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Fast Algorithm of Infrared Point Target Detection in Fluctuant Background

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***Abstract*—**The background estimation approach using a small window median filter is presented on the bases of analyzing IR point target, noise and clutter model. After simplifying the two-dimensional filter, a simple method of adopting one-dimensional median filter is illustrated to make estimations of background according to the characteristics of IR scanning system. The adaptive threshold is used to segment canceled image in the background. Experimental results show that the algorithm achieved good performance and satisfy the requirement of big size image's real-time processing.

***Keywords*—**Point target, background estimation, median filter, adaptive threshold, target detection.

I. INTRODUCTION

IN the high technology local duel fares, it is required that the weapon system must have a fast reaction, a long detection distance, namely, the system must detect the target at a long distance in the real-time warfare. The target image is of a small size with only one or few pixel's area while the interferences of noise and clutter background remain strong. Therefore, the issues about long distances, low signal to noise, strong disturbances are hot and difficult tasks we are now facing with [1,8].

At present, the mutual warfare machines are turning their way to be maneuverable and confidential. The satellites movements on target detection and recognition task of spatial satellites detection system are special to a certain extent: (1) the extensibility of the search space; (2) target location space (randomness of time); (3) the diversity, variability and complexity of target/background. Meanwhile, the requirement of real-time performance of target detection system processing is much stricter than other fixed target since the target is moving (mobile)[2]. So, it is necessary to make real-time processing on the big size fluctuating IR images.

The rest of the paper is organized as follows. In Section II the target and background model is given, in Section III the Background estimation and cancellation is described and in Section IV Target segmentation and detection is given. The experiment results are presented in Section V, followed by the discussion and conclusion.

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II. TARGET AND BACKGROUND MODEL

We can describe the output image $F(i, j)$ of IR detector as follows:

$$F(i, j) = S(i, j) + C(i, j) + N(i, j) \tag{1}$$

where $S(i, j)$ is target projection on image planar, $C(i, j)$ denotes strong fluctuating cloud background clutter, $N(i, j)$ is image noise while (i, j) represents one pixel coordinate value in the image coordinate.

The noise of IR imaging system is composed of two parts, one part only related with the IR radiance intensity of sky background in the response wavebands, and the other related with the internal parameter of IR imaging system only. These noises mainly are white noises and non-stationary $1/f$ noises.

Apart from the non-related noises of IR remote sensing background, the main part of it is the clouds which change slowly with a large size. Those clouds not only change slowly, but relative to each other in some way. However, due to the extensibility of the search space, the clouds background fluctuates severely. According to the reference [5], the real IR clouds fluctuating background image is steady in a broad sense, which makes Gaussian distribution on space and have a strong correlation.

The ambient background of point target intensity in the remote sensing image is high and doesn't related to the background, being an isolate light point in the image. The IR scanning system will experience a process with the target become obscure, and the size get larger and finally become a small target, this is because of the jitter, spatial optical interference, atmosphere vibration. Viewing from the optical angle, the target size can be modeled as a discrete Gaussin pulse[9] in two-dimensional space.

$$S(x, y) = \exp(-\frac{1}{2}((\frac{x}{\sigma_x})^2 + (\frac{y}{\sigma_y})^2)) \tag{2}$$

where σ_x , σ_y are the size parameters in horizontal and perpendicular direction of the target, respectively.

In terms of reference [6], the target contour is the spreading and narrowing of the image point spread function's one-dimensional contour; extracting one line or one column which contains the target, we can see that the target appears to be a narrow and high pulse, which could be considered as a point pulse, while the edge of cloud clutter changes slowly, appears to be a broad pulse, the intensity of it apparently is weaker than the target's.

After the above analysis, we can know that except for the target, there is no point pulse noise in the IR remote sensing image, basically. Therefore, it is advisable to regard the point (small) target as the point pulse noise in the image in the process of filtering.

III. Background Estimation and Cancellation

The background is the main part of the IR image which contains fluctuating cloud background according to the equation (1), if we can get the accurate estimation of background clutter and noise:

$$\hat{F}(i,j) = \hat{C}(i,j) + \hat{N}(i,j) \tag{3}$$

And then we can get：

$$F(i,j) - \hat{F}(i,j) = S(i,j) + N'(i,j) \tag{4}$$

where $N'(i,j)$ denotes remained noise caused by false background estimation.

A. Small Window Median Filter Background Estimation Approach

According to analysis 2: In order to get precise background estimation, it is required to remove the target point equals to point pulse noise while try the best not to change the other part of the image. One effective approach to remove the noise is median filter approach, which leaves a bad result on other noise when it removes the pulse noise. It should have been one weakness of median filter, but we can here use this "weakness" to save image background as precisely as we can by the filtering. When estimate background, try not to smooth the background image, instead, adopt small window (not above 7x7) median filter. Experiment shows that 3x3window get a better background estimation and a quicker calculation speed.

B. Simplified Fast Median Filter Background Estimation

When processing the big size's IR remote sensing image, the real-time performance requirement of system is strict, namely, the algorithm should be simple and fast. In order to accelerate the speed of median filter, the pixel in the window should be as few as possible. After analyzing the IR liner scanning system, one can learn that adjacent pixels of the system in the same line is of great correlation, which is why the obscure point target becomes the small target while the real background is of strong spatial correlation. Highlight the point impulsive of the target by neglecting the system correlation among the pixels when making the background estimation, and then we can get a good result by highlighting the spatial correlation of the background. Therefore, it is advisable to extract diagonal pixel $\left(f((i-1),(j-1)), f(i,j), f((i+1),(j+1))\right)$ in the filtering window only to filter it, to reduce the amount of calculation while try not to reduce the estimation result.

$f((i-1),(j-1))$		
	$f(i,j)$	
		$f((i+1),(j+1))$

Fig. 1 Filter window

Pixel estimation:

$$f'(i,j) = med(f((i-1),(j-1)), f(i,j), f((i+1),(j+1))) \tag{5}$$

IV. Target Segmentation and Detection

For images which have been removed the background $F(i,j) - \hat{F}(i,j)$, we should segment them to detect the target. The target in the image without background seems to be a rather light point for the respective local background, so, we should segment target by using an adaptive threshold.

For the input images, we can define the output images as follows [7],

$$h(x,y,k) = \begin{cases} 1 & f(x,y,k) \geq th(k) \\ 0 & f(x,y,k) < th(k) \end{cases} \tag{6}$$

where th(k) is the threshold, which changes with the sequence images:

$$th(k) = m(k) + \alpha \cdot \mathrm{var}(k) \tag{7}$$

where m(k) is kth local mean value in the image sequence, var(k)denotes local variance value, α is the weighted coefficient, we can choose it among 6 to 12.

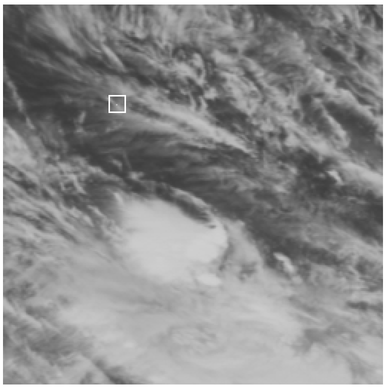
After segmenting the threshold, the image becomes a binary image which contains a few possible target points.

According to the continuity and regularity of the target movement as well as the known randomness of the noise, we can use the position relation of the possible target point in adjacent frames to distinguish the target, to make it short, is to find the possible target point in the current frames, if the suspicious target appear *k* times or above *k* times around this point in the next *n* frames, then we can distinguish this point as target point.

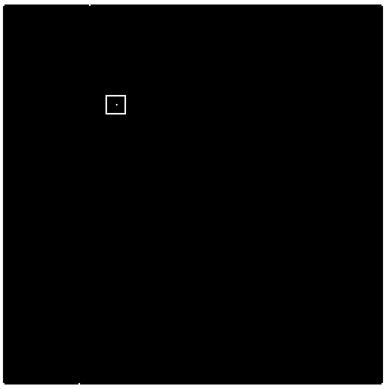
V. Experimental results

The experimental image is the image sequence of IR small object which moves in the cloud, the size of the image is 256x256 pixels, the SNR is around 3, the total frame of the image is 15. Select $\alpha = 10$ when segment the target, and n=5, k=4 when detect it. As long as the local window and weighted coefficient are selected properly, a good detected result can be obtained.

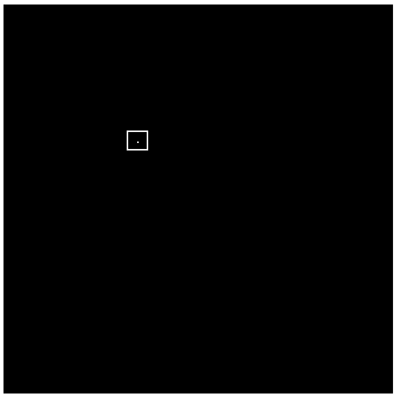
The experimental result is showed in Fig. 2: (a) is the eighth frame of the sequence images, (b) is the detected result of the small median filter, (c) is the modified result of fast median filter, (d) is the target trajectory the image sequence detected. From the figure, we can see the target is detected out effectively.



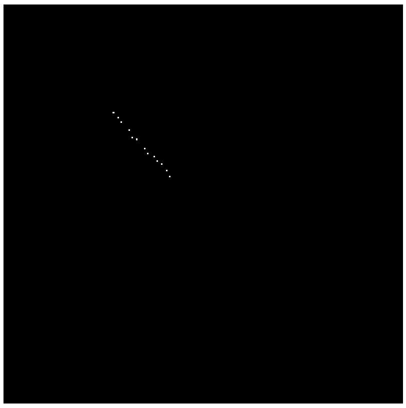
(a) 8th frame original image



(b) Detected result of the small median filter



(c) The modified result of fast median filter



(d) Target trajectory the image sequence detected

Fig. 2 Experimental results

VI. Conclusion

This paper analyzed the target, background, and noise in the IR remote sensing image; proposed a small window median filter approach to make background estimation in terms of the characteristics of the background target; and further simplified the small window median filter according to the characteristics of the IR scanning system; concluded a modified fast median filter background estimation approach. Experimental results showed that the approach is able to detect the low SNR moving point (small) target on the strong fluctuating cloud background. Moreover, the algorithm of it is simple, and calculation amount is small, and thus can satisfy the requirement of big size's real-time processing. However, when the fluctuation of the background is too strong, once selected the weighted coefficient α , there will be detection omission (too big) or too much false alarm (too small) appear when make several frames detection.

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