An Infrared Image Synthetic Method of Real Sky Background and Molded Target

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Abstract. This paper proposes a synthetic method of IR signatures of background and target object. For verification by simulation, actual IR background image from IR camera and modeled target are used as IR signature of background and target. In the proposed synthetic method, individual radiances corresponding to minimum/maximum temperatures of IR signatures, background and target object are calculated through the Planck’s law. And, after adjusting gray level of respective signatures based on the radiances, these IR signatures are synthesized as one image for specific wavelength. The proposed method is verified through simulation and IR target images (signatures) were created using the RadThermIR, infrared analysis software.

Keywords: IR signature, Spectral radiance, IR image synthetic

1 Introduction

This paper proposes a synthetic method of real IR background from IR camera and modeled IR target signature for DIRCM (directed infrared countermeasures) [1-4]. In the proposed synthetic method, individual radiances corresponding to the minimum/maximum temperatures of IR signatures of background and target object are calculated through the Planck’s law. And, after adjusting gray level of respective signatures based on the radiances, these IR signatures are synthesized as one image for specific wavelength. The proposed method is verified through simulation and IR target images (signatures) were created using the RadThermIR infrared analysis software.

2 IR Image Synthesis Method

This paper proposes a method to synthesize real IR background image and modeled IR target image. IR background and target images have independently gray levels for its temperature distribution. So, for synthesizing these background and target images,
its gray level should be adjusted for temperature level. The steps for IR images synthesis is as the following.

2.1 IR Background and Target Image

Basic synthesis information for IR background and target image is shown in Table 1.

<table>
<thead>
<tr>
<th>Image information</th>
<th>Background image</th>
<th>Target image</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image size</td>
<td>$X_b, Y_b$</td>
<td>$X_t, X_t$</td>
</tr>
<tr>
<td>Maximum/minimum gray level</td>
<td>$G_{b_{\text{max}}}, G_{b_{\text{min}}}$</td>
<td>$G_{t_{\text{max}}}, G_{t_{\text{min}}}$</td>
</tr>
<tr>
<td>Maximum/minimum temperature</td>
<td>$T_{b_{\text{max}}}, T_{b_{\text{min}}}$</td>
<td>$T_{t_{\text{max}}}, T_{t_{\text{min}}}$</td>
</tr>
</tbody>
</table>

The range of gray level for background and target image is given by

$$\Delta G_b = G_{b_{\text{max}}} - G_{b_{\text{min}}}$$  \hspace{1cm} (1)

$$\Delta G_t = G_{t_{\text{max}}} - G_{t_{\text{min}}}$$  \hspace{1cm} (2)

2.2 Radiance According to Wavelength Band and Temperature

The radiances, $L_{t_{\text{min}}}$, $L_{t_{\text{max}}}$, $L_{b_{\text{min}}}$, and $L_{b_{\text{max}}}$ of min/max temperature of IR background and target are calculated using Equation 3-4.

$$L_{t}(T) = \tau_{\text{atm}}\int_{\lambda_{b}}^{\lambda_{t}} 1.191 \times 10^{4} \varepsilon(\lambda)/\{1.428 \times 10^{4} / \lambda T_{i}) - 1\} d\lambda$$ \hspace{1cm} (3)

$$\tau_{\text{atm}} = \exp(-\sigma D)$$ \hspace{1cm} (4)

where $\tau_{\text{atm}}$ is atmosphere transmissivity. $\varepsilon(\lambda)$ is emissivity of an object. $T_{i}$ is min/max temperature in table 1. $D$ means distance between detector and target. And $\sigma$ is atmosphere attenuation coefficient affected by atmosphere conditions. Using $L_{t_{\text{min}}}$, $L_{t_{\text{max}}}$, $L_{b_{\text{min}}}$, and $L_{b_{\text{max}}}$ minimum and maximum radiances of IR background and adjusted IR target, radiance difference of $L_{\text{max}}$ and $L_{\text{min}}$ is given by

$$\Delta L = L_{\text{max}} - L_{\text{min}}$$ \hspace{1cm} (5)
2.3 Size Control of Target Image According to Distance

The size of target image synthesized in background image should be adjusted according to its distance and FOV (field of view) of camera.

2.4 Gray Level Adjustment of Synthesis Image

In order to achieve a synthesis image, gray levels of IR background image and modeled IR target image should be adjusted using temperature information on the synthesized two images. The transformation formula and displacement of max/min gray level for target image is given by

\[
\frac{255}{\Delta_{max}} = \frac{L_{t_{max}} - L_{t_{min}}}{\Delta L \times 255} \]

\[
\frac{255}{\Delta_{min}} = \frac{L_{t_{max}} - L_{t_{min}}}{\Delta L \times 255} \]

\[
\Delta G_t = G_{t_{max}} - G_{t_{min}}
\]

Also, similarly to target image, transformation formula and displacement for background image.

2.5 Image Synthesis

In order to synthesize Image from gray level adjusted at step 4, gray level adjustment on synthesis image, transformed image using IR background image, \(G_b(x,y)\), and IR target image, \(G_t(x,y)\) are given by

\[
\hat{G}_t(x,y) = (G_t(x,y) - G_{t_{min}}) \times \Delta G_t / \Delta G_t + \Delta G_{t_{min}}
\]

\[
\hat{G}_b(x,y) = (G_b(x,y) - G_{b_{min}}) \times \Delta G_b / \Delta G_b + \Delta G_{b_{min}}
\]

3 Simulation Results

IR target and background images are shown in Fig. 1. Fig. 1(a) and 1(b) are modeled F16 using RadthermIR developed by TAI corp. Fig. 1(c) shows IR background image captured by a thermal camera of LWIR (long-wave IR). FOV of the background image has each \(3' \times 2'\) and \(5' \times 3.3'\). Fig. 2 shows results of IR synthetic image. We can show that the synthetic image to MWIR (middle-wave IR) is difficult to distinguish between background and target because the radiance of MWIR at low temperatures is very low. On the other hand, the synthetic image to LWIR is easy to distinguish at even low temperatures.
4 Conclusions

This paper proposes a synthetic method of IR background and target signatures which its gray level is adjusted by temperature magnitude for DIRCM simulation. For actual test, we performed simulations that synthesize modeled aircraft on real IR background. We could confirmed that the proposed synthetic method can create 2 IR band-synthetic images using an IR background image and IR target image, as setting temperature, distance, and FOV.

![Image](a) ![Image](b) ![Image](c)

**Fig. 1.** IR background and target modeling images. (a) F16 of MWIR, (b) F16 of LWIR, and (c) IR background image.

![Image](a) ![Image](b)

**Fig. 2.** The results of synthetic modeling. (a) MWIR, and (b) LWIR.

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References