Target polarization characteristics analysis and detection in complex background

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Abstract. Polarization feature contains important information of the target and especially related to the surface properties of target. In some complex conditions, such as the background of bushes and shrubs, masking target detection is of great significance. In order to realize target detection in complex conditions, we propose a new method based on the traditional CEM detection method, utilizing the polarization feature of the material, and finally achieve the purpose of target detection by using the polarization dimension feature of the material.

Key words. Polarization feature; CEM; Target detection

1. Introduction

Because of the uncertainty of environment and interference, target detection has always been a subject of constant exploration. Back to the current detection, we can be divided into two categories: one is on the basis of two dimensional information, namely the use of image space coordinate information, interested in detecting the differences between the target with the surrounding scene, and then achieve the goal of detection and advantages of the method is that the amount of image data to be processed is low, the algorithm is relatively simple, of high efficiency and its disadvantage is difficult to apply complex scenes, especially when the goals are imposed on camouflage means, the difficulty of target detection will rise; Additionally one kind is in the image space information, on the basis of introduction to reflect material intrinsic characteristics of the third dimension information, such as time, spectral dimensions, polarization information, according to the difference of material in these dimensions, such as time dimension on the state of different material movement, spectral dimension on material reflection and radiation spectrum difference and polarization on material surface properties to distinguish itself, etc.) and then detect the target of interest.

In recent years, with the development of polarization devices, cameras that can quickly acquire multiple polarization angles have been developed. Therefore, the abundance of target polarization information makes it possible to detect targets. At present, the technology of detecting target with polarization information is to synthesize the information from different polarization angles and use the different polarization information to highlight the target. We believe that the method of target detection based on the integrated polarization Angle information cannot fully extract the polarization characteristics of the material, and the results only reflect the partial regional energy with the maximum polarization Angle. Method proposed in this paper the polarization as and spectral dimensions similar
spectral information, extract the line between the characteristics of the information, and then draw lessons from the network structure concept, on the basis of traditional [1] CEM detector, to join the activation function and the multilayer structure of detector, through the measured data, can be achieved in high target detection under the complicated background.

2. Polarization property analysis of target and background

The polarization properties of matter are mainly affected by its surface properties. [2] The incident natural light is generally fully polarized light and has the same polarization component at all angles of the vertical incident plane. [3] When the reflection occurs on the surface of matter, the polarization component will change. According to the observation results of the collected sample data, as shown in figure 1 and figure 2, the polarization curves of vehicle surface and background show that specular reflection mainly occurs on the smooth surface, while the polarization component of light changes gently, while irregular diffuse reflection mainly occurs on the rough surface, and the polarization component of light changes irregularly. Since the surface of man-made objects is relatively smooth and the natural surface is relatively rough, this property can be used to distinguish different objects.

3. Target detection algorithm based on polarization characteristics

In order to realize target detection algorithm, the first step is extracting vehicle polarization spectrum from the image data, because this article in using the multistage CEM algorithm detector parts detector, the same as the single-stage CEM detector, its main idea is based on the input the vehicle target polarization characteristics, strengthen the polarization characteristics of similar area, inhibition of different background region, finally realizes the target detection. Figure 3 shows the overall flow of the algorithm.

3.1. Acquisition of polarization curve of target vehicle

The first step of the algorithm is to obtain the polarization spectrum data of the car window and the car body, which are respectively used as two types of inputs for detection in the detector. In this paper,
different attitudes of the car are photographed in the same scene, and the average of them is taken as the standard polarization spectrum line of the target.

3.2. Polarization dimension feature extraction

In order to make more effective use of the characteristics of the polarization spectrum, this paper does not directly use the polarization spectrum as the detector’s input. First, the polarization spectrum of the target is processed by the feature extraction step. Inspired by the deep Forest Algorithm, the feature extraction part adopts window sliding at different scales, divides the polarization feature spectrum into several independent bands, insets each band into the CEM detector, and then splice the output result as the feature of the target polarization spectrum. Figure 4 shows the process of feature extraction.

![Figure 4. Multi-scale windows](image)

3.3. Polarization detection

3.3.1. CEM detector. The main idea of CEM algorithm is to design a FIR linear filter to minimize the output energy of the filter under the condition of satisfying the constraint conditions. The algorithm does not need background information of the image, just need to know to test for a prior spectral information (vector), the specific method is through the hyperspectral image data and a priori known targets to be detected to determine a vector filter, make image through the filter vector can be detected as a result, the function of the filtering vector is the target pixels in images, let the target can be interested in, at the same time suppress filter output energy from other signals.

First, the image sequence is processed in two dimensions to obtain normalized data and eigenvectors $\mathbf{r}$, the size of $\mathbf{r}$ is $L \times N$, Equation (3.1) shows how to calculate the autocorrelation matrix of the image.

$$\mathbf{R} = \frac{1}{N} \sum_{i=1}^{N} \mathbf{r}_i \mathbf{r}_i^T$$  \hspace{1cm} (3.1)

Equation (3.2) shows how to obtain FIR linear filter coefficient matrix.

$$\mathbf{w} = \frac{\mathbf{R}^T \mathbf{d}}{\mathbf{d}^T \mathbf{R} \mathbf{d}}$$ \hspace{1cm} (3.2)

As in equation (3.3), the 2d image data is passed through FIR filter, and then the detection results are obtained.

$$\mathbf{y}_i = \sum_{i=1}^{L} \mathbf{w}_i \mathbf{r}_i = \mathbf{w}^T \mathbf{r}_i = \mathbf{r}_i^T \mathbf{w}$$ \hspace{1cm} (3.3)

3.3.2. Multistage CEM polarization detection. The multistage CEM detector contains multiple detection layers, and the detection layer contains multiple CEM detectors. Its structure is as follows. The cascade detection consists of multiple detection layers. In this stage, the input is the spectrum feature vector...
generated by the multi-scale scanning stage, and the output is the average operator part of the last detection layer. Figure 5 shows the block diagram of the detector.

![Figure 5. Multi-scale windows](image)

**Figure 5. Multi-scale windows**

The output score of each CEM detection layer is used to transform the eigenvectors, which are then used as inputs to the next layer. Then, according to the transformed features, a new detection score is obtained. In addition, in each layer, we designed M detectors with random regularization coefficients $\lambda_1, \lambda_2, ..., \lambda_m$, in order to improve the generalization ability of the detector. In this way, Equation (3.2) becomes Equation (3.4). [3] In our approach, we have different $\lambda$ on different basic detectors, that is, further increase the divergence of each model to improve the robustness of the final detection.

$$w(\lambda) = \frac{(R + \lambda I)^{-1} d}{d^T (R + \lambda I)^{-1} d}$$

(3.4)

Assuming that the input feature vector of the layer-$t$ is $r_t$, according to the relationship between input and output of FIR linear filters, the average function output of the layer-$t$ is Equation (3.5).

$$\bar{u} = \frac{1}{m} \sum_{i=1}^{m} w(\lambda_i) r_i$$

(3.5)

The input of the layer-$t$ is converted into the CEM coefficient $h(\bar{u})$ of the layer-$t+1$, as shown in Equation 3.6, $h(x)$ is the sigmoid function in the [4] CNN network structure as the nonlinear transformation function, and the sigmoid function is shown in Equation 3.7.

$$r_{t+1} = h(\bar{u}) r_t$$

(3.6)

$$h(x) = \frac{1}{1 + e^{-x}}$$

(3.7)

The significance of using the sigmoid function is that the small features of the output will be suppressed, while the large features of the output will remain unchanged, that is, the target information will be retained and the background information will be suppressed. After passing through several layers, the last layer serves as the detection output of the algorithm.

3.4. Polarization results fusion

Due to the different inclination angles of planes at different positions on the target, the imaging rules of polarization spectral lines are also different. Therefore, multiple spectral lines of the target vehicle are selected as the target curve, and after feature extraction and detection, the results are synthesized to achieve the final target detection.

4. Experimental analysis and summary
We compared the detection results of several detection algorithms, as shown in Figure 6.

![Figure 6](image)

(a) DoLP  (b) SAM  (c) ACE  (d) Proposed

**Figure 6.** The comparison of some algorithm

From Figure 6, our method can greatly suppress the background and highlight the target. In order to show the results more clearly, target to background contrast is used to measure the effect of the algorithm.

5. References

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The definition of contrast is shown in Equation 4.1. $x_T$ is the average gray value of the target area and the average gray value of the background area, $x_B$ is the average gray value of the background area. Table 1 shows the contrast results of every algorithm.

$$C = \frac{x_T - x_B}{x_T + x_B}$$  \hspace{1cm} (4.1)

**Table 1.** Contrast of the above algorithm

| Algorithm | Contrast |
|-----------|----------|
| DoLP      | 0.302    |
| SAM       | 0.385    |
| ACE       | 0.014    |
| Proposed  | 0.724    |