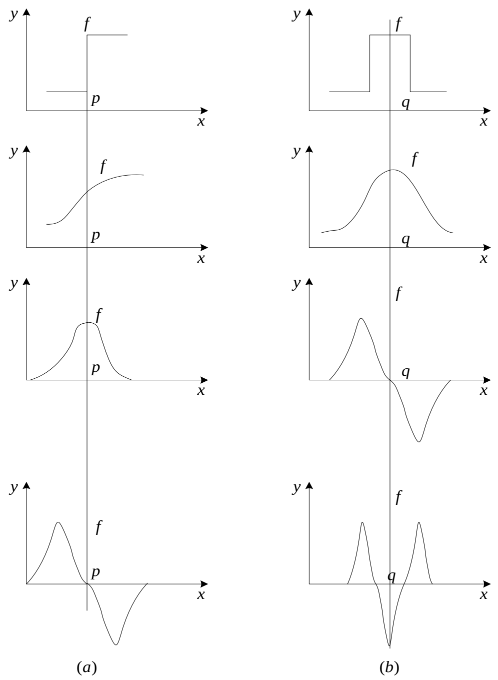


Figure 1 Sectional view of image edge, first derivative and second derivative

As is shown in figure 1(a), the change of the step edge is the brae edge because of the characteristics of image sensor and optical diffraction effect in the actual image. Line edge is the change of image brightness from one gray to another gray and becomes original or near-original gray soon. The line edge is located in the turning point on which gray changes from increase to decrease in the image. As is shown in figure 1(b), the first derivative of image brightness is zero but the amplitude of the second derivative is large for the line edge. Therefore, edge information is the important information for the target to be recognized [10]. For the gray images, the image edge is shown by the form of local discontinuities, and edge feature is the basis to obtain the smooth curve through processing image. Among the much analysis of image, image smoothing method need to obtain by using all kinds of filtering method, and its basic principle is: assuming that the original image is $f(x,y)$, the impulse response is $h(x,y)$, and then their convolution $g(x,y)$ is the method to get smoothing, expressed as:

$$g(x,y) = f(x,y) \otimes h(x,y) \tag{10}$$

In formula (10), $\otimes$ is the convolution operator. Their discrete function is:

$$g(i,j) = f(i,j) \otimes h(i,j) = \sum_{k=-n}^{n} \sum_{l=-m}^{m} f\left[(i-k),(j-l)\right]h(k,l) \tag{11}$$

Convolution is actually a weighted calculation of pixels from continuous state to discrete state, $h(i,j)$ is a model in the processing. Each pixel of target image $[i,j]$ is obtained by transmit function from convolution template to each pixel, $g(i,j)$ is an output image in formula (11). For two-dimensional template, two-dimensional discrete zero means Gaussian function is shown in following:

$$h(i,j) = e^{\frac{i^2+j^2}{2\sigma^2}} \tag{12}$$

In (12), σ is the mean variance of Gaussian function, i and j are pixels of image, σ controls smoothing effect of image. For the same pixel, the smoothing effect is better if σ is greater and $h(i,j)$ is smaller, but the result of this processing brings another side effect which is that image feature is too vague to detect image edge.

Currently, based on various image edge detection algorithms and different environmental background image with different algorithms, image edge detection algorithm is generally decided by calculation and adaptability of the system [11]. Edges of the image can be detected by using first derivative or second derivative. *Canny* operator, *Roberts's* operator, *Prewitt* operator, *Kirsch* operator, *Sobel* operator, *zero-crossing* operator, difference operator and

Gaussian *Laplace* operator are the common edge detection operator and they are processed according to the selected model. According to template sizes, the processing effects are not the same[12]. When in the processing, the template center is often corresponded to each pixel position of processing image and the coordinates of each pixel position are found, then according to the template formula, the calculated value is numerical size or position of corresponding pixels of output image.

Edge has two characteristics which are direction and magnitude and First derivative of edge processing is finished by using the two features. For step edge, we can find that magnitude changes are slow along the edge direction and are dramatic in the vertical direction after processing.

In order to obtain the true edge of target image, algorithms of *Laplace* operator and *Canny* operator are put forward. *Laplace* operator is common second-order differential edge detection operator. For a continuous function $f(x,y)$, *Laplace* values on the position (x,y) are defined in formula (13).

$$\nabla^2 f(x,y) = \frac{\partial^2}{\partial x^2} f(x,y) + \frac{\partial^2}{\partial y^2} f(x,y) \quad (13)$$

For processing of the sum of second derivatives on x-axis and y-axis, calculations of each pixel in the digital image are the same, and second-order difference equation is:

$$\nabla^2 f(x,y) = f(x+1,y) + f(x-1,y) + f(x,y+1) + f(x,y-1) - 4f(x,y) \quad (14)$$

Convolution template of *Laplace* operator is:

$$\nabla^2 f(x,y) \approx \begin{pmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{pmatrix} \quad (15)$$

In the image processing, the *Laplace* operator can be achieved with a variety of templates. In the processing, there is an edge when the zero crossing output of *Laplace* operator occurs. In theory, the output position accuracy of zero crossing can be obtained by solving on sub-pixel resolution ratio with linear interpolation method, but the accuracy of processing results will be reduced because of the presence of noise. Features of *Laplace* operator are isotropic, linear and invariant shift, good detection effect of isolated point and thread. For this algorithm, it is easy to lose the edge information, produce edge of double pixels and make double strengthening effect on noise in the edge disposed[13].

Based on the algorithm of *Laplace* operator, edge information is processed with the algorithm of *Canny* operator. For *Canny* operator in image processing, target and background are separated by separation method. Although the basic thoughts of edge detection methods are very simple, there are some troubles for detection target in various complex background images. Because actual signals of image are noise, and they are Gaussian distribution and high-frequency signals, if images in complex situations are processed with some simple operators, basically background noise signals are detected, in the same, false edge points caused by noise signals are appeared and these edge points disturb the actual signal points. To solve this problem, the conventional method is to eliminate noises with smoothing filter for image of original signal[14]. In order to improve edge characteristics of target image more effectively, In *Canny* operator, convolution operation between the original image and the smoothing filter impulse is proposed to eliminate noise.

$h(i, j)$ is smoothing filter impulse response, $f(x, y)$ is the original input image, output image $g(x, y)$ after smoothing filter can be got by the formula $g(x, y) = f(x, y) \otimes h(x, y)$ and image gradients after smoothing can be got by formula (16).

$$\nabla g(x, y) = \begin{bmatrix} g_x^{'} \\ g_y^{'} \end{bmatrix} = \begin{bmatrix} \frac{\partial g}{\partial x} \\ \frac{\partial g}{\partial y} \end{bmatrix} \qquad (16)$$

According to characteristics of convolution, formula (17) can be got:

$$\nabla g(x, y) = \nabla f(x, y) \otimes h(x, y) = f(x, y) \otimes \nabla h(x, y) \qquad (17)$$

This process is *Canny* edge detection operator. *Canny* edge operator is a Gaussian function, which can select the template to calculate pixels of two-dimensional direction according to the template window size[15]. This method eliminates the gradient magnitude smaller than adjacent areas by mutually comparing gradient magnitude of adjacent pixels in the direction perpendicular to edge. In the case of two-dimensional space, *canny* operator makes edge detection and edge location better and has anti-noise performance.

E. Real image processing

Figure 2 is original target images, it can be obtained through the infrared imaging system.

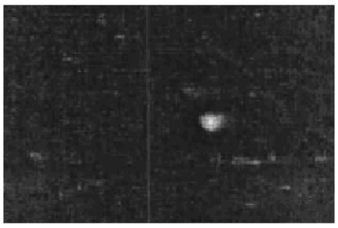


Figure 2 Original target images

Figure 3 is the result with the window of 3×3 based on median filtering, Figure 4 is the result image with the window of 5×5 based on median filtering. We can know that the effect of median filtering is better from the processing images. A part of tiny background edge information can be filtered when noises are filtered. It is beneficial to remove background information and locate target edge by preserving the thick target edge information.

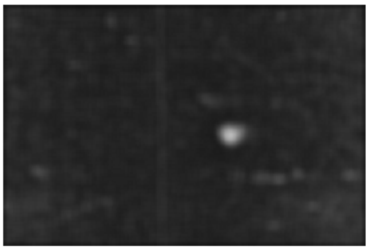


Figure 3 Processing result with the window of 3×3 based on median filtering

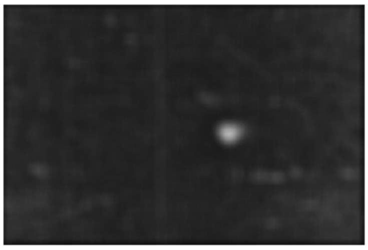


Figure 4 Processing result with the window of 5×5 based on median filtering

Figure 5 is the image edge detection processing result with *Gauss-Laplace* operator, the result shows that there is large noise effect and non-target-noise is processed as target when target characteristics are processed.

Figure 5 the edge detection result image with *Gauss-Laplace* operator

The edge detection image with canny operator is showed in the figure 5, we can find that the edge of the target is single edge which is beneficial to locate bonder because there are no extra boundary pixels in some corners. But there are some background noises in some corners.

Figure 6 the edge detection result image with *canny* operator

According to the analysis and comparison, effect of various operators for edge detection has certain differences because of the high contrast between image edge and background after threshold. In this paper, in order to get the smooth single-pixel edge and suppress the parasitic noises on the contour, *Canny* edge detection operator with the smooth effect on the noise and suppression on the false-edge is used, thus, the edge contour of burst is obtained.

III. Improved difference images processing algorithm in sequence target image

A. the basic principle of difference image processing

In target tracking system, the characteristics of moving targets should be extracted in the image to track targets accurately and synchronously. Difference images are put forward because there are significant differences between the previous frame image and latter frame image in the target image. Difference image is the foundation of extraction of moving target characteristics[16]. Target image motion reflects changing characteristics of image intensity between the previous frame image and the latter frame image. Characteristics of moving target are detected according to changing gray feature points if target image is processed by time integral calculation. Relative changes of image gray intensity can be described by the difference of image with adjacent time in the image sequence. Moving target image can be got by formula (18).

$$f_d(x,t_1,t_2) = f(x,t_2) - f(x,t_1) \tag{18}$$

In (18), f_d is the difference image? Difference images are effective combination of these motions if there are several independent moving targets in the scene.

The difference image in the target image can be regarded as an approximation of function derivation. The finite difference of two points in the image can be regarded as an approximation of $df(x,y)/dt$ at intermediate point of $t_2 - t_1$; there are the same effect between difference image which obtained in the actual background dynamic image and edge image which obtained from static image. The extraction of moving image characteristics still reflects the changing process of image intensity. The description of moving image is showed in figure 7. Assuming that image $f(x,t_1)$ at the time of t_1 contains a gray square area whose intensity is f_p. The area moves towards right with a constant horizontal speed v. The intensity of image background is 0 and the gray values of other images are more than 0, the image at the time of t_2 is $f(x,t_2)$, and square area moves to the right of image. The result is: the area which background intensity is 0 covers the original square area in the time interval $t_2 - t_1$, so, the difference image contain area which intensity is set $-f_p$, and right square area covers the background which intensity is 0 in the time interval $t_2 - t_1$, difference image contain area which intensity is set f_p, so, Intensity of the area is 0 after image difference operation if there are square areas in two images[17-18].

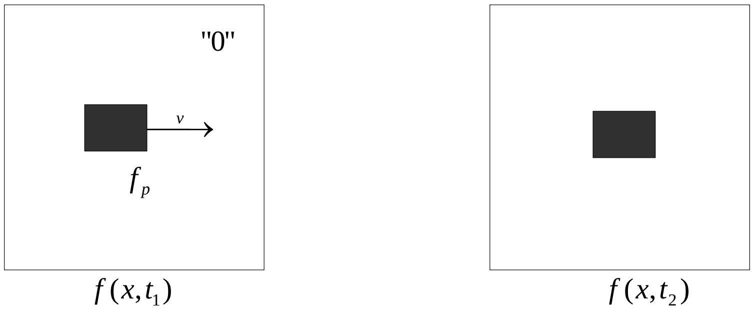


Figure 7 Description on differential image motion

B. Improved difference image processing algorithm in sequence target image

Difference image method has many advantages such as faster speed, high sensitivity and so on [20]. The difference image can be got by making the adjacent frame difference operation for obtained target image in real time with the optical camera. Motion of dynamic target can be achieved according to the target position of difference image to select proper tracking control algorithm. According to characteristics of difference image, tracking target is corrected to achieve the purpose of tracking in real time. However, the difference image has some disadvantages. For example, background of imaging area is still changing in the whole tracking process when environment background is complex. False targets are detected by the system with interference and it is not beneficial to target tracking detection when the background changes obviously.

In this paper, based on the principle of difference image, an improved method with background compensation mechanism is put forward. A dynamic background is changed into static background through compensating environment background. There are two methods of compensation. Firstly, the moving target of theodolite sequences images is detected with difference image method according to motion of known background. Moving target can be got with background motion compensation and difference image according to elevation angle and azimuth angle of the theodolite age. Secondly, according to motion of unknown background, the next background moving image can be forecast with image information estimation algorithm and the adjacent image is made background compensation[19]. It can eliminate the difficulty of target detection in the complex background.

Detection algorithm of positive and negative difference image is put forward based on difference image compensation theory. In the condition of fixed-field optical imaging, we can take a image without target as background image in advance for the problem of moving target detection. Difference images can be got by making a difference operation between the background image and images containing targets. Moving targets can be got according to the obvious gray difference between target area and background area because the background of difference images is eliminated basically. The core issue of the algorithm is some shadow interference that caused by change of background.

In the whole process in tracking path, clarity of the imaging physiognomy has differences because of the change of motion distances in optical imaging system, so we should make appropriate correction processing, thus, It is generally difficult to obtain in advance the background image for the difference operation in the whole dynamic tracking processing[20]. Therefore, background motion compensation is used for two adjacent frame images and difference of two adjacent images can be regarded as the approximate value of background image. Because the difference operations of the absolute value are used in the method of traditional difference image, the difference image usually appears two target areas. It is inevitable to have some noise areas on the difference image due to background motion compensation errors, image noises and so on. If the frequency of taking image is high enough, we can think that gray pattern of target and background in two images processed by difference operation does not change and target has not overlapping part in two images. According to operation rules of difference image: $\mathrm{I}_{sub} = \left| I_{t2} - I_{t1} \right|$, I_{t1} and I_{t2} are gray value of two images and two areas of targets on the difference image should have the same gray and distribution pattern of shape. In order to find target areas from the difference image, areas that gray and distribution pattern of shape is similar are corresponding to the target when shape information of target is not limited and all possible areas of the difference image are processed by pair wise combination method. Assuming that there are n possible areas on the difference image of tracking system, with a theory of combination, the total number of combinations is $C_{abs} = C_m^2 = m(m-1)/2$.

If there are 10 areas in the image, then the total number of combinations is 45. In these combinations, when two noise areas and some noise area are likely similar to a target area, there will result in incorrect detection. This situation of incorrect detection will be more likely to occur with the increasing number of combinations, thereby, detection reliability of moving targets on the difference image processed by absolute value operation is reduced. The absolute value operation of difference image requires background motion compensation, but the background motion compensation is a difficult task and it is as difficult as the target detection, so there is a big limitation on using absolute value difference image[21]. In order to eliminate misjudgment caused by the excessive number of combinations, the method of positive and negative difference images is put forward to detect moving target. Using the symmetry of positive and negative difference images to leave out background motion compensation and improve the reliability and adaptability of target detection, the whole tracking system is more stable.

The method of positive and negative difference images is to respectively generate two difference images based on the positive or negative difference during the difference operation, one is positive difference image $P(x,y)$; the other is negative difference image $N(x,y)$. We use formula (19) and (20) to express.

$$P(x,y) = \begin{cases} I_1(x,y) - I\ \ (x,y) & if\,(I_1(x,y) - I_2(x,y)) > 0 \\ 0 & if\,(I_1(x,y) - I_2(x,y)) \le 0 \end{cases} \qquad (19)$$

$$N(x,y) = \begin{cases} I_1(x,y) - I\ \ (x,y) & if\,(I_1(x,y) - I_2(x,y)) > 0 \\ 0 & if\,(I_1(x,y) - I_2(x,y)) \le 0 \end{cases} \qquad (20)$$

In (19) and (20), $I_1(x,y)$ and $I_2(x,y)$ are collected images at two moments in the optical system. The positive and negative difference image about possible appearance of target area has two characteristics, one is that areas of the same target are located on the positive and negative difference image, and two areas distributed on a positive or negative difference image are impossible corresponding to the same target[22]; the other is that if the number of the possible target areas on absolute value difference image is m, the number on positive image is m_1 and the number on negative image is m_2, we can know $m = m_1 + m_2$. According to these two characteristics, with positive and negative difference image for moving target detection, possible target area is made up with the area of positive difference image and the area of negative difference image, without considering the combination of areas inside positive and negative difference images, therefore the total number of combinations is $C = m_1 \times m_2$.

When $m_1 = 1$ or when $m_2 = 1$, the minimum value of C is $m-1$. When $m_1 = m_2 = m/2$, the maximum value of C is $m^2/4$. Formula (21) and formula (22) can be got:

$$m-1 \le C \le \frac{m^2}{4} \qquad (21)$$

$$\frac{2}{m} \le \frac{C}{C_{abs}} \le \frac{m}{2(m-1)} \qquad (22)$$

When m is larger, $m/2(m-1) \approx 1/2$, we can know that the number of combinations on image areas can be reduced, processing speed can be improved and the target detection efficiency can be enhanced with the method of positive and negative difference image.

C. Target detection algorithm based on positive and negative difference image

(1) Processing algorithmic procedure

Processing algorithm diagram of positive and negative difference image is shown in figure 8. Firstly, the current moment image is obtained through the optical system, and two adjacent images are done subtraction to obtain positive difference image and negative difference image in the tracking process. Images subtracted are made preprocessing by the method of median filtering to eliminate background noise, and target is effectively extracted out with the separation technology between target and background[23-24], then the target edge is detected; secondly, after the image processed through edge detection, target areas are marked and areas of two images are matched. If areas that coincided with target characteristics are found by the method of match, the possible target area may be obtained; finally, the images in the matching area are detected. If the detection is successful, the target is determined and target area is output. With much detection, target is determined when the same result occurs.

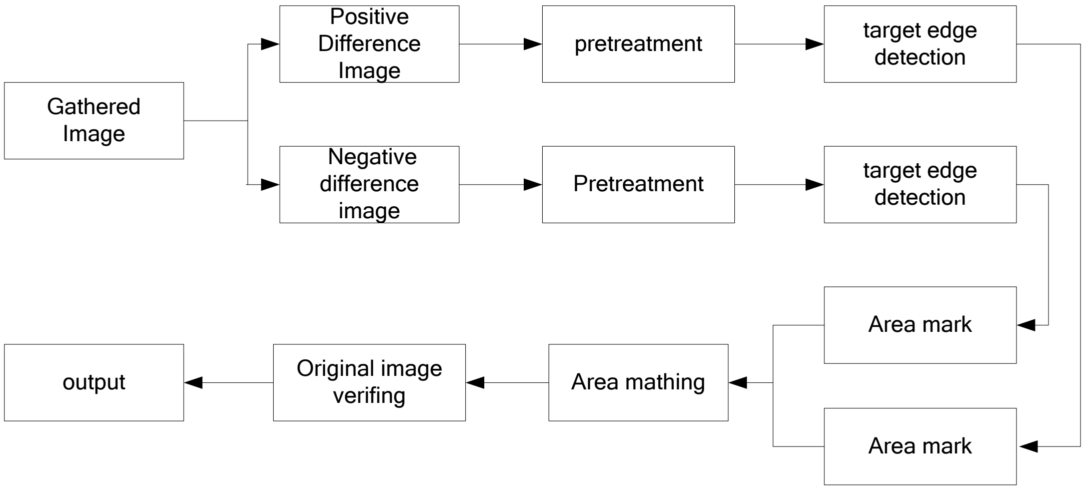


Figure 8 Processing algorithmic diagram figure of difference image

(2) The acquisition and processing of positive and negative difference image

The target image sequence is showed in formula (23).

$$f_i(x,y) = \left(r_i^f(x,y), g_i^f(x,y), b_i^f(x,y)\right), x \le N, y \le M, i = 0,1,2,\cdots \qquad (23)$$

In (23), $r_i^f(x,y)$, $g_i^f(x,y)$, $b_i^f(x,y)$ is the pixel (x,y) of the i frame image, M is width of the obtained image, N is height of the obtained image, i is frame sequence number of the obtained image. Based on the sequence image, view area of the moving target is determined by making difference operation for the obtained image. The difference sequence image is showed as in formula (24).

$$d_i(x,y) = \left(r_i^d(x,y), g_i^d(x,y), b_i^d(x,y)\right), x \le N, y \le M, i = 0,1,2,\cdots \qquad (24)$$

In (24), $r_i^d(x,y)$, $g_i^d(x,y)$, $b_i^d(x,y)$ is pixel (x,y) of the i frame difference image.

$$r_i^d(x,y) = \left|r_i^f(x,y) - r_{i-1}^f(x,y)\right| \qquad (25)$$

$$g_i^d(x,y) = \left|g_i^f(x,y) - g_{i-1}^f(x,y)\right| \qquad (26)$$

$$b_i^d(x,y) = \left|b_i^f(x,y) - b_{i-1}^f(x,y)\right| \qquad (27)$$

The i frame and $i+1$ frame original image and corresponding positive and negative difference image are obtained by real-time collection. In order to get the area of moving target, appropriate threshold is selected for the edge processing according to processing algorithmic diagram of difference image. The value of pixel higher than threshold is 1and the value of pixel lower than threshold is 0. The difference image sequence is changed into binary image sequence after preprocessing, edge detection and area mark for the difference image through selecting appropriate threshold. Then formula (28) can be got.

$$B = \{b_i(x, y), x \le N, y \le M, i = 0,1,2,\cdots\} \tag{28}$$

$$b_i(x, y) = \begin{cases} 1, & \|d_i(x, y)\|_\infty \ge T_i \\ 0, & \|d_i(x, y)\|_\infty < T_i \end{cases} \tag{29}$$

The difference image reflects not only the edge and area of moving target but also the background disturbance when the background image appears disturbance, and the position of moving target is not detected with difference image. In order to remove the interference, the symmetrical difference image sequence is obtained with symmetrical difference method based on the difference method. The symmetrical difference method is to make AND operation on the i frame image and the $i+1$ frame image. The processing method is showed in formula (30) and formula (31).

$$D = \{d_i(x, y), x \le N, y \le M, i = 0,1,2,\cdots\} \tag{30}$$

$$d_i(x, y) = b_i(x, y) \oplus b_{i-1}(x, y) \tag{31}$$

Symmetrical difference image includes not only edge points of the moving target but also the isolated points, which is caused due to the camera shake. The symmetrical difference image is made filtering processing in order to eliminate the influence. Detecting whether the neighborhood of every non-zero pixel includes other non-zero pixels is the filtering method. These points are not caused by camera shake or background shakes if the points of non-zero pixels are larger than a threshold. They are boundary points of moving target; otherwise they are noise to be eliminated.

(3) target area image extraction

The area of moving target can be got with the horizontal projection and vertical projection of the symmetrical difference image after filtering. The projection vector is showed in formula (32) and formula (33).

$$P_{i,X}(x) = \sum_{y=1}^{H} d_i(x, y) \tag{32}$$

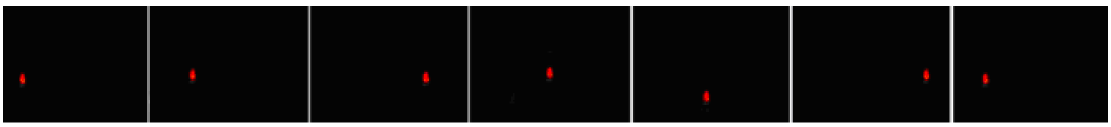
$$P_{i,Y}(y) = \sum_{x=1}^{D} d_i(x, y) \tag{33}$$

In (32) and (33), $P_{i,x}(x)$ is the projection value when the horizontal coordinate is x and $P_{i,Y}(y)$ is the projection value when the vertical coordinate is *y*. D is the width of image and H is the height of image. $d_i(x,y)$ is gray value of the i frame image.

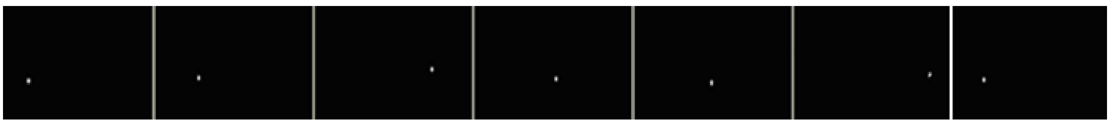
For the horizontal direction, the sign variable $j=0$, the moving target area $N=0$, boundary points $P_{x(start)}[i]=0$, $P_{x(end)}[i]=0$. $x=0$ and L is the gray value. If $P_{i,X}(x)\geq L$ and $j=0$, x is the start boundary point of moving target on the horizontal direction, then $j=1$, $N=N+1$, $P_{x(start)}=x$; if $P_{i,X}(x)<T$ and $j=1$, x is the end boundary point of moving target on the horizontal direction, then $j=0$, $N=N+1$, $P_{x(end)}[N]=x$. When $x=x+1$, the above judgment and calculation are repeated. When, $x=D$, x is the width, if $P_{i,X}(x)\geq T$ and $j=1$, x is the end boundary point of moving target on the horizontal direction. Boundary points on the vertical direction can be determined in the same way.

IV. Target sequence image acquisition and tracking performance analysis

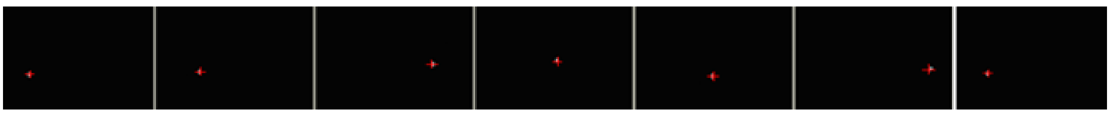
In order to verify the dynamic target tracking algorithm, the sequence image on the start tracking path is showed in the figure 9. The right image is the first frame image and images are collected and output from left to right in turn. The original infrared sequence image is showed in the figure 9（a）, the processing result of different image filtering and edge detection is showed in the figure 9（b）, the center area mark result of tracking, recognizing and location is showed in the figure 9（c）.



（a） The original infrared sequence image



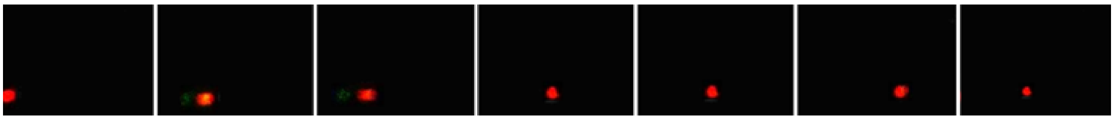
（b）The processing result of difference image filtering and edge detection



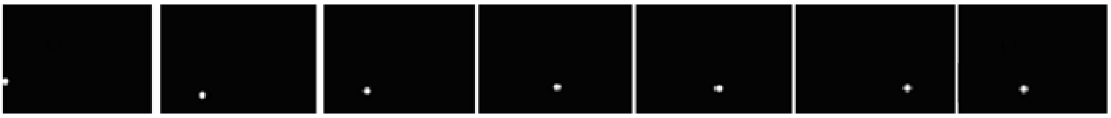
（c）The center area mark result of tracking, recognizing and location

Figure 9 The collected sequence image on the start tracking path

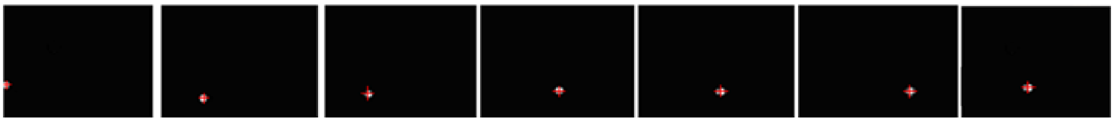
The collected sequence image on the middle tracking path is showed in the figure 10. The right image is the first frame image and images are collected and output from left to right in turn. The original infrared sequence image is showed in the figure 10（a）, the processing result of different image filtering and edge detection is showed in the figure 10（b）, the center area mark result of tracking, recognizing and location is showed in the figure10（c）.



（a） The original infrared sequence image



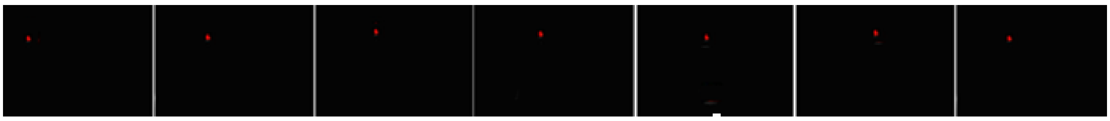
（b）The processing result of difference image filtering and edge detection



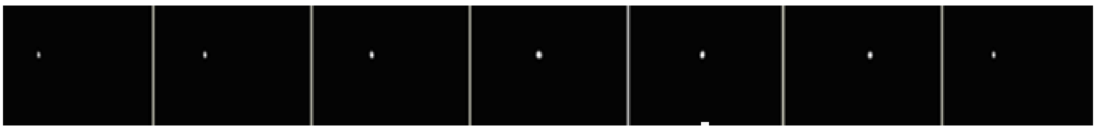
（c）The center area mark result of tracking, recognizing and location

Figure 10 the sequence collected image on the middle tracking route

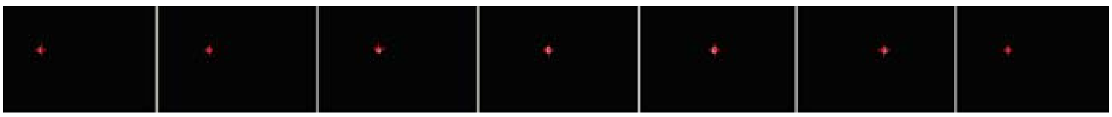
The collected sequence image on the end tracking path is showed in figure 11. The right image is the first frame image and images are collected and output from left to right in turn. The original infrared sequence image is showed in figure 11（a）, the processing result of different image filtering and edge detection is showed in figure 11（b）, the center area mark result of tracking, recognizing and location is showed in figure11（c）.



（a） The collected original infrared sequence image



（b）The processing result of difference image filtering and edge detection



（c）The center area mark result of tracking, recognizing and location

Figure 11 the collected sequence image on the end tracking path

The target optic imaging size of points on the different positions is not same in the whole tracking path from the processing result. The target distance of imaging and the size of imaging are not the same because the distance from tracking turntable to tracking path is different in the whole tracking process. The position of the collected frame image is not fixed because of the shake when the tracking platform is moving. In order to verify the tracking timeliness of the entire tracking path, using high-precision angle encoders as the contrast real-time reading angle in control turntable, the tracking effect is to determine base on the deviation between theoretical ballistic speed and measured projectile velocity. Table 1 to Table 3 is the part of data measured in a particular experiment and the results based on the analysis of data and images. Tracking platform rotation angle controlling unit time is set to 0.3s, Table 1 shows the data of the initial dynamic state, Table 2 shows the data of the middle section dynamic state and Table 3 shows the data of close to the end of the segment state, speed error is the difference between the theoretical and measured speed.

Table 1. The test data of the initial dynamic state

theory desired angle（°）	the measured angle reading（°）	speed error（%）
0.108	0.110	1.92
0.198	0.207	1.63
1.809	2.012	4.21
2.988	3.451	5.08
2.361	2.488	3.34
3.382	4.009	6.15
4.091	4.118	3.98

Table 2. The test data of the middle section dynamic state

theory desired angle（°）	the measured angle reading（°）	speed error（%）
20.812	20.997	4.87
24.677	24.566	4.78
30.756	30.908	5.49
35.871	36.083	5.37
38.070	38.573	3.81
40.237	41.244	2.76
41.240	41.889	3.16

Table 3. The test data of close to the end of the segment state

theory desired angle（°）	the measured angle reading（°）	speed error（%）
59.461	59.608	5.74
60.608	60.573	3.88
65.543	64.998	3.63
68.803	68.089	4.89
70.341	70.945	3.45
72.306	72.017	4.85
74.087	74.334	2.98

It can be shown from the data analysis of Table 1 to Table 3 that the tracking system has more error in the initial state because of the rotating platform’s jitter and other effects, and has less error and is more stable in the middle section state.

V. Conclusions

In this paper, the tracking image is obtained and the characteristics of the target are analyzed by tracking camera platform. The original image is processed with median filtering to improve SNR of image and restrain the background noise. Target and background in the projective burst image are analyzed and the information of the burst and the target is extracted. The image is segmented with the OUSU method and infrared target image edge is extracted and detected with *Laplacian* operator and *Canny* edge detection operator. The *Canny* edge detection operator has good signal edge characteristics and the small noise background, and is beneficial to target recognition and processing in the complex environment from processing result. Combined with the characteristics of tracking system, sequence image of dynamic target is processed with the improved difference image method based on the image recognition processing, improving the real time and reliability of the tracking system.

ACKNOWLEDGEMENT

This work has been supported by Science Technology Research and Development Plan in Shaanxi Province of China (No. 2014K0558), university and graduate school technology transfer plan In Xi'an Science Technology Bureau of China (No. CXY1520 (1)).

REFERENCES

[1] Hu Jwu-sheng, Juan Chung-wei, Wang Jyun-ji, “A spatial-color mean-shift object tracking algorithm with scale and orientation estimation”, Pattern Recognition Letters, 2008, Vol.29, No.16, pp.2165-2173.

[2] Kato J., Watanabe T., et al, “An HMM/MRF-based stochastic framework for robust vehicle tracking”, IEEE Transactions on Intelligent TransPortation Systems, 2004, Vol.5, No. 3, pp.142-154.

[3] Jung S K, Wohn K Y, “A model-based 3-D tracking of rigid objects from a sequence of multiple perspective views”, Pattern Recognition Letters, 1998,Vol.19, No.6, pp.499-512.

[4] Mallat S, “A theory for multi-resolution signal decomposition”, IEEE Transactions on Pattern Analysis and Machine Intelligence, 1989,Vol.11, No.7, pp.674-693.

[5]Hu W., Xiao X., et al, “Traffic accident prediction using 3-D model-based vehicle tracking”, IEEE Transactions on Vehicular Technology, 2004, Vol.53, No.3, pp.677-694.

[6]Osher S, Sethian J A, “Fronts propagating With curvature dependent speed: algorithms based on Hamilton-Jacobi formulations”, Journal of Computational Physics, 1988,Vol.79, No.l, pp.12-49.

[7] Li P H, Zhang T W， Pece A E C, “Visual contour tracking based on Particle filters”, Image and Vision Computing, 2003,Vol.21, No.l, pp.111-123.

[8] Rohr K, “Towards model-based recognition of human movements in image sequences” , Image Understanding, 1994,Vol.59, No.l, pp.94-115.

[9] Meng An, Zhiguo Jiang, “High Speed Robust Image Registration and Localization Using Optimized Algorithm and Its Performances Evaluation”, Journal of Systems Engineering and Electronics, 2010, Vol.21, No.3, pp.520-526.

[10]R. H. Zhan, Q. Xin, J. Wan, “Modified unscented particle filter for nonlinear Bayesian tracking”, Journal of Systems Engineering and Electronies, 2008,Vol.19, No.1, pp.7-14.

[11] K. Nummiaro, E. Koller-Meier, L. V. Gool. “An Adaptive Color-Based Particle Filter”, Image and Vision Computing, 2003, Vol. 21, No.1, pp.99-120.

[12] Hanshan li. Research on target information optics communications transmission characteristic and performance in multi-screens testing system. Optics Communications, 2016, Vol.364, pp.139-144.

[13] Xiang Hua,Jinjin Zhang, Bin Le, “Investigation on photoelectric the odolite data processing and random errors model”, International Journal on Smart Sensing and Intelligent Systems, 2015, Vol.8, No2, pp.1180-1202.

[14] Pillay P, Bhattacharjee A, “Application of wavelets to model short-term power system

disturbances", IEEE Trans on Power Systems, 1996, Vol.11, No.4, pp.2031-2037.

[15]B.Hilt, P.Fessler, G. Prevot, "High-Speed Data Acquisition System for Spectroscopic Imaging of Ionizing Particles", IEEE Transactions on Nuclear Science，1999, Vol.46, No.5, pp.1285-1288.

[16] Gauda A M, Saadany E F E, Salama M M A, et al, "Monitoring HVDC Systems Using Wavelet Multi-resolution Analysis", IEEE Transactions on Power Systems, 2001, Vol. 16, No.4, pp.662-670.

[17]M, S. ArulamPalam, S. Maskell, N. Gordon, et al, "A tutorial on particle filters for online nonlinear/non-Gaussian Bayesian tracking", IEEE Transaction on Signal Processing, 2002, Vol. 50, No2, pp.174-188.

[18] Hanshan Li. Limited magnitude calculation method and optics detection performance in a photoelectric tracking system. Applied Optics, 2015,Vol.54, No.7, pp.1612-1617.

[19]M. Isard, A. Blake, "CONDENSATION-conditional density propagation for visual tracking", International Journal of Computer Vision, 1998, Vol.29, No.l, pp.5-28.

[20]C. S. Hsieh, "General two-stage extended Kalman filters", IEEE Transaetions on Automatic Conirol, 2003,Vol. 48, No. 2, pp.289-293.

[21] Hanshan Li. "Space Target Optical Characteristics and SNR Calculation Model on Sky Screen", IEEE Sensors journal, 2016, Vol.16, No. 4, pp. 912-917.

[22]D. Comaniciu, V. Ramesh, P. Meer, "Kemel-based object tracking", IEEE Transactions on Pattern Analysis and Machine Intelligenee, 2003,Vol. 25, No. 5, pp. 564-577.

[23] Z. Li, Q. L.Tang, N. Sang, "Improved mean shift algorithm for occlusion pedestrian tracking", Eleetronics Letters, 2008, Vol. 44, No. 10, pp.622-623.

[24] Liu Erlin. "Automatic segmentation of brain tumor magnetic resonance imaging based on multi-constrains and dynamic prior", International Journal on Smart Sensing and Intelligent Systems, 2015, Vol.8, No2, pp.1031-1049.