Moving target detection method based on polarization characteristics under the condition of moving detector

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Abstract: Moving target detection is a important field of image processing. Because the existing algorithms are vulnerable to background disturbance's interference in the case of moving detector, a moving target detection algorithm based on target's polarization characteristics under the condition of the moving detector has been proposed in this paper. Firstly, for the problem of the target detection such as the movement of background and parallax which are caused by the moving detector, a moving target detection method under the condition of moving detector has been proposed. The method gets detector's motion estimation and compensation parameters by using image feature points matching method, and uses background updating method to achieve target's detection. Then LK optical flow method is used to get target's movement information and detector's movement information and model the target's and background's movement information. Eventually this method calculates the relevance of the background's and target's movement information model to achieve target detection. Secondly, for the moving target detection method could not solve the problem of Background disturbance which interferes the detection result, a target detection method fused target polarization characteristics has been proposed on the basis of moving target detection method under the conditions of the rotation detector. This method realizes the target detection algorithm based on target's polarization characteristics under the condition of moving detector, by pre-processing the polarization images to solve the parallax's effect, clustering and segmenting the pretreated polarization image to extract polarized target, and fusing the moving target detection method. The experiment result shows that this method can effectively detect moving targets with a strong polarization characteristics in the scene, while suppressing the interference brought by strong polarized but still region and weak polarized background disturbance in the sense.

Key words: polarization characteristics, moving target detection, motion estimation, compensation parameters

1 Introduction

Moving target detection technology is one of the key technologies in the field of image processing, it can achieve the goal of automatical capture of moving targets capture in the view field, providing necessary conditions for the subsequent moving target tracking and recognition. D.S Lee, M. Heikkila and S. Zhang et al. studied moving target detection in the condition that probe keep stationary l, proposing the method to detect the moving target ,using a background modeling to suppress the background[1-3]. These methods are applied to the detector stationary target detection system, and achieved good results. However, in these systems since the detectors

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are stationary, so that the monitoring of the field keeps stationary, resulting in the target can not be detected beyond the field of view, it is necessary to use a rotation detector to expand the detection area for detecting moving targets from the moving images. In order to realize the moving target detection in the motion detector conditions, and solve the problem of interference caused by background disturbances, this paper will introduce the target polarization characteristics to the target detection, proposing a target detection method under a polarization rotation detector conditions.

2 Multiple features of target detection

2.1 Moving target detection

Estimation and compensation of motion detectors

In order to solve the problem of influence on the background updating caused by the scene motion of rotational motion detector, the input image sequence need estimation and compensation of the detector motion. Through the detector motion estimation and compensation, we can eliminate the impact of position offset between adjacent frames scenarios caused by the rotation detector effects, improve the accuracy of background update[4-5], therefore, this paper uses the feature point matching method for estimation and compensation of detector motion.

Background update

After the detector motion estimation and compensation, we need to achieve the goal that target is detected once by background updating. Background updating is an algorithm that the moving object in the field of view is extracted from the background by establishing the field of background model[1]. According to the algorithm ,assumming that the background model is $P(x \mid \psi_B)$, foreground model is $P(x \mid \psi_F)$,established the following classifier to achieve target's detection.

$$\sigma(x) = \begin{cases} -1 & \text{if} \quad \tau > k \\ 1 & \text{other} \end{cases} \tag{1}$$

where $\tau = -\ln \dfrac{P(x \mid \psi_B)}{P(x \mid \psi_F)}$.

Finally, using morphological filtering methods to achieve marking the target of a detection, as shown in figure (d).

Get target and background motion information

According to the target detection results by updating background, select the corner points belong to background as interesting points of LK optical flow, as is shown in figure (a). By calculating the optical flow information of background corner points to describe the state of motion in the background.

The motion of the background image is assumed as vector $H_B = \{(x, y), (\Delta x, \Delta y), P \mid (x, y) \in \psi_B\}$;where (x, y) is the coordinates of background corner points, the motion vector $(\Delta x, \Delta y)$ is the calculation results of LK optsical flow, P is the weight which corner belongs to the background ψ_B .

P can be calculated by spatial correlation, assumming a as the pixel value of background corner points , and the pixel value within 3×3 range is $C=\{a_1,a_2,\cdots a_8\}$. The weight of the angular points belong to the background ψ_B can be expressed by the following equation:

$$P(x,y)=P(a,a_1,a_2,\cdots,a_8\,|\,\psi_B)=P(a\,|\,\psi_B)\prod_{i=1}^{N}P(a_i\,|\,\psi_B) \tag{2}$$

where $N=8$ 。

Because imaging area of long-range infrared target is small, and with less texture, we use the foreground pixels in the connected region of target image as the interesting points of LK optical flow, as is shown in figure (d) and figure (e).

The motion information of target is assumed as vector $H_F=\{(x,y),(\Delta x,\Delta y),R)\,|\,(x,y)\in\psi_F\}$;where (x,y) is the foreground pixel coordinate, R is the weight of the pixel belonging to the target ψ_F. R can be calculated by the same method referencing to P.

Assumming b as the foreground pixel, and the pixel value within 3×3 range is $C_F=\{b_1,b_2,\cdots b_8\}$, R can be expressed by the following equation:

$$R(x,y)=P(b,b_1,b_2,\cdots,b_8\,|\,\psi_F)=P(b\,|\,\psi_F)\prod_{i=1}^{N}P(b_i\,|\,\psi_F) \tag{3}$$

where $N=8$.

Modeling the target's and background's movement information

Because the background motion information is complex, and optical flow information is two-dimensional data $(\Delta x,\Delta y)$, so the two-dimensional mixed Gauss model is used to smooth optical flow of background corner points information, establishing the background motion information model.

The optical flow information of background angular point is a vector. The vector can be assumed as $x=[\Delta x\ \Delta \mathrm{y}]^T$. Then the Gauss mixture probability density function can be expressed by the following equation:

$$P(x)=\sum_{j=1}^{M}\alpha_j N_j(x;u_j,\Sigma_j) \tag{4}$$

where, $\sum_{j=1}^{M}\alpha_j=1$, $N_j(x;u_j,\Sigma_j)=\dfrac{1}{\sqrt{(2\pi)^2\,|\Sigma_j|}}\exp\left[-\dfrac{1}{2}(x-u_j)^T\,\Sigma_j^{-1}(x-u_j)\right]$ is the probability density function of the j^{th} Gaussian distribution

Figure 1 shows the process of the background and target motion information modeling. Figure (b) is the distribution of background corner points' optical flow. Figure (c) is the distribution of hybrid Gauss curve fitting. Gaussian mixture can effectively describe the distribution of background corner points' movement.

Since moving target is with integrity and consistency, according to the detection results of background updating, we use Gauss function to model the target movement information of foreground pixels in each Connected region, as shown in figure (f) and figure (g).

Assumming $x_k = [\Delta x \ \Delta \mathrm{y}]^T$ as the pixel's motion information of the kth connected region, then the probability density function of Gauss mixture can be expressed by the following equation:

$$G_k(x) = \frac{1}{\sqrt{(2\pi)^2 \,|\, \Sigma_k \,|}} \exp\left[-\frac{1}{2}(x-u_k)^T \Sigma_k^{-1}(x-u_k) \right] \tag{5}$$

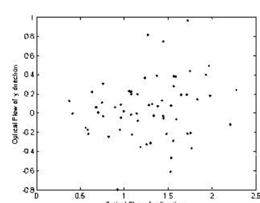
Because Δx and Δy are independent with each other, $\Sigma_k = \begin{bmatrix} \mathrm{var}(\Delta x) & 0 \\ 0 & \mathrm{var}(\Delta y) \end{bmatrix}$.

Target's seconed detection

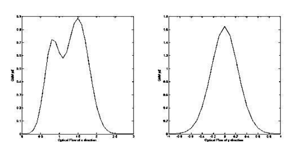
In order to eliminate the false alarm which is caused by disparity and detector's trembling, the relative entropy is used to analyze the differences between probabilistic model of target's motion information and background's motion information.

The relative entropy is also known as Kullback-Leibler divergence, used to measure the difference between the two probability distributions[6].

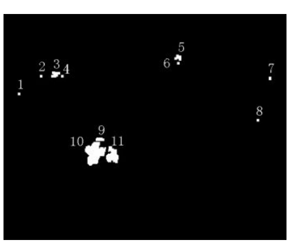
(a)optical flow of background corner points



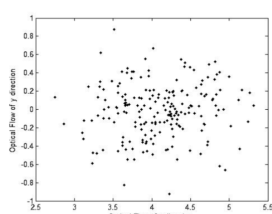
(b)distribution of background corner points' optical flow



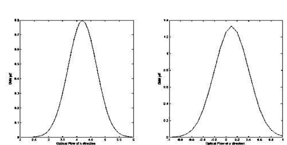
(c)model of background corner points' optical flow information



(d)Target's signature



(e)distribution of the foreground pixel's optical flow in tenth connected region



(f) model of foreground pixels optic flow's information in tenth connected region

fig1 modeling background and target motion's information

The relative entropy of distribution density $f(x)$ and $g(x)$ is defined as

$$D(f \| g) = \int f(x) \log \frac{f(x)}{g(x)} dx \tag{6}$$

Based on this ,the differences between probabilistic model of target's motion information and background's motion information are defined herein as

$$D_k = \sum_{j=1}^{M} \alpha_j D_j \tag{7}$$

where $D_j = D(N_j(x; u_j, \Sigma_j) \| G_k(x))$, substituted into Eq(1)

$$\begin{aligned}
D_k &= \sum_{j=1}^{M} \alpha_j D_j \\
&= \sum_{j=1}^{M} \alpha_j D(N_j(x; u_j, \Sigma_j) \| G_k(x)) \\
&= \sum_{j=1}^{M} \alpha_j \left(\int N_j(x; u_j, \Sigma_j) \log(N_j(x; u_j, \Sigma_j)) dx - \int N_j(x; u_j, \Sigma_j) \log G_k(x) dx \right) \\
&= \sum_{j=1}^{M} \alpha_j (-\log 2\pi - \frac{1}{2} \log \left|\Sigma_j\right| - \frac{1}{2} T_r \left(\Sigma_j \Sigma_j^{-1} \right) + \log 2\pi \\
&\quad + \frac{1}{2} \log \left|\Sigma_k\right| + \frac{1}{2} T_r (\Sigma_j \Sigma_k^{-1}) + \frac{1}{2} \left\{ (u_j - u_k)^T \Sigma_k^{-1} (u_j - u_k) \right\}) \\
&= \sum_{j=1}^{M} \alpha_j \left(\log \frac{\left|\Sigma_k\right|}{\left|\Sigma_j\right|} + T_r \left(\Sigma_j \left(\Sigma_k^{-1} - \Sigma_j^{-1} \right) \right) + \left(u_j - u_k \right)^T \Sigma_k^{-1} \left(u_j - u_k \right) \right)
\end{aligned} \tag{8}$$

According to the analysis above, the motion model of false alarms which caused by disparity and trembling is well correlated with the background's motion model, target's motion model is independent with the background's motion model. We can eliminate the false alarms in the background updating by calculating the relative entropy of motion information's probability model and background's motion information in each connected region.

2.2 detection of polarization target

Detecting man-made targets in complex natural background is a hot topic in the field of target detection and recognition. Through the domestic and foreign research on the technique of polarization imaging, we knows that the target's polarization information obtained by using polarization imaging method is quite different from the natural background's polarization information in certain conditions. It is beneficial to distinguish artificial target from natural background. In the case of that the image's gray, texture and other features are not obvious, it can be used to distinguish between military targets and natural background

The surface of vehicles and other artificial target is relatively smooth, polarizing effect is more obvious, and distribution evenly. Background composition of natural scenery, road and others is more complex, the surface is rough, the degree of polarization is low and the distribution is not uniform. Therefore, the differences of polarization can be used to get targets' detection and classification.

Pretreatment of polarization image

to get the polarization image is get by using a three-channel polarization imaging system, and among the three channels ,three optical paths are separated. Although the optical paths are parallel, the disparity effect is still existed.Because of the disparity, the registration of scene images is not complete. The following picture shows the image which was collected by the three-channel polarization imaging system.

(a) original image (b) polarization image

fig.2 the image collected by the three-channel polarization imaging system.

Figure (b) shows that because of the disparity, three-channel polarization imaging system cannot make the registration for all pixels among three channels. Therefore, Scenery edges in the polarization image are project noticeably, affecting the performance of target detection.

Morphological filtering of image

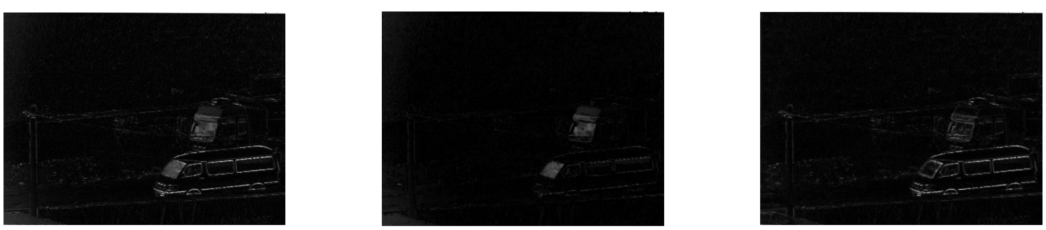
In order to extract the edges of the polarization image, we need to make the image's erosion operation. b is defined as a flat structure element size of 3×3 .The corrosion process was defined as following[7-12]:

$$f_e = (f \Theta b)(x,y) = \min\left\{ f(x+x', y+y') \mid (x',y') \in D_b \right\} \tag{9}$$

where， D_b is the definition domain of b， f is the input image， f_e is the corroded image.

The edge image can be obtained by subtracting the corroded image from the original image:

$$f_{edge1} = \begin{cases} f - f_e & f - f_e > 0 \\ 0 & else \end{cases} \tag{10}$$



(a) polarization image to be processed (b) corroded image (c) extracted edge image

(d) expansive edge image (e) processed image

Fig.3 polarization image before and after morphology filtering

In order to solve the problem that some wider edges affect the extraction effect, we need to make the expansion processing for the extracted edge f_{edge1} [13-17]:

$$f_{edge} = \left(f_{edge1} \oplus b\right)(x, y) = \max\left\{ f\left(x - x', y - y'\right) \mid \left(x', y'\right) \in D_b \right\} \tag{11}$$

The processed polarization image can be obtained by subtracting edge image f_{edge} from original polarization image.

$$f_{out} = \begin{cases} f - f_{edge} & f - f_{edge} > 0 \\ 0 & else \end{cases} \tag{12}$$

Figure.3 is the polarization degree images before and after morphological filtering. The after morphological filtering polarization image's edge problems which caused by parallax can be effectively solved ,and the noise in the image is significantly reduced.

Clustering of polarization image

KFCM clustering method is used to cluster the polarization images, and the membership matrix is generated based on the polarization information.

(a) result by KFCM clustering (b) target image divided by OTSU after clustering

Fig4 Result by polarization target detection

Fig4 is the result by polarization target detection. From fig(a) we can see polarization image is divide into a number of classes after KFCM clustering. Like fig(b) we can get polarized target image by using Otsu method.

2.3 Fusion Detection

Since moving target detection is susceptible to interference from local disturbances in the scene, for instance, many false targets will be detected in the scene where leaves are shaking. So the detection result is not stable only using the movement feature. The still scenes with strong polarization also affect the test results only using target's polarization features. In order to detect moving targets effectively, we need fusion detection using targets' motion characteristics and polarization characteristics.

The steps of fusion detection are as follow:

1) Use a three-channel polarization image system to capture the scene's polarization image, meanwhile, take the image from any channel as the original image be detected.

2) Do estimation and compensation of motion detectors for original image, extracting

moving target.

3) Cluster polarization image after morphological filtering, extracting polarization target.

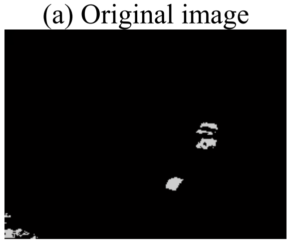
4) calculate the difference of two-dimensional Gaussian model between the moving target and the polarization target, keep the target of the similar Gaussian model, Completing fusion detection.

2.4 Experimental results

To compare the effects of moving target detection method, polarization target detection method and fusion detection method, we use these methods to detect targets separately in the same scene.

(a) Original image

(b) Result by moving target detection



(c) Result by polarization target detection

(d) Result by integration detection

fig5 Result by target detection

As it can be seen from Figure (c), local plane with larger angle of the vehicle and detector in the scene and smooth reflective surface in background buildings have strong polarization, but rough surfaces have low polarization like vegetation, soil and roads. After processing the polarization image by Morphological filtering and clustering, strong polarization area in the scene can be effectively highlighted. However, not all regions of strong polarization have the moving targets which need to be detected, such as metal roof on the left bottom of fig(c). At the same time, moving target detection can detect the moving object, but not all moving objects are the target which need to be detected. From fig(b) we can see that the moving target detection method can detect moving vehicles in the scene effectively. But local area disturbance in the scene has a great impact to the result of moving target detection. Fig(d) is the target image which is detected by the algorithm proposed in this paper. From fig(d) we can see that moving target with a strong polarization characteristics can be detected effectively by combining motion detection and target polarization detection, while suppressing the background disturbances in the strong polarizing but still region and weak polarization scene.

3 Conclusion

In order to solve the problems in the existing target detection system such as small field of view can be detected and ease to be interfered by the background's noise, a moving target detection method based on polarization characteristics in the condition of moving detector has been proposed in this paper. This method overcomes the impact of the detector rotation by modeling the target and background, and uses the targets' polarization characteristics to overcome the effects caused by the background's disturbance. The experiment result shows that the proposed algorithm can effectively detect moving targets with polarization characteristics in the condition of moving detector.

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