An Efficient Method of Small Targets Detection in Low SNR

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Abstract. In this paper, an efficient method based on nonlinear adaptive filtering is proposed to detect the small IR target of low SNR under the complex background. The morphologic filter can be constructed firstly based on the IR radiation traits of low SNR small targets in the complex background and then a morphological method is used to eliminate the influence of the unbalance background to the image segmentation. Next an algorithm of adaptive threshold segmentation is adopted in order to select the small moving target and the noise points. Finally, on the basis of image sequences, the satisfactory targets detection is accomplished after eliminating wrong point targets. The method presented in this paper can effectively suppress the noise and the air background of the original image, enhance the ability of point target detection in single frame.

1. Introduction

The detection and processing of the small moving target is always the important subject in the computer visualization and the image processing, especially in the condition of the complicated background and the long distance. The difficulties of the small moving target detection are the following. Firstly, the detection is of multiple frames image and multiple targets, so that many characteristics of image cannot be used when the target is too small. Secondly, the low SNR will result in decreasing the detection threshold and increasing the false warning, so that the track cannot be successful. Furthermore, another difficulty is that many factors are unknown such as the position, the speed, the direction, the time and the point targets in every frame of images. At present, there are many methods of the small moving IR target detection. In this paper, on the basis of the SNR analysis of the target, a non-linear filtering of omnidirectional multiple structuring elements morphology is used[1]. In the next, the difference image between original image and background image is used to eliminate the influence of the unbalance background to the image segmentation. After the noise is eliminated, it adopts the adaptive threshold segmentation method in order to separate the infrared point targets efficiently from low SNR and complex background[2]. At the same time, based on the relativity between image sequences, the spot targets are detected by eliminating false point targets.

2. Simulation of infrared image and scene model of small target

A general simulation model of the infrared image system is established according to the transport process of infrared radiation. The infrared radiation brightness of the small target and background is firstly computed. Taking into account the factors of the infrared radiation attenuation such as the atmospheric transmission and the photo translating of the detection system, then the whole infrared image is obtained. The whole simulation process of infrared image involves analyzing radiation characteristic, atmosphere transmission and calculating the vision parameters of the detection system.
Though the process is so complicated, simplified models must be used [3]. Using simplified models, the processes of generating and transferring infrared radiation are firstly analyzed, and then the noise is superposed to that. The infrared image simulation system is just as figure 1 show below. In the actual system, the treatment on infrared image in the detector can be considered as level control for the signal plus of time domain image. In this paper, the analysis result of SNR and the model of small target are gained by calculating the radiation energy of the small target and background, which is obtained from the detector.

\[
f(x, y) = f_T(x, y) + f_B(x, y) + n(x, y)
\]

(1)

Where \(f(x, y)\) - the scene image from the IR sensor; \(f_T(x, y)\) - the target dot-pixel; \(f_B(x, y)\) - the background image; \(n(x, y)\) - the noise image.

Based on the characteristic of the small target and the background in the IR image, the luminance and the size of the image dot-pixel are assumed in a small scope so that the gray scale of the target image can accord to the conditions of SNR detection. An equation can show the SNR:

\[
SNR = \frac{f_T(x, y) - \mu}{\sigma}
\]

(2)

Where \(\mu\) - the mean of the image gray; \(\sigma\) - the standard deviation. Usually, the gray probability density function of the background image is the normal distribution. Noise component of the image is the summation of all the noises in the sensor and the circuit. It can be seen as the zero-mean Gaussian white noise, and it is irrelevant to the background image.

3. The design of the small moving infrared target identification algorithm

3.1. The design of the morphology structure element

Structure element is the key of the morphological operation. Choosing different structure elements will result in different information analysis and disposal. Structure element determines the aim and the capability of the morphological filter, and at the same time, it also determines the data distribution form and the data dosage for the transform. As a result, structure element can determine the complexity of the calculation transform.

In this paper, an method of omnidirectional multiple structuring elements morphological filter, combining with the SNR analysis, is used for keeping the image better [4]. The frame is shown as figure 2.
Commonly, small targets are brighter than the background in the IR image. This paper adopts the method of selecting a structure element bigger than small targets to do opening operation for the single frame image in order to get a mild background image through eliminating the targets smaller than the selected element and then making subtraction between original image and background image in order to get the image of the small moving target and noises. The process is described as below:

\[ f_b(x, y) = f(x, y)^0 k(x, y) \]  
\[ f_T(x, y) + f_N(x, y) = f(x, y) - f_b(x, y) \]

3.2. The adaptive threshold selection

In this paper, the method of adaptive threshold segmentation is adopted in order to select the infrared point targets efficiently, which include the small moving target and the noise points. The adaptive threshold selection is the key problem. If we use \( E \) stand for the gray around the image \( f(i,j) \), after filtering, the gray of it is expressed as \( f'(i,j) \), the equations can show the relationship of them:

\[ E = \sum \sum f(i, j) \]  
\[ f(i, j) = f(i, j) \cdot \left( f'(i, j) - \alpha E > 0 \right) \]  
\[ f(i, j) = 0 \cdot \left( f'(i, j) - \alpha E \leq 0 \right) \]

Based on the method of adaptive decision threshold, the filtered targets image and the background image compare to select the point targets. This method can resolve two problems. One is the pre-selected points are too much at single threshold, the other is the targets cannot be segmented from intensive noises in a single non-linear filter.

4. Eliminate wrong point targets with the image sequences

Hereto, the result of the former arithmetic is some point targets that include the small moving target and the noise points. In this step, the method as following is adopted to eliminate wrong point targets as possible in order to select the required targets. If we use image \( I \) and image \( I+1 \) stand for two sequential frame images, the process can be described as below:

step 1. Select a small window around every possible target in the image \( I \) and then calculate the spatial correlation of the same position in the image \( I+1 \);
step 2. In the image \( I+1 \), based on the spatial correlation, find the optimal window position matching with the image \( I \);
step 3. Reduce the window size in the image \( I+1 \) to track the possible targets and then remember the optimal window position in the goal image \( I+M \);
step 4. Repeat the former 3 steps until all the possible targets positions are added to the goal image I+M, where M is the maximum of the image sequences;
step 5. Eliminate the possible point targets that have no matching window in five or more sequential frames images.

5. Experiment
The images for the experiment are some simulative infrared small target image sequences. The size of every image is 768×576. The SNR of the target is lower than 2. There are 11 frames emerged within 16 frames. The results show that this method can obtain good detection performance. Several pictures of the experiment are shown just as figure 3.

6. Conclusion
The proposed method can efficiently accomplish complicated background depression and required targets selection and enhance the ability of point target detection in single frame. This method is easy to be parallel implemented in real time or realized with hardware. Furthermore, the image’s SNR and target detection speed can be improved even further if farther data processing is taken.

References
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