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Research on Target Characteristics and Target Recognition Algorithm under Complex Background

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Abstract

To improve the recognition rate of dynamic target under complex background, this paper studied the target characteristics and recognition algorithm of moving target. According to the light intensity, target shape and motion characteristics, the calculation model of the target characteristics was established, the optical radiation characteristic and the detection performance of photoelectric detection system under complex background were analyzed. By means of image segmentation and mathematical morphology transform, the target information extraction and recognition algorithm was researched and analyzed. Through the simulation calculation and experimental verification, the results show that target characteristics model and recognition algorithm is feasible.

Keywords*: target characteristics, target recognition, detection performance, complex background*

1. Introduction

In the aspect of recognition, target recognition is one of the key items in computer vision field, and under complex background it is one of important applications in the military field. The photoelectric detection device achieves detection function through the spectral characteristics and detects energy which is emitted by reflected sunlight of space targets and other light source. And the reflected light energy from other targets will be detected also by the photoelectric detection device [1-2]. These targets other than radiation source for image acquisition system belong to the interference source. It will cause a certain degree of interference in photoelectric detection device. Therefore, to improve the target signal detection ability of photoelectric device, it is necessary to analyze and research the characteristics of target under complex background, which has the vital significance of effective and reliable target recognition method.

At present the domestic and foreign scholars have done some research on characteristics of targets under the complex background. For example, the literature [3] has introduced the research trend of target characteristics; the concept of pattern classification has been issued based on the different characteristics of target and environment. However, the current study of the target and environment feature is only a general introduction or is to keep from talking about [4]. Till now, there is no strict theoretical derivation and analysis, and the methods of target recognition are only built on the basis of image processing, which is not from the deep study on target characteristics. The essence of target recognition is to make full use of the difference between the target and environment characteristics, through the enhancement of target characteristics or weakening of environmental characteristics[5], so as to greatly improve the separability of

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target and environment and finally to identify the target after further processing. This paper analyzes based on the characteristics of targets under complex background.

2. The Characteristics of Targets under Complex Background

Conceptually, the complex background is defined comparing to a simple background. The so-called simple background refers to the gray distribution of background image in the space is stable, and all pixels in the image gray value of the statistical mean and variance have null shift in variance, such as the image by a single physical components like sky, sea, grassland and desert[6]. Complex background refers to the gray distribution of background image in space is not stable, and the statistical mean and variance of image pixel gray value is not null shift in variance, such as the composite image composed of various physical components like the junction between sky and sea, airport and port.

The target characteristics under complex background refer to optical radiation characteristics when the space target is as the source of radiation. Optical radiation characteristic of target radiation source directly affects the imaging effect of the target region in the image. Under radiation of light source like sun, space target itself will form a new radiation sources [7]. There are many other targets in the surrounding of complicated background targets. The new radiation source origin from those targets after effects of the light belongs to a kind of interference source for the target recognition. It is the fundamental reason for the image background clutter and noise point interference. Therefore, in order to better detect the target, it is very necessary to research the characteristics of targets.

Target characteristics reflect the physical phenomenon which is caused due to the influence of light source like sun. It reveals the inherent characteristic of target. The main content on target characteristics include the characteristics of the target radiation source and optical radiation characteristics.

3. The Characteristics of the Target Radiation Source

When the light rays hit the target, the surface of the target will carry on the absorption and reflection of light. Part of the reflected light will enter the probe field so as to be detected by the detector. The strength of reflecting light received by detectors is relative to the material of target surface and the spatial position of the target.

At present, in the research on reflection characteristics of the target surface, the characteristic parameter of target surface reflection properties is described by bidirectional reflection distribution function. Bidirectional reflection distribution function (BRDF) shows the relationship between the irradiance along a direction of the incident and the radiance along the exit direction after the reflection of target surface. t is determined by the target surface roughness, dielectric constant, the radiation wavelength, polarization and so on.

The BRDF is a four-dimensional function. It has been defined as the radiance ratio between irradiance $dE(\theta_i, \phi_i)$ along the direction (θ_i, ϕ_i) of incident to the measured surface, and radiance $dL_r(\theta_i, \phi_i, \theta_r, \phi_r)$ along the direction (θ_r, ϕ_r). The mathematical expression is shown as follows [8]:

$$f_T(\theta_i, \phi_i, \theta_r, \phi_r) = \frac{dL_r(\theta_i, \phi_i, \theta_r, \phi_r)}{dE(\theta_i, \phi_i)} sr^{-1} \quad (1)$$

Figure1 is the geometric relationship diagram of BRDF. On the surface dA , incoming light direction is (θ_i, ϕ_i), the observation direction of detector is (θ_r, ϕ_r). θ, ϕ are the zenith and azimuth angle respectively. Z is the normal direction of small bin

in the target surface. Considering the incoming light as the sun, below relationship can be gotten.

$$L_T(\theta_i, \phi_i, \theta_r, \phi_r) = f_T(\theta_i, \phi_i, \theta_r, \phi_r) E_0 \quad (2)$$

L_T is the irradiation brightness of target reflection light, E_0 is the irradiance from sun to target.

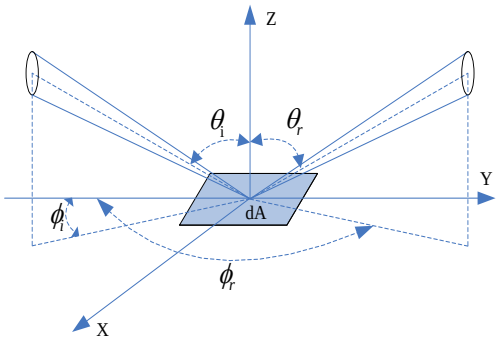


Figure 1. The Geometric Relationship Diagram of BRDF

The photoelectric detector is to realize the detection function through the detection of light of the target radiation source in the radiation field range. The image of each target collected by detection corresponds to the corresponding target in space. Therefore for the detector, space target and the target around the target is equivalent to a radiation source. The energy of this radiation source comes from reflection on the energy of other sources. From this point of view, BRDF is a parameter to show energy level from different radiation sources [9]. Thus, it can be seen that the energy intensity of target radiation source is not only relative to itself characteristics of the target such as the target shape size, the surface material and the surface roughness, but also relative to incoming light direction of lights like sun, the measured distance and viewing direction by detector.

4. Optical Radiation Characteristic of Target

Optical radiation characteristic of target refers to the radiation distribution of target radiation source. According to the definition of BRDF, outgoing radiance from target radiation source is relative to the material of target surface and the spatial position between the detector and the target. Thus, for the detector, the target radiation characteristics can be summarized as the characteristic of space and time. Characteristic of space refers to the spatial position relation between detector receives radiation illumination and target. A characteristic of time refers to the rule that radiation received by detector can change with time.

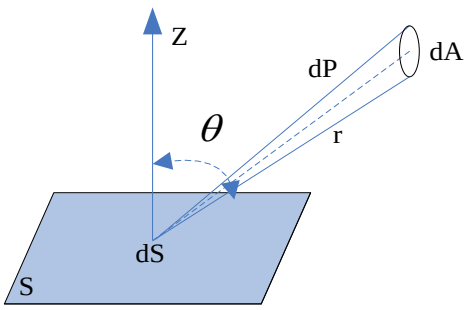


Figure 2. Radiation Intensity Diagram of Target Radiation Source

As shown in Figure 2, the radiation intensity of *E* received by detector is defined as the ratio between the radiation flux dP irradiated in the unit surface of the photosensitive surface of the detector and the unit area dA . It can be expressed by (3).

$$E = \frac{dP}{dA} \tag{3}$$

According to the science of amplitude, the relation between radiation flux and radiation intensity will meet the function $dP = Id\Omega$. At the same time, radiation intensity is defined as the radiation flux of the detector orientation on the surface radiation source [10]. It is shown as following.

$$L(\theta, \varphi) = \frac{dI(\theta, \varphi)}{dS\cos\theta} \tag{4}$$

In (4), θ is the angle between incoming light direction and the surface normal?

According to formula (2), (3) and (4), we can get the radiation illumination received by detector, which is shown in formula (5).

$$E = L_T \frac{S^2 \cos\theta}{Ar^2} \tag{5}$$

S is the radiation area of the target radiation source, *r* is the spatial distance between a detector and the target, *A* is the sensitive area of the detector. Therefore, radiation intensity of target radiation source, affecting detector, is decided by those aspects, which are the reflected light irradiation brightness L_T , the target radiation source area *S*, detector photosensitive area *A*, the azimuth angle between the detector and the target, and the distance r from the detector to the target.

Radiation target radiation received by the source detector is $Q = Pt$. At the same time, the solid angle between target radiation source and the detector $d\Omega$ is

$$d\Omega = \frac{dS}{r^2} \tag{6}$$

According to formula (2), (5) and (6), radiation of the target radiation source received by detector can be shown as follows:

$$Q = EAt \tag{7}$$

It can be seen that radiation received by detectors is relative to the sensitive area of the detector, radiation received by detector and the duration of irradiance. In the actual measurement process, sensitive areas of the detector are the established factors. So the radiation received by detectors is the accumulation of certain strength of the irradiance during the time.

Due to the scope limit of the view field of the detector, when space target movement speed is faster, the detectable time of detector becomes shorter. So the radiant energy received by the detector is mainly associated with the movement speed of target. When the target speed is large, radiation target radiation received by the source detector can be greatly reduced. Through collecting the continuous multi-frame image, the energy of target pixels detected by the detector can be improved effectively. It makes the target more prominent so as to improve the system detection probability.

5. Analysis of Image Gray Model and Detection Performance Model under Complex Background

Treatment methods of target recognition are, according to the different characteristics of target and environment, based on the separation between the target and background regions in the image, then further to process and recognize the target. Therefore, the key of target recognition lies in the region separation between target and background. Because of the difference of optical radiation characteristic between target and environment, and the difference gray value among the imaging region of each target in the image, the target irradiance received by detector is stronger, the target in the imaging region on the image is brighter and gray value is smaller. On the contrary, the target in the imaging region on the image is darker and gray value is bigger. Therefore the difference of gray value can be made use of to do the segmentation of the target in the image in the background region. The mathematical model of image gray can be established as follows

5.1. The Image Gray Model

The collected image by system can be described as the following mathematical model.

$$f(i,j,k)=\begin{cases} t(i,j,k)+v(i,j,k), \\ b(i,j,k)+v(i,j,k), \end{cases} \tag{8}$$

$f(\mathrm{i},\mathrm{j},\mathrm{k})$ is the Image gray value, $t(\mathrm{i},\mathrm{j},\mathrm{k})$, $\mathrm{b}(\mathrm{i},\mathrm{j},\mathrm{k})$, $v(\mathrm{i},\mathrm{j},\mathrm{k})$ are the gray value of the target area in the image, the gray value on the background, gray value of the noise points in the image separately, i and j are the coordinate values in image plane, K is image sequence frames.

According to the space distribution of optical radiation characteristics of target, the radiation intensity of target is nothing with radiation intensity of environment, and is higher than radiation intensity of environment around itself. Therefore, the background areas occupy the low frequency part in the image, but the target area is located in the high frequency part in the image [11]. Based on the difference of gray characteristic between background region and target region, by the principle of threshold segmentation, the target and background in the image can be divided primarily. There is radiation interference in other target in the environment, and there are various types of noise in the system during the detection process, which brings some noise in the image. Those noises will bring the interference for further recognition of target, which should be removed. Morphology transformation is often used to smooth the image and filter out noise during the image process.

5.2. Detection Performance Model

For a detection system, when the target signal appears, the system should detect a target as far as possible. And when the target signal is not present, the system should avoid false positives situation as far as possible. That is, system detection probability should be maximum with minimal false-alarm probability. Detection probability $\mathrm{P}_{\mathrm{DET}}$ and false-alarm probability P_{FA} is the main index to judge the performance of the detection system. Their mathematical expressions are as follows [12]:

$$\mathrm{P}_{\mathrm{DET}}(\mathrm{x})=0.5\left[1+erf\left(\frac{SNR-TNR}{\sqrt{2}}\right)\right] \tag{9}$$

$$P_{FA}(x) = 0.5\left[1 - erf\left(\frac{TNR}{\sqrt{2}}\right)\right] \tag{10}$$

In (9) and (10), $erf(x) = \frac{2}{\sqrt{\pi}}\int_0^x \exp(-t^2)dt$, $SNR = (f_T - u)/\sigma_I$, $TNR = V_{th}/\sigma_I$. f_T is gray extremum of the target, u is the image gray mean, σ_I is the image gray standard deviation, SNR is noise-signal ratio, *TNR* is threshold noise ratio and V_{th} is threshold.

According to formula（9）and（10）, in order to improve the probability of detection system the system signal-to-noise ratio (SNR) should be increased, or the system threshold noise ratio (TNR) should be reduced.

According to the continuity of gray value among multi-frame image of moving target, the accumulation of frames can reduce the variance of the image pixels without changing the mean value. It can increase SNR and reduce the TNR. So you can enhance the target signal energy detected by detector through the approach of multi-frame accumulation for collected image. It will make more prominent target so at to improve the probability of detection system.

The main reason why it is difficult to identify the target under complex background is that there are many interference sources around the target environment, and there is higher degree of coincidence between target effective characteristics information, such as geometrical shape and surface texture, and background characteristics. Therefore, it is difficult to divide the background region and the target fully, only according to the gray level threshold segmentation and morphological transformation. There is some isolated compounds and the strong noise point in the image hard to get rid of. Thus, in order to detect the target effectively, it is need to use the motion information of multi-frame image target and consider the continuity of motion characteristics and consistency of tragedies trajectory both, so as to achieve effective recognition to the target in image ultimately.

6. Target Recognition Method Based on Image Flow Analysis

Based on the analysis of image gray model and detection performance, this paper puts forward specific target recognition under complex background method. Firstly, this paper does the pre-process for the single frame image; takes use of image segmentation to do preliminary separation of target region and background region. The discrete parts in the image and the noise are eliminated through mathematical morphology transform on the image. The system SNR and detection performance is improved, using accumulation processing of multi frame image. Based on the image flow analysis, according to the consistency and continuity of target motion, the real target can be identified. Among them, the single frame image pre-process is the precondition, which is the foundation of the multi-frame image processing. Multi-frame image accumulation processing based on the image flow analysis is the focus, which is the key whether system can recognize the target.

6.1. Image Segmentation

According to the difference of gray feature between target and background regions in an image, the image can be divided into different gray value region.

The basic principle of threshold segmentation is available as follows:

$$g(x,y) = \begin{cases} 1 & f(x,y) \geq T \\ 0 & f(x,y) \geq T \end{cases} \tag{11}$$

$f(x, y)$ is the original image, $g(x, y)$ is binary image after the threshold segmentation, T is the gray threshold choose. Binary image is marked as the corresponding target pixel 1 while the mark of pixel 0 corresponds to the background. So any point which meets $f(x, y) \geq T$ is called the target point, the other point is known as the background [13].

For the image under complex background, there is a small difference between gray value of target region and background value. Therefore if the target will be separated from the background effectively, threshold selection is the key. If the threshold is too high, it will lead too much target pixels to be divided into the background region [14]. However if the threshold is too low, more background pixels will be attributed to the target area. Here, bimodal threshold value method is taken to determine the gray threshold image segmentation. Figure 3 is gray histogram of the original gray image.

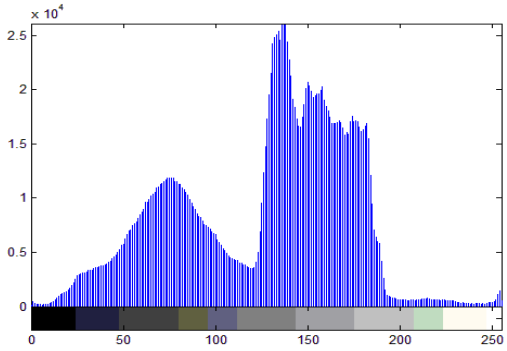


Figure 3. The Gray Level Histogram of Original Image

The two peaks in gray histogram are the image pixel points in the target zone and the pixel points of the background area respectively. Peak valley between two peaks represents relatively few pixels near the intersection between the area of target and background in the image. Therefore, selecting the gray value in gray level histogram bottom as the image segmentation threshold can separate the target and background region better.

6.2. Mathematical Morphology Transform

Through the discrete part there are more noise points existing after the image threshold segmentation. It can carry out filtering and demonizing by morphological transform in image processing. Morphological transformation is based on the geometry and mathematics theories with a certain morphological structure elements to measure and extract the image in the shape of the corresponding regional parts, so as to achieve the purpose of image analysis and recognition.

The basic idea is to use the origin of the selected structural elements for translation in the whole image area. According to the overlap situation between pixel structure elements and image zone, the origin position on the structural elements can be marked and the structure information of image will be gotten finally. So whether the design of structural elements is reasonable or not will directly affect the results of morphological transform. The open operation can remove the target area without the structural elements, the smooth out-frame of target; disconnect the narrow connection, and prominent part out fine. Closed operation will fill the hole smaller than structural elements and connect the narrow gap to form the long narrow mouth. So the two are often combined together to smooth the image and remove the noise.

6.3. Multi-Frame Image Processing

After the method of processing the single frame image such as image segmentation and morphological transform, there are still some isolated targets in the image and strong noise as a potential target affecting the final recognition result, which also needs further treatment through multi-frame image accumulation.

The nature of multi-frame image accumulation processing is to improve the image SNR according to the correlation among the continuous multi-frame image target and non-correlation noise. Through the accumulation of N image, mean gray u of target points and noise points in the image remains unchanged. However the standard deviation σ_1 of image gray is down to the original $1/\sqrt{N}$. According to the definition of SNR in formula (9), the SNR of detection system is improved by $\sqrt{N}$ times, it improves the detection probability of the system and reduces the probability of false alarm system, so as to ensure the reliability of the system detection performance.

Through the analysis of image, isolated targets in the space in the position of the stationary state and strong noise is in random variation. Two are difficult to form continuous motion trajectories. While the space target is in the state of continuous movement, it has a certain regularity of continuous trajectory. On this basis, multi-frame image sequence can be analyzed by the method of image flow. According to continuity and consistency principle of space target motion the true moving target can be detected.

The basis of image flow analysis is the image flow constraint equation. The image flow constraint equation reflects the relation between spatial gradient change of the radiation image of an arbitrary point (x,y) on the image plane and instantaneous speed (u,v) of this point. Assuming $E(x,y,t)$ is the gray value of point pixels (x,y) in the image plane, and then the expression of the image flow constraint equation is as shown below:

$$E_x u + E_y v + E_t = 0 \tag{12}$$

From (12), it can be seen, the image flow constraint equation is essentially a linear equation of velocity (u,v) plane. Due to the continuity of target motion space, the movement of the target velocity mutation will not occur. Therefore, in the continuous N (N>2) image, the target's movement speed is almost unchanged. In successive N images, N motion constrained linear target should be approximate to the intersection point in speed plane. As shown in Figure4, the N motion constrained linear poly at a point P.

For the isolated target in the stillness, because of its no continuous motion trajectory, it is good be eliminated. But for the strong noise, because of the randomness of its appearance, even in a few frames continuous motion trajectories can be formed. However with the increase of image frames, these noise points can't form an aggregation point in speed plane. It can remove a strong noise points so as to identify the real target.

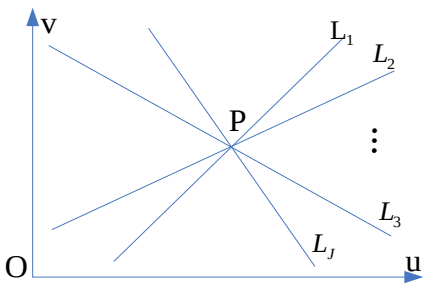


Figure 4. Fusion of Target Motion Constraints Linear in Velocity Plane

7. Simulation and Experimental Analysis Processing

7.1. The Target Radiation Characteristics Simulation

According to the analysis of target optical radiation characteristic, during the actual measurement process, effect on the radiation intensity of illumination received by the detector is mainly decided by the distance R between the detector and the target, and the angle θ of target deviation from detection surface element normal. Here for these two parameters the simulation analysis was made on the influence degree of the light irradiance received by detector.

To simplify operation, during the simulation analysis of the target radiation space characteristics, solar irradiance on the target radiation source E_0 is $900W/m^2$, the average reflectivity of the target surface is generally 10%-35%, it take 20% here, detector photosensitive area A is $48mm^2$, target radiation source area S is $5m^2$. The relation among the distance r from target radiation source to detector, the angle θ from standard deviation to detection surface normal and the irradiance received by detector, Figure5 is the relation among the angle of goal deviate from detection surface element normal, detection distance and radiant illumination.

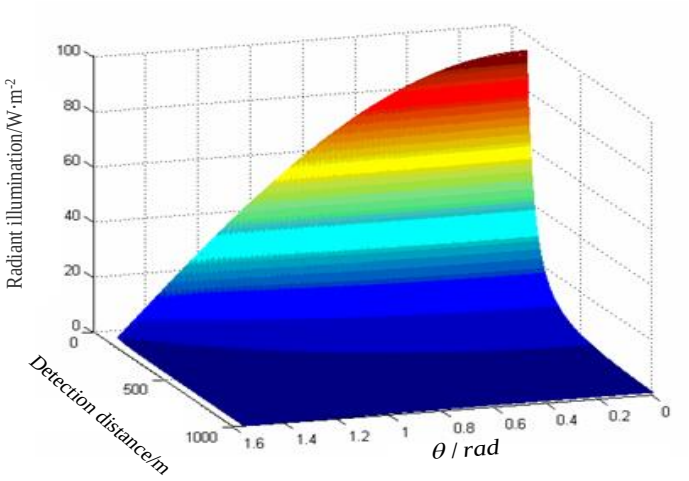


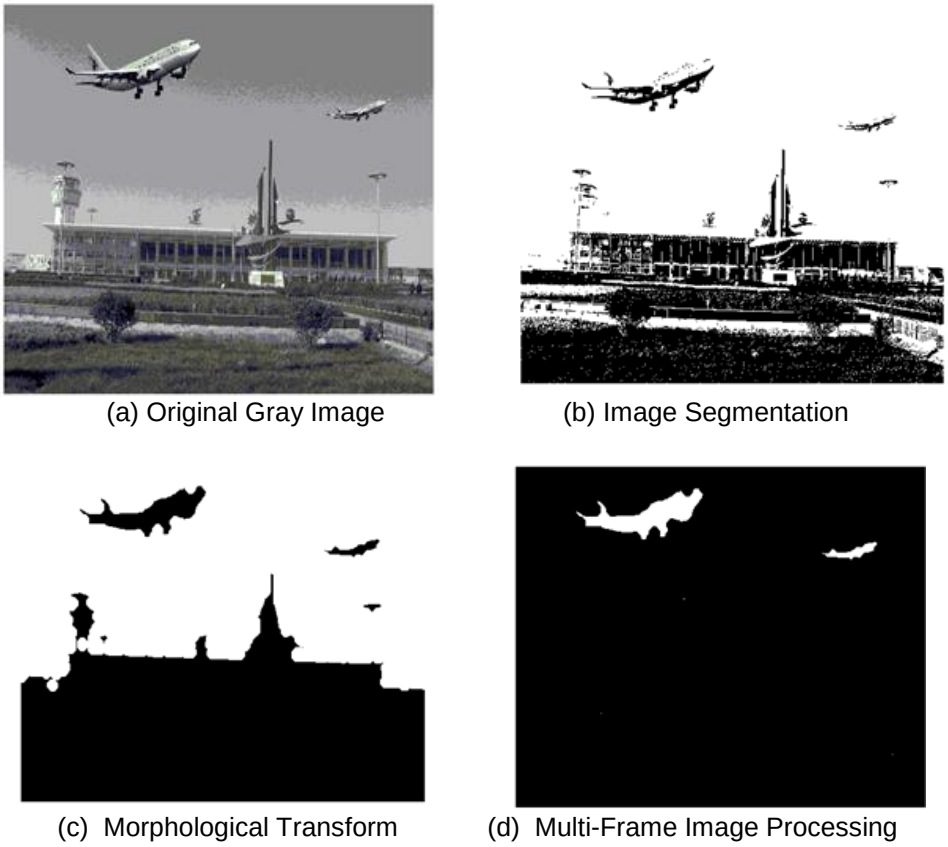
Figure 5. The Relation among the Angle of Goal Deviate from Detection Surface Element Normal, Detection Distance and Radiant Illumination

It can be seen from Figure 5, in the case of other factors under certain, with the angle from target deviation to detection surface normal increasing gradually and the distance from target to detector increasing, irradiance received by detector weakened rapidly. It shows in image that the target imaging area is not obvious and gray value in image region increases.

Under complex background radiation characteristics of the interference sources around target each are not identical, therefore, in the image, the severity of the interference on the target are not the same. But on the whole, the existence of these interference sources makes the contrast of target and background areas in an image, which make the SNR of detection system lower. In the actual situation, radiation intensity of target radiation source is influenced by the target material and is limited by the radiant energy of the incident light source surface. So the irradiance received detector has a limit value.

8.2. Target Recognition Processing Analysis

By the method of target recognition based on image flow analysis, the target recognition processing can be done to the image. Its result can be seen in Figure 6.



(a) Original Gray Image (b) Image Segmentation

(c) Morphological Transform (d) Multi-Frame Image Processing

Figure 6. The Results of Target Recognition Algorithm

Figure 6 (a) is as the original gray image. It can be seen that there is a little difference of gray in the whole image, and the contrast of target and background is not obvious. Interference also exists around the flight target. Through segmentation method of the gray level threshold in original image, it will be divided into different areas of gray value. Figure 6 (b) is the original gray image processing results of the image after segmentation. It can be seen that the target and background regions has been separated after preliminary image segmentation. At the same time, there are still many discrete parts and the noise in image. Figure 6 (c) is the results of morphological transform. After image segmentation, it can be seen that in the image slender curved mouth, prominent parts and dentate inner edge and a small hole has been removed. This image becomes smooth. However there are still a few isolated part and noise in this image are not removed. Figure 6 (d) is the result of accumulation of multi frame image after processing. From the consequence of treatment in Figure6, it can be seen that with image flow method, the characteristics of moving target can be exacted and useful information can be effectively identified from the background. It can achieve the purpose of target recognition in complex background.

8. Conclusions

Target recognition in complex background is a hot and difficult problem in computer vision research. Aiming at the problem of target recognition in complex background, domestic and foreign scholars have put forward different kinds of recognition algorithm. However most of the target recognition algorithm is based on image processing itself, it is

not related to the nature of target recognition. The essence of target recognition is based on making full use of the characteristics of the target and environment, to improve the separability of the target and environment through the enhancement of target characteristics or weaken the environmental characteristics, and to identify the target after further processing. This paper is based on this starting point, to analysis from the target and environment characteristics under complex background. Based on the analysis of image gray model and detection performance model, this paper proposes an effective moving target recognition method is proposed. First of all, this paper does preliminary separation from the target and background via the image segmentation, and eliminates discrete parts in the image and the noise points by morphological transform, then improves the detection performance of the system according to the accumulation of multi-frame image processing. And based on the analysis of the image flow, the real target is detected according to the consistency and continuity of target motion. Finally, the reliability of the algorithm is verified by simulation experiments, the experimental results show that the movement target identification method is equally effective for multiple moving targets recognition.

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