Simulation program to transform IR images from band to band

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Abstract

A transformation method is propose to convert IR image of an arbitrary wavelength into IR image of another wavelength band by using Planck's law to compute radiance of image in one band then estimate temperature of it then generate a new image from the original one. By comparing the radiance of generated image with the original one, we confirm that the body gray-levels of the converted image obtain darker. That's mean this method can be used to estimate temperature of the target and background, if the pixels' temperature is known radiance can be calculated and inversely We can use this method in detection and tracking of IR missile and IRCM. By applying this method on image of machine damaged. It is better solution to problem detection and analysis capabilities with IR Technology.

Keywords: IR image, track, detection, analysis capabilities with IR Technology

1. Introduction

Infrared search and track systems are wide field of view surveillance systems, designed free search, detection, tracking, and classification with identification targets. IR systems are becoming more and more important in air defense applications because radars do not meet the requirement of passive surveillance, suffer from jamming, and are susceptible to anti-radiation missiles.

2. Radiance Theory

In order to obtain an IR image of different wavelength-regions, a thermal surveillance device is required for each bands\cite{2}. A black body means atypical IR radiance body at a certain wavelength (\(\lambda\)) and temperature (T) given by plank's law\cite{1}:

\[
R(\lambda, T) = \frac{e(\lambda) e_1}{\lambda^2 \left( \exp \left( \frac{e_2}{\lambda T_{max}} \right) - 1 \right)} \left[ \frac{W}{cm^2 \mu m \ sr} \right] 
\] \tag{1}

Where the radiation constants C1 and C2 are

\begin{align*}
C_1 &= 1.191 \times 10^8 \left[ \frac{W}{cm^2 \mu m \ sr} \right] \\
C_2 &= 1.428 \times 10^8 \left[ \mu m \ K \right]
\end{align*}

\(e(\lambda)\) is the spectral emissivity of an object and if it is gray body then \(e(\lambda) < 1\), \(\lambda_1, \lambda_2\) are wavelengths The radiance of an object is given by

\[
R(T) = \int_{\lambda_1}^{\lambda_2} \frac{e_1}{\lambda^2 \left( \exp \left( \frac{e_2}{\lambda T_{max}} \right) - 1 \right)} d\lambda \left[ \frac{W}{cm^2 \mu m \ sr} \right] 
\] \tag{2}

Using equation (1) to get, the spectral radiance depending on the wavelength of the black body plotted in figure (1):
The result of the radiance depending on the temperature by Equation (2) as three bandwidths is showing in (Figure 2).

3- Algorithm of IR Image Simulator Using Conversion Method

In order to achieve a good simulation to provide accurate image in the spectral wavelength we proposed a conversion method to convert an IR image of single bandwidth into other bandwidth. An algorithm is get for conversion an arbitrary IR image of arbitrary wavelength into another wavelength-bandwidth. Assuming all objects are gray bodies of similar emissivity, the bandwidth conversion method was derived using maximum and minimum temperature information corresponding to maximum and minimum values of the gray level [2]. IR images of other wavelength-bandwidths created by transforming them to gray level after calculating radiance based on the estimated temperature and this is possible if the object's emissivity recognized. First, convert image to Data and find the pixel temperature and individual radiances corresponding to the temperatures of IR signatures of background and target object calculated through the Planck’s law. Then by adjusting gray level of respective signatures based on the radiances, these IR signatures is created as one image for specific wavelength [3]. Assuming the object in image is gray body its emissivity $\varepsilon(\lambda) < 1$ in a pixel of maximum and minimum gray level ($G_{max}, G_{min}$). The image of title original of Beechcraft King Air twin propeller was taken with a FLIR SC7000 midwave-infrared (MWIR) camera of temperature range (299.45-413.15 K), we will used it as the standard measure of thermal images. Others object illustrated in table 1.[4]

<table>
<thead>
<tr>
<th>Series</th>
<th>TYPES OF IMAGE</th>
<th>emissivity</th>
<th>Temperature</th>
<th>Transmission</th>
<th>Image Range</th>
<th>Camera Model</th>
<th>Lens description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Secondary power station</td>
<td>0.95</td>
<td>$T_{min}=301.1k$</td>
<td>1.00</td>
<td>-9.4°C to 87.9°C</td>
<td>Ti55FT</td>
<td>20mm/F0.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>$T_{max}=361.5k$</td>
<td></td>
<td></td>
<td>Fluke</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Machine tool bit Turner</td>
<td>0.28</td>
<td>$T_{MIN}=283.6$</td>
<td>1.00</td>
<td>20.6°C to 140.1°C</td>
<td>Ti10</td>
<td>20mm</td>
</tr>
</tbody>
</table>
It was taking a picture of the tool bit lathe machine specifications (HSS 4x3x20x200 mm) after heated from one terminal, and image processingAfter install thermally emissive and the degree of background heat to pen pieces when captured.

**The steps of the method to converting images**

1. Calculated radiances through the Planck’s law corresponding to the minimum/maximum temperatures of IR signatures of image according to:

   \[ R(T_{\text{max}}) = \int_{\lambda_{\text{min}}}^{\lambda_{\text{max}}} \frac{c_1}{\lambda^5} \exp\left(\frac{c_2}{\lambda T}\right) d\lambda \frac{W}{(\text{cm}^2 \text{ st})} \]  
   \( R(T_{\text{min}}) = \int_{\lambda_{\text{min}}}^{\lambda_{\text{max}}} \frac{c_1}{\lambda^5} \exp\left(\frac{c_2}{\lambda T}\right) d\lambda \frac{W}{(\text{cm}^2 \text{ st})} \)

2. Calculate the gradient of the conversion function from equation (5) and then calculate the inversion formula for the radiance \( R \) from the gray level by using equation (6):

   \[ \Delta G = \frac{G_{\text{max}} - G_{\text{min}}}{R_{\text{max}} - R_{\text{min}}} \]  
   \[ R(G) = \frac{G - G_{\text{min}}}{G_{\text{max}} - G_{\text{min}}} R_{\text{max}} + R_{\text{min}} \]

3. From equation (3) temperature of the target surface can be estimated by using equation (7):

   \[ T = \frac{c_1}{\Delta G} \frac{1}{\exp\left(\frac{c_2}{T}\right) - 1} \]

4. Take the value of the estimated temperature from equation (7) to account radiance for all pixel of another band with different wavelength then generate new image from the calculated data by convert data to image.

5. Used a code to change the size of generate image to correspond it to the size of original image in order to combine them, now it can be get new image with new wavelength bandwidth.

6. To verify the results, use gray level of the conversion formula \( G(R) \) as in equation (8)

   \[ G(R) = \frac{R - R_{\text{min}}}{R_{\text{max}} - R_{\text{min}}} G_{\text{max}} + b, 0 \leq G(R) \leq 255 \]

The gray level distributed from zero to 255 where \( b \) is brightness control constant.

7. To obtain a synthesis image, the 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 [5]

   \[ G_{t, \text{max}} = \frac{(R_t - R_{\text{max}})}{\Delta R} \times 255 \]  
   \[ G_{t, \text{min}} = \frac{(R_t - R_{\text{min}})}{\Delta R} \times 255 \]

   \[ \Delta G = G_{t, \text{max}} - G_{t, \text{min}} \]

8. To achieve a good synthesis of gray level images the adjusted previous step should be adjustment on synthesis image of the IR transformed image \( G(x,y) \), it is given by

   \[ G'_{t}(x,y) = (G_t(x,y) - G_{t,\text{min}}) \times \Delta G_t / \Delta G_{t,\text{min}} \]

**4- RESULT:**

The output images of proposed transformation method are illustrate in figures of temperature range (301.1-361.5K)
Figure 4 Images after displacement. (Figure 3), (Figure 4) illustrate converted wave length band wave image by comparing image s wavelength (SWIR).
Figure 5 Images before displacement

(Figure 5),( Figure 6) orginal image is in temperature range (283.6-413.9 K) from figure we can show that image in SWIR blacker than image LWIR.
By comparing the output images, the image in SWIR is darker than image in MWIR and image in LWIR is lighter than image in MWIR. We can confirm that the body gray-levels of the converted to SWIR get darker.

Transformation method can be used to estimate temperature and radiance for an arbitrary IR image without any known information just temperature only. It used to estimate temperature of the target and background, if the pixels’ temperature known radiance can calculated and vice versa.

After using displacement of gray level image, it 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.

5- Conclusions

Apply this transformation method expected in IR guided missile and discrete IR counter measure (DIRCM) system simulations. In addition, it is better solution to problem detection and analysis capabilities with IR Technology. Simply certificate through the different viewing modes quickly to better identify trouble areas in Full IR thermal, picture-in-picture distinguish even small temperature differences that could indicate problems with excellent thermal sensitivity (NETD). [7]

References


[4] Basaad H. Hamzal, Duaa A. Taban2 (proposed method to calculate Radiance and estimate Temperature for IR images in different wavelength bandwidth) specialized scientific conference of the faculty of education/ Almustansriyah University, issue (2), Iraq, 2015.
