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Implementation of Pseudo-Coloring Technique on Thermal Images

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Abstract

The present investigation is concerned with measuring the effects of applying pseudo-color technique on the thermal images. In this study, thermal images of different scenes were tested, the thermal images are produced using (Argus Falcon thermal camera from Raytheon Company) with waveband (3-5 & 8-12 micron). Pseudo-coloring technique was adopted to make thermal images more perceivable and understandable. Two methods for image coloring (intensity slicing and color shading) were considered with two kinds of colors distributions (uniform and non-uniform).

الخلاصة

يختص هذا البحث في قياس تأثيرات تطبيق تقنية الألوان الزائفة Pseudo-Coloring Technique على الصور الحرارية، حيث تم في هذه الدراسة اختبار العديد من الصور الحرارية ولمشاهد مختلفة، تلك الصور أخذت باستخدام (Argus Falcon Thermal Camera) والتي تعتمد الطول الموجي (3-5 & 8-12 Micron) والمنتجة من قبل شركة (Raytheon).

إقترح تحوير جديد لتقنية الألوان الزائفة مما يزيد من إمكانية التمييز والإدراك للصور الحرارية، حيث اقترحت طريقتين لتلوين الصور الحرارية(Intensity slicing and Color shading methods) وبنوعين من التوزيع اللوني (Uniform and non-uniform distributions).

Introduction

Coloring

In computers, large numbers of colors are normally available to the programmer or user. The monitors can display a lot of colors (usually more than 256 up to 16 million). To be able to use these colors effectively and to produce a colored image that is optimal for a particular application, a reasonable understanding of the way in which colors can be designated and specified is required. To deal with color in the digital image we need to quantify it in some way and this gives us the notion of a color space or domain. Colors are usually defined in a three dimensional space, which have been used. Although there are lists of color spaces that have been used in computer applications, but our interest is concentrated upon the RGB-space. This model represents the more traditional form of color representation in computer images. Color is labeled as relative weights of three primary colors in an additive system using the primaries Red, Green and Blue. The space of all colors available in this system is represented by the RGB cube as in figure (1). It is important to

remark that the RGB-space is perceptually non-linear.
The equal distances in the color space do not in general correspond to perceptually equal sensations. A step between two points in one region of the color space may produce no perceivable difference; the same increment in another region may result in a noticeable color change.

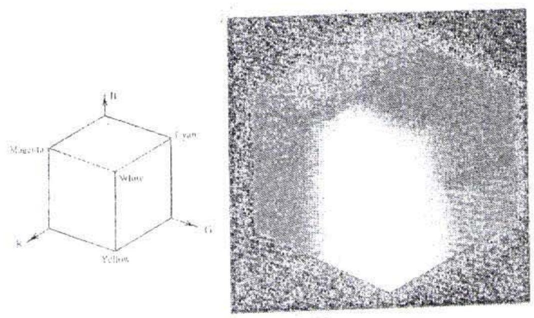


Fig. (1): The RGB Cubic.

In other words, the same color sensation may result from a multiplicity of RGB triples [1].

Pseudo-coloring Technique

The human vision system (HVS) can perceive thousands of colors in a small spatial area but only about 100 gray levels. An enhancement technique called pseudo-color takes the advantage of this aspect of our visual perception to enhance gray level images. Pseudo-color involves mapping the gray-level values of a monochrome image to red, green and blue values, creating a color image.
To transform gray-level to color, we have three different mapping equations for each of the red, green and blue color bands. These equations use a set of functions of the gray levels in the image F(i,j) , as follows:

$$\left.\begin{aligned} F_R(i,j) &= R[F(i,j)] \\ F_G(i,j) &= G[F(i,j)] \\ F_B(i,j) &= B[F(i,j)] \end{aligned}\right\} \qquad (1)$$

where R[ ], G[ ], and B[ ] are the mapping function used to map the gray-levels to the Red, Green, and Blue components. These equations can be linear or non-linear. The Intensity slicing technique implies the splitting of the range of gray-levels into separate colors, so, the gray-levels that fall within a specified range are mapped to fix RGB values (colors). Figure (2) illustrates the intensity slicing method for pseudo-color. The gray-scale range is divided into four different colors, as shown in the figure. The colors in the first range, 0 to Max/4, are mapped to color 1; the colors of the second range extended from Max/4 to Max/2, are mapped to color 2, and so on [2].

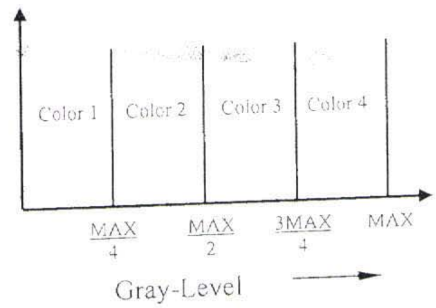


Fig. (2): Intensity slicing.

Pseudo-coloring Implementation

Pseudo-Coloring is an important tool for image enhancement, it is utilized to improve the visualization of thermal images, it can better reflect some information about the thermal scene properties, such as, image construction, contrast, and features.
Cold and hot targets could be recognized perfectly by using the pseudo-coloring technique, and also their heat distribution can be visualized (i.e., we can easily discriminate between heat parts in the target). Figure (3) presents the block diagram of the implemented pseudo-coloring method.

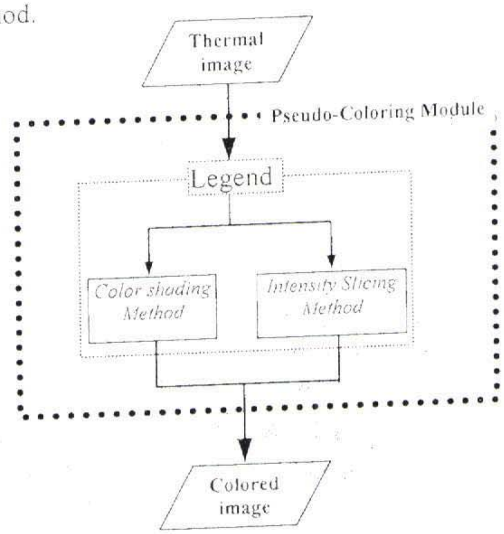


Fig. (3): The block diagram of Pseudo-coloring module.

In this work, an algorithm was designed and implemented to perform pseudo-coloring, by using either intensity slicing technique and color-shading technique.
The main advantages of these methods is its ability to use any number of colors slices (20, 50, 100, ...), and a variable width for each slice, and also uniform and non-uniform color distributions were used to implement pseudo-coloring, see figure (4).

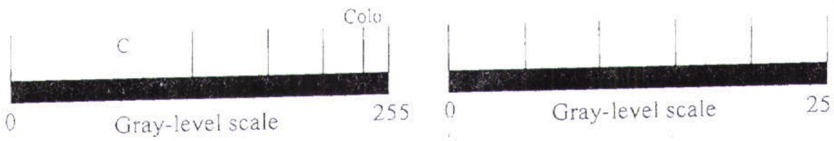


Fig. (4): An example for pseudo-coloring pattern on the gray-level

The difference between color shading and intensity slicing techniques is that the first one assign to each segment of the gray scale with certain color, while the second make a gradual color change when moving from certain reference color to the subsequent color. For example, moving from red reference to yellow reference require one step of color change in the intensity slicing technique while in color shading technique, the movement between red and yellow will pass through many sub-colors that falling between these two reference colors.
Figure (5) shows color pattern generated by intensity slicing and color shading techniques with uniform and non-uniform color distribution.

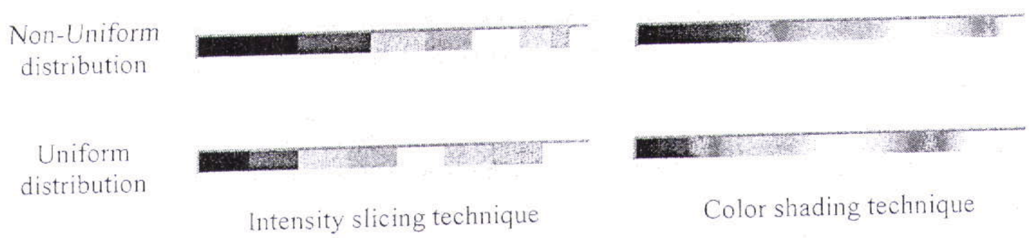


Fig. (5): Pseudo-color patterns generated by using intensity slicing and color shading techniques with uniform and non-uniform distributions.

Thermal distribution (i. e., intensity distribution) in the thermal image obey to the Stefan-Boltzmann law, $\omega = \sigma\varepsilon T^4$, and it is clear that the energy emitted from the target is proportional forwards with the fourth power of temperature, $\omega \propto T^4$. So, it is clear that the image intensity of hot targets will be high, and the information related to hot target will concentrated in the high intensity values (i. e., gray scale). Therefore, the uniform color distribution on the gray-level cannot precisely reflect the suitable representation for the heat distribution because small number of colors may take place big amount of information and that may causing hidden for some details in the image.
The non-uniform colors distribution was adopted to implement intensity slicing and color shading techniques. The pseudo-colors were distributed according to the intensity-temperature relationship in the thermal image, see figure (4).
To give a suitable imagination to the heat distribution of the thermal image, the legend of colors which we proposed supposed that the very

cold targets (have low intensities) represented with blue color, while the very hot targets (have high intensities) with white color, and the range between the two intensity boundaries was assigned with the following sequence of colors; cyan, green, yellow, orange and red, as it is clear in figure (5).

Isolating targets from the background by using thresholding method value was adopted to give targets as much as possible number of colors, and the background values (i.e., the gray values less than threshold) have been represented by black color.

The general design of the color shading technique is based on selection some reference colors distributed along the gray scale. Table (1) shows an example about the adopted notation for specific reference colors that selected to construct a shade of colors, the reference colors are distributed either in uniform or non-uniform manner.

Table (1): The notation of the reference colors that adopted to construct pseudo-color table.

Gray	Red	Green	Blue
g0	R0	G0	B0
g1	R1	G1	B1
g2	R2	G2	B2
g3	R3	G3	B3
.	.	.	.
.	.	.	.
Gn	Rn	Gn	Bn

For any gray value (g) we have to find the reference colors such that their corresponding gray values (g_i) satisfy the condition,

$g_i \le g \le g_{i+1}$ where i=0 < i < no. of reference colors

The corresponding color components (R, G, B) for the gray value (g) were computed by using the following mapping equation:

$$R = \frac{R_{i+1} - R_i}{g_{i+1} - g_i}(g - g_i) + R_i$$

$$G = \frac{G_{i+1} - G_i}{g_{i+1} - g_i}(g - g_i) + G_i \quad (2)$$

$$B = \frac{B_{i+1} - B_i}{g_{i+1} - g_i}(g - g_i) + B_i$$

Applying the above equations will produce shaded colors that distributed smoothly over the corresponding gray scale. The results of applying pseudo-coloring technique on some selected images are presented in figures (6), (7), which describe the differences between the two adopted methods (i.e., uniform and non-uniform colors distributions) which are implemented by using the lookup table (2), and a threshold value was selected visually to perform image segmentation. Table (2) presents the adopted reference colors used in current work, and the area for the non-uniform distribution was selected wide in the dark (cold) region and it was gradually shorten when moving toward the bright (hot) region, this choice can provide the possibility to sense the bright region (i.e., target region) better than other region.

Table (2): The selected color reference values used to implement pseudo-coloring technique with uniform and non-uniform colors distribution.

Gray	Red	Green	Blue	Color	Percentages
g0	0	0	0	Black	%30
g1	0	0	255	Blue	%23
g2	0	255	255	Cyan	%17
g3	0	255	0	Green	%12
g4	255	255	0	Yellow	%8
g5	255	170	0	Orange	%5
g6	255	0	0	Red	%3
g7	255	255	255	White	%2

The test result indicated that the non-uniform colors distribution could reflect a widespread range of colors better than the uniform case especially in the target region and bigger amount of target details will be shown, which in turn give acceptable feeling about the heat distribution for the target(s).

Intensity slicing method will segment the image into separate regions so it could be more benefit to use for classification based on uniformity criteria. Color shading method will produce smooth and soft colored image that may be suitable for detecting the hot and cold region.

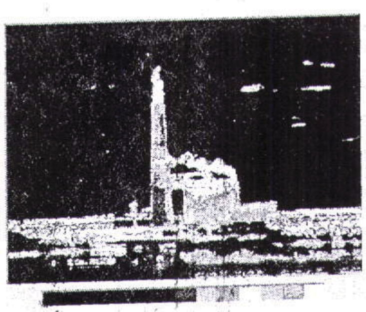
Intensity slicing technique
Uniform distribution
Threshold=85

Intensity slicing technique
Non-uniform distribution
Threshold=85

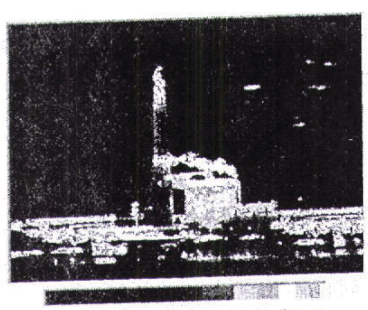
Color shading technique
Uniform distribution
Threshold=105

Color shading technique
Non-uniform distribution
Threshold=105

Fig. (6): Applying pseudo-coloring technique on uniform & non-uniform colors distribution with variable thresholds.



Intensity slicing technique
Uniform distribution



Intensity slicing technique
Non-uniform distribution

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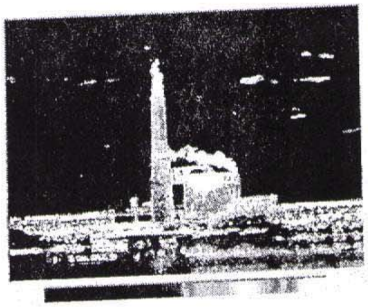
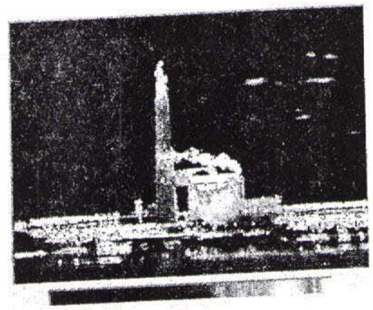


Color shading technique
Uniform distribution



Color shading technique
Non-uniform distribution

Fig. (7): Applying pseudo-coloring technique on uniform & non-uniform colors distribution with fix threshold=100.

Conclusion

The implementation of pseudo-coloring on the thermal image by using color shading method will produce soft images with gradual changes in their colors, it is more useful to detect cold and hot regions in the image that can reflect image information in more details and give wide understand about the heat distribution of the thermal target(s), while intensity slicing method may be suitable for image segmentation purpose. Applying pseudo-coloring based on non-uniform distribution of colors can be used to highlight on some interesting regions of the thermal images, even when the number of involved colors is small. So the non-uniform choice may recover details in the image that the first one may hide it.

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