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Calculation model of scattering depolarization for camouflaged target detection system

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ABSTRACT

As a new physical model to identify the camouflaged targets in the complex environments, the main effect of the polarization measurement system is the scattering depolarization information of different measured parts. This paper had observed the multiple scattering theory of electromagnetic wave, and analyzed the mechanism of the relation between the depolarization and scattering path. The correctness and accuracy of the theoretical model had been verified by the Fresnel formula. In order to prove the practicability of this model, the experiments on two kinds of camouflage materials had been conducted at seven different angles. Research shows that, as a link between material physical characteristics and optical signal information, the model could accurately and effectively identify the moving camouflaged objects. Therefore, this method has a great application value, and the paper has very important significance on the development of tracking technology.

1. Introduction

Moving targets tracking is an indispensable part of visual surveillance system [1–4]. There are many situations that make the target tracking tasks even more difficult, such as unidirectional motion, no rigid target structure, occlusion between target and scene, motion of detector and so on. Especially in the specific scene, in order to analyze the moving target better, the special methods must be used to lock the observation target [5–7].

The Mean-Shift algorithm can quickly find the most similar location with the least number of iterations, and the effect is also good [8–10]. However, it cannot solve the occlusion problem of the target, and it as well cannot recognize the shape and size of the moving objects. The Cam-Shift algorithm is the improved algorithm. It can adapt to the changes of the targets with better tracking effect [11–13]. Nevertheless, when the color of the background is similar to that of targets, it is easy to make the target area larger, which may eventually lead to the loss of tracking target. The method of moving object modeling relies on the establishment of target models to track the moving targets [14–16]. Even so, this method must know the target object in advance, and then trace the specified target, so the generalization is relatively poor. These techniques are all based on the reflectance spectrum information to obtain the reflectivity, color, size and shape of the moving objects. Therefore, these methods still have limitations. They cannot be used to identify the target which has the same reflectance spectrum information with the background.

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Combined with the physical characteristics of the targets, the scattering depolarization technique can be used to analyze the multiple scattering paths of incident light in the microstructure of medium, and the depolarization characteristic of scattered light could be used as the detection information. It is found that the model of scattering depolarization could effectively improve the general ability of robust classification and tracking of targets in special scenes. Because of the different microstructures, the depolarization characteristics of these objects are unusual. There are many important research values in the process, and the more attention should be taken for them. In this paper, the phenomenon of scattering depolarization had been discussed, and the model of scattering depolarization had been established to track and recognize targets in two complex environments successfully.

2. Scattering and depolarization of electromagnetic waves

2.1. Mechanism of electromagnetic scattering

Consider a plane monochromatic wave incident on an obstacle of arbitrary form. The field at any point in the medium surrounding the obstacle may again be represented as the sum of the incident field and the scattered field

$$\boldsymbol{E} = \boldsymbol{E}^{(\boldsymbol{i})} + \boldsymbol{E}^{(\boldsymbol{s})}, \boldsymbol{H} = \boldsymbol{H}^{(\boldsymbol{i})} + \boldsymbol{H}^{(\boldsymbol{s})}. \tag{1}$$

The time-averaged energy flux is represented by the time-averaged Poynting vector [17], and

$$\left\langle \boldsymbol{S} \right\rangle = \frac{1}{2T'} \int_{-T}^{T} \frac{c}{4\pi} (\boldsymbol{E} \times \boldsymbol{H}) dt \approx \frac{c}{8\pi} \Re(\boldsymbol{E_0} \times \boldsymbol{H_0^*}). \tag{2}$$

Where $\Re$ denoting the real part, according (1) and (2), we can get:

$$\left\langle \boldsymbol{S} \right\rangle = \left\langle \boldsymbol{S}^{(i)} \right\rangle + \left\langle \boldsymbol{S}^{(s)} \right\rangle + \left\langle \boldsymbol{S}^{'} \right\rangle. \tag{3}$$

Where

$$\left.\begin{aligned} \left\langle \boldsymbol{S}^{(\boldsymbol{i})} \right\rangle &= \frac{c}{8\pi} \Re\{\boldsymbol{E}^{(\boldsymbol{i})} \times \boldsymbol{H}^*_{(\boldsymbol{i})}\}, \\ \left\langle \boldsymbol{S}^{(\boldsymbol{s})} \right\rangle &= \frac{c}{8\pi} \Re\{\boldsymbol{E}^{(\boldsymbol{s})} \times \boldsymbol{H}^*_{(\boldsymbol{s})}\}, \\ \left\langle \boldsymbol{S}' \right\rangle &= \frac{c}{8\pi} \Re\{\boldsymbol{E}^{(\boldsymbol{i})} \times \boldsymbol{H}^*_{(\boldsymbol{s})} + \boldsymbol{E}^{(\boldsymbol{s})} \times \boldsymbol{H}^*_{(\boldsymbol{i})}\}. \end{aligned}\right\}. \tag{4}$$

Let the unit vector be in the direction, so that

$$\boldsymbol{E}^{(\boldsymbol{i})} = \boldsymbol{e} e^{ik(\boldsymbol{s_0} \cdot \boldsymbol{r})}, \boldsymbol{H}^{(\boldsymbol{i})} = \boldsymbol{h} e^{ik(\boldsymbol{s_0} \cdot \boldsymbol{r})}. \tag{5}$$

We assume that this wave is linearly polarized, so that e and $\boldsymbol{h}$ may be assumed to be real unit vectors. At a large distance r from the obstacle the scattered wave is spherical:

$$\boldsymbol{E}(\boldsymbol{n}) = \boldsymbol{a}(\boldsymbol{n}) \frac{e^{ikr}}{r}, \boldsymbol{H}(\boldsymbol{n}) = \boldsymbol{b}(\boldsymbol{n}) \frac{e^{ikr}}{r}. \tag{6}$$

The vectors $\boldsymbol{a}(\boldsymbol{n})$ and $\boldsymbol{b}(\boldsymbol{n})$ characterize the strength of the radiation scattered in the direction $\boldsymbol{n}$. Since the incident and scattered waves obey Maxwell's equations:

$$\boldsymbol{E} = -\sqrt{\frac{\mu}{\varepsilon}} \boldsymbol{n} \times \boldsymbol{H}, \boldsymbol{H} = \sqrt{\frac{\varepsilon}{\mu}} \boldsymbol{n} \times \boldsymbol{E}. \tag{7}$$

Where, μ is the magnetic permeability, ε is the dielectric constant. By multiplying $\boldsymbol{n}$, we can obviously get: $\boldsymbol{E} \cdot \boldsymbol{n} = \boldsymbol{H} \cdot \boldsymbol{n} = 0$. This formula shows the transverse nature of the field, that is, the electric field vector and the magnetic field vector are in the plane perpendicular to the propagation direction.

From these relations it follows that on the surface of the large sphere $\sum$,

$$\left.\begin{aligned} &(\boldsymbol{E}^{(\boldsymbol{i})} \times \boldsymbol{H}^{(\boldsymbol{s})*}) \cdot \boldsymbol{n} = \boldsymbol{e} \cdot \boldsymbol{a}^*(\boldsymbol{n}) e^{ikR(\boldsymbol{s_0} \cdot \boldsymbol{n})} \frac{e^{-ikR}}{R}, \\ &(\boldsymbol{E}^{(\boldsymbol{s})} \times \boldsymbol{H}^{(\boldsymbol{i})*}) \cdot \boldsymbol{n} = \\ &\{(\boldsymbol{n} \cdot \boldsymbol{s_0})[\boldsymbol{a}(\boldsymbol{n}) \cdot \boldsymbol{e}] - (\boldsymbol{n} \cdot \boldsymbol{e})[\boldsymbol{s_0} \cdot \boldsymbol{a}(\boldsymbol{n})]\} e^{-ikR(\boldsymbol{s_0} \cdot \boldsymbol{n})} \frac{e^{ikR}}{R}. \end{aligned}\right\}. \tag{8}$$

The resulting integral may be evaluated by the use of Jones' lemma (9).

$$\frac{1}{R} \iint_{\Sigma} G(\boldsymbol{n}) e^{-ikR(\boldsymbol{s_0} \cdot \boldsymbol{n})} d\Sigma \approx \frac{2\pi i}{k} [G(\boldsymbol{s_0}) e^{-ikR} - G(-\boldsymbol{s_0}) e^{ikR}]. \tag{9}$$