Wavelength-band Transformation Method of Infrared (IR) Image for Modeled Target and IR Background

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Abstract. Infrared (IR) image is achieved by measurement of the radiant energy emitted from an object in arbitrary wavelength-band (WB). In this paper, we propose a WB-transformation method that transforms an IR image of certain WB to one of the other WB. An object surface temperature can be estimated from arbitrary IR band image, using a temperature-radiance curve for. Based on the estimated temperature, we can calculate radiance of the other WB and generate its IR band image. To verify the performance of the proposed method, we conducted a WB transformation experiment of IR target image and real IR background image utilizing RadThermIR, IR signature prediction software.

Keywords: infrared image, wavelength-band transform, band-transformation

1 Introduction

Infrared (IR) image is widely used for military purpose for detecting and tracking target, surveillance, and object discrimination. The IR wavelength can be divided into short wave IR (SWIR), middle wave IR (MWIR) and long wave IR (LWIR) band by the atmospheric transmission.[1] In order to obtain IR images for these three wavelength-bands (WB), thermal equipment are required for each band. Moreover, through a computer simulation, it is difficult to obtain a precise IR image for an identical object.

In this paper, we propose a WB-transformation method for converting one IR band image into the other band images. Assuming that we know the temperature and emissivity of maximum and minimum pixel value of an IR image for a specific WB, the pixel's radiances can be calculated using its temperature and emissivity. Based on the radiance of an IR image, we can derive a gray level-radiance mapping function. And the radiance value of object (target) surface temperature is calculated from Planck's law. Through inverse formulas of radiance, gray-level, and temperature, we can estimate the surface temperature of objects, including an IR band image. Based on the estimated temperature, an IR image can be transformed to the other band image. To verify the performance of the proposed method, we conduct a WB transformation

experiment of IR target image and real IR background image utilizing RadThermIR, IR signature prediction software.

2 Radiance theory

From Planck's law, spectral radiance of black body for specific wavelength λ and temperature T can be represented as follows.[2]

$$L(\lambda,T)=\frac{C_1}{\lambda^5[\exp(C_2/\lambda T)-1]} \qquad [W/cm^2\mu m] \tag{1}$$

where C_1 and C_2, radiance constants are as the following

$$C_1 = 1.191\times10^4\ [W\mu m^4/cm^2]$$
$$C_2 = 1.428\times10^4\ [\mu m\,K].$$

2 Proposed wavelength bandwidth transform

In this paper, algorithm which transforms a given IR band image to the other bands is proposed, and a block diagram is shown in Fig. 1.

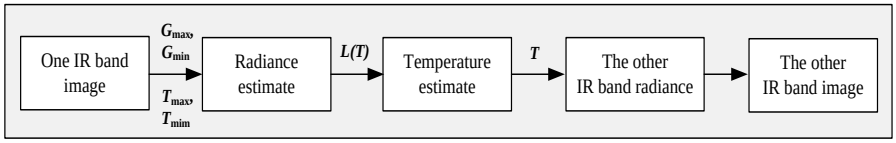


Fig. 1. The block diagram of proposed method.

Step 1. For a real IR background and modeled target image of a certain WB, minimum and maximum gray-levels on these IR images is detected. We assumed that temperature and emissivity corresponding to minimum and maximum gray level of an IR image are known. And then, based on this assumption, we can set the detected minimum and maximum gray-level and its corresponding temperatures for these two IR image.

Step 2. For a desired WB among SWIR, MWIR, and LWIR, radiance corresponding to maximum gray-level on original two IR image is obtained by

$$L(T)=\int_{\lambda_1}^{\lambda_2}(\varepsilon(\lambda)\times C_1)/(\lambda^5(\exp(C_2/\lambda T)-1))d\lambda\ [W/cm^2sr] \tag{2}$$

where $\varepsilon(\lambda)$ is emissivity of an object, $\varepsilon(\lambda)=1$ for black body and $\varepsilon(\lambda)<1$ for

a gray body. Similarly to this, minimum radiance can also be achieved. We assumed that $\varepsilon(\lambda)$ is constant in arbitrary WB. Using Plank's law, temperature to radiance curve for individual WBs can be drawn as Fig. 3.

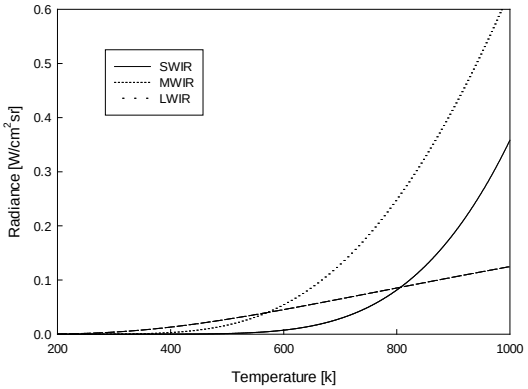
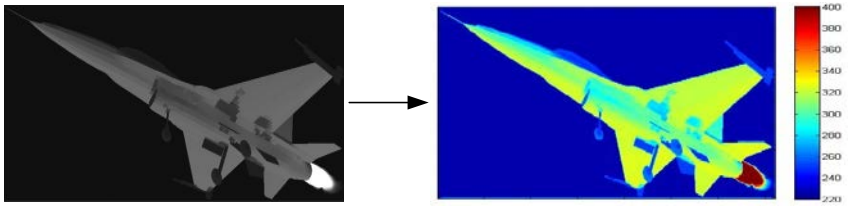


Fig. 3. Temperature-radiance curve for individual WBs.

Step 3. To estimate a surface temperature of modeled target, we use a look-up table for gray-level to temperature through inverse model of Eq. (2). Based on this, an input gray-level image can be converted into a temperature image as shown in Fig. 3.



Input image **Estimated temperature image**

Fig. 3. Input image and estimated temperature image.

Step 4. Calculate radiance values of the other WB for all the pixels of original IR image, using Eq. (2), radiance to gray-level transformation formula. The WB range, $\lambda_1 \sim \lambda_2$ for SWIR, MWIR, and LWIR is shown in table 1. Finally, output transformed IR image is obtained through linear scaling of radiance to gray-level.

Table 1. Range of the wavelength band

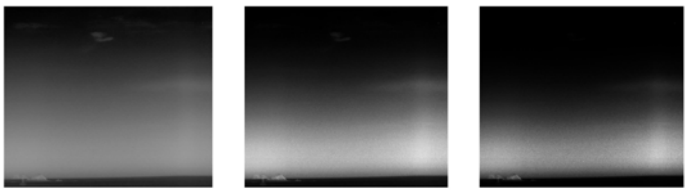
	SWIR	MWIR	LWIR
$\lambda_1 \sim \lambda_2$	1.9~2.9 μm	3~5 μm	8~12 μm

4 Simulation Results

Fig. 4(a) is a modeled F16 target image (LWIR) using RadthermIR, developed by T AI corp. Fig. 4(b) and 4(c) represent the transformed MWIR and SWIR target image from Fig. 4(a). IR background image (LWIR) of Fig. 5 (a) is captured by a thermal camera of LWIR. Fig. 5 (b) and 5(c) are transformed in the same way.

(a) (b) (c)

Fig. 4. IR target (F16) images. (a) Original LWIR; Transformed target image to (b) MWIR and (c) SWIR band.



(a) (b) (c)

Fig. 5. IR background images. (a) Original LWIR; Transformed background image to (b) MWIR and (c) SWIR band.

5 Conclusions

This study suggested a WB transformation method of an actual IR background and modeled IR target image. We confirmed that one IR band image can be transformed to the other WB band image, using actual IR background and modeled F16 target image. It is expected that the proposed WB transformation method can be applied to directed infrared countermeasures (DIRCM) simulation.

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