A Novel Approach to Enhance the Hyperspectral Image for Effective Visualization

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Abstract: Color enhancement of hyperspectral or multispectral images is too important to visualize the spectral features. Many color enhancement techniques are available to enhance the feature of a spectral band without changing the average color distribution. Sometimes the enhanced spectrum lies outside the visible spectrum range, the enhanced features are also invisible. In order to overcome this problem, a novel image enhancement method, known as Advanced Histogram Equalization (AHE) is proposed in this paper for more effective visualization of the spectral features both in visible range and non-visible range. This paper also specifies both the color for visualization and the spectral band for extracting the spectral feature, so that the spectral feature is enhanced with arbitrary color. This proposed color enhancement method is applied to different type of hyperspectral images where its effectiveness to visualize spectral features is verified.

Keywords: *Hyperspectral Image, Color Enhancement, Multispectral Image.*

I. INTRODUCTION

Hyperspectral imaging systems are acquired images in over one hundred contiguous spectral bands. While multispectral imagery was useful to discriminate land surface features and landscape patterns, hyperspectral imagery allows for identification and characterization of materials. In addition to mapping distribution of materials, assessments of individual pixels are often useful for detecting unique objects in the scene. Set of brightness values for a single cell position in the image was used to identify surface materials are shown in Fig.1.

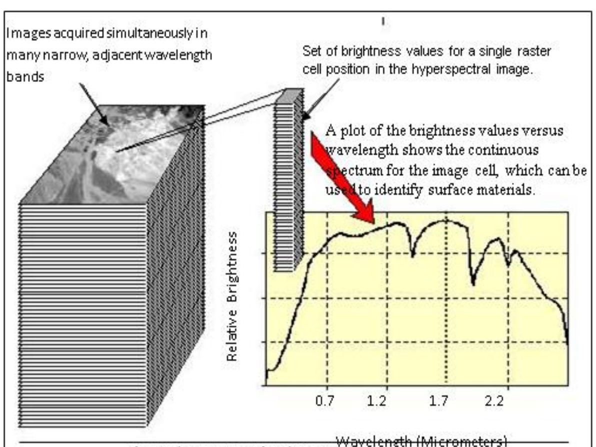

Fig. 1. The concept of multispectral imagery.

Multispectral or hyperspectral imaging uses more than 3 spectral filters to capture images that include spectral information which was useful for remote sensing[1–3], color reproduction[4, 5], image analysis[6–9] and so on. High fidelity color reproduction[4, 5], which was difficult to accomplish with traditional RGB systems due to the limited information contained in RGB images, is made possible by using multispectral images of visible spectral range. The spectral color features that are invisible to the human eyes can be also captured and employed for object detection, recognition, or quantification. Color enhancement was an effective tool to explore the spectral features contained in multispectral images. For example, Ward etal. [7], Gillespie etal. [6] and other authors are proposed color enhancement methods for multispectral images. In most cases, the enhancement results are pseudo-color images in that image the natural colors of the objects are not preserved. However, the natural color of the objects are also important to interpret the spectral features when the multispectral image includes the visible spectral range. Mitsui etal.[8,9] proposed a multispectral color enhancement method, in which the enhanced results are overlaid to the original natural-colored images. In this method, the difference between the original multispectral or hyperspectral image and its approximation by a few principal components at specified spectral bands are amplified. Then, the unnoticeable spectral features in the multispectral image are visualized without changing the average color distribution. However, sometimes the enhanced feature could not be observed, especially when the specified spectral bands are not visually significant, for example, near ultraviolet or infrared. Also when an image has a large number of spectral bands, the enhanced results are not clear. This paper extended the conventional method by modifying the visualization algorithm to effectively visualize the enhanced spectral features of a multispectral or hyperspectral image, which could not be visualized well in the conventional method. In the proposed method, the any one user can specify the spectral band to extract the spectral feature and the color for visualization independently so that the desired spectral feature was enhanced with the specified color. This allows the enhanced spectral features to be visualized clearly even if the enhanced feature was in the invisible range or the image has a large number of spectral bands such like hyperspectral images.

II. MULTISPECTRAL/HYPERSPECTRAL HISTOGRAM EQUALIZATION METHOD

The color enhancement presented in this is paper is mainly based on histogram equalization. The AHE has the goal to preserve brightness while improving the contrast by eliminating the domination of higher histogram components on lower histogram components in the image histogram. Instead of processing the whole histogram at the same time, it has been divided into a number of sub-histograms. AHE enhances contrast for brightness values are close to histogram maxima, and decreases contrast near to minima.

A. Advanced Histogram Equalization method

The algorithm of the multispectral or hyperspectral image color enhancement procedure is shown in Fig.2.

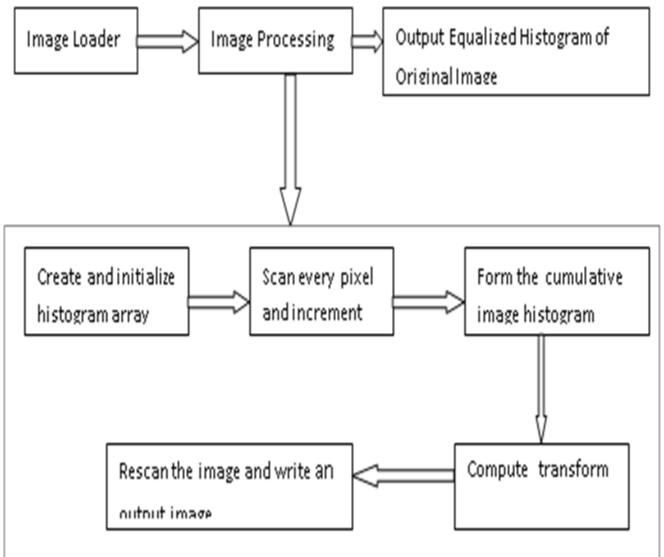

Fig.2. AHE Flow diagram

First, the image loader is specifying where the image is from either a camera or a file on the PC. Then it goes through the image processing block and inside the block, the image goes through five steps before the system produce outputs the equalized histogram of the original image. Once the equalized image is output to the camera, a display or one can save it to a file.

Formally, the algorithm to perform equalization is as follows:

Algorithm: AHE

(1) For an NxM image of G gray-levels (often 256) create an array H of length G initialized with 0 values.

(2) Form the image histogram: Scan every pixel and increment the relevant number of H—if pixel p has intensity g_p, perform

$$H[g_p] = H[g_p] + 1.$$

(3) Form the cumulative image histogram H_c:

$$H_c[0] = H[0]$$

$$H_c[p] = H_c[p-1] + H[p] \quad p=1,2,\ldots\ldots,G$$

(4) Set

$$T[p] = \text{round}(G-1/NM * H_c[p])$$

(5) Rescan the image and write an output image with gray-levels g_q, setting

$$g_q = T[g_p]$$

(6) Call color image enhancement method

(7) Call color mapping method.

B. Color Image Enhancement Method

Different color image enhancement techniques are applied in different color space. Although each color space has different properties, a majority of the multispectral or hyperspectral image use RGB color space. The most commonly used method for color image processing, equalize R, G and B independently is used for color image enhancement.

C. Color Mapping Method

In this method, the relationship between the wavelength of the multispectral or hyperspectral image and the color for the visualization is defined. Then the spectrum of the color assigned to the n-th band is derived by spectral estimation technique, and is used as g_d when n-th band is specified for the enhancement. For example, hue between blue through red is assigned to the band between the shortest and the longest wavelengths of the multispectral or hyperspectral image. In this method, the spectrum g_d is calculated by employing a spectrum estimation technique as follows,

$$g_d = HC^{+} \begin{pmatrix} X_d \\ Y_d \\ Z_d \end{pmatrix}$$

where C^{+} is the pseudo-inverse matrix of CMF and the tristimulus value (Xn, Yn , Zn), which corresponds to the color for enhancement of n-th band, is used as (Xd, Yd , Zd). H is the system matrix which fulfills the relationship between pixel signal values g and spectral data f,

$$g = Hf.$$

III. IMPLEMENTATION AND RESULT

All Digital images are represented as two dimensional pixel arrays. Each pixel indicates the brightness or color of the image at a given point. Histogram equalization creates an image with equally distributed brightness levels over the whole brightness scale 2. The MATLAB high-performance language for technical computing integrates computation, visualization, and programming, and permits algorithms to be executed and simulated. MATLAB has syntax similar to many programming languages, therefore allowing one to create a code parallel to the algorithm. In MATLAB, if a small set of data are used to test an algorithm, results can be extended to a larger set of data set. Although, MATLAB has a histogram equalization function.

In this experiment, the proposed color enhancement method applied on the multispectral image paris.lan is shown in Fig.3. This LAN file, contains a 7-band 512-by-512 Landsat image. To increase the band number, 128-byte header was followed by the pixel values, which are band interleaved by line (BIL). These bands are used to cover the visible part of the spectrum. When they are mapped to the red, green, and blue planes, respectively, of an RGB image, the result was a standard truecolor composite.

Fig.3. Natural color presentation of paris lan

The final input argument to multibandread method specifies which bands to read, and in which order, so that can construct an RGB composite. The truecolor composite has very little contrast due to that the colors are unbalanced.

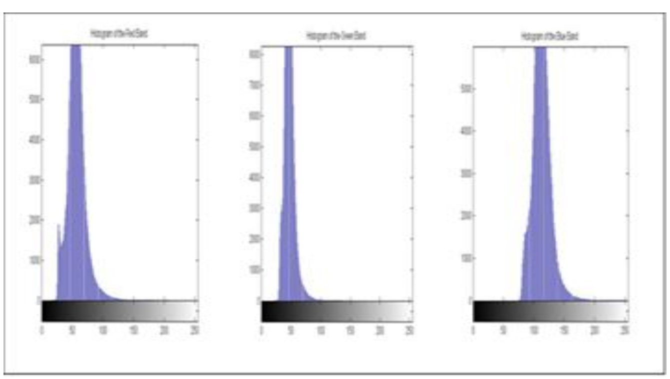

Figure 4: Histograms to explore an un-enhanced image composite

By viewing a histogram of the red, blue and green band the data was concentrated within a small part of the available dynamic range. That was one of the reasons why the image appears dull. Another reason for the dull appearance of the composite was that the visible bands are highly correlated with each other.

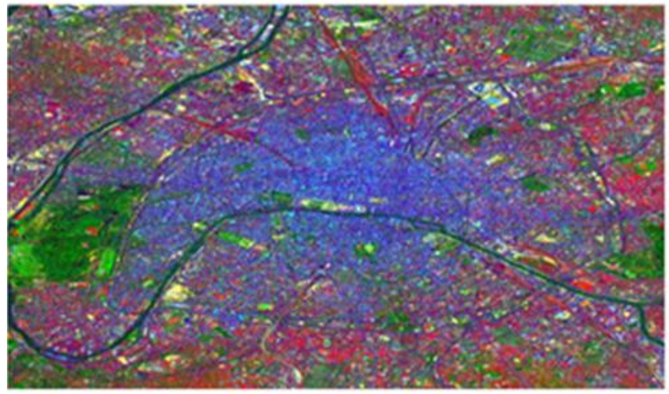

Figure 5: Paris Lan After Color Enhancement

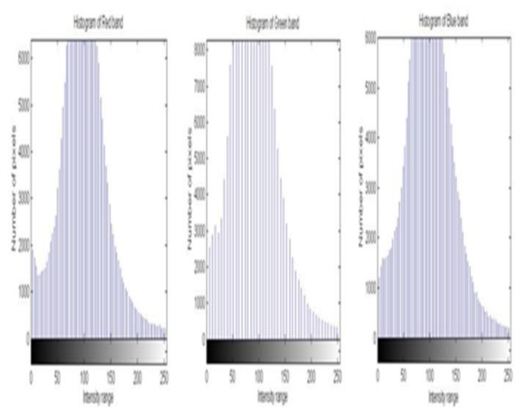

Figure 6: Histograms after Color Enhancement

To solve this problem image color enhancement method applied on the experimental image. It can be observed from the Fig.3 and Fig.5, that the result produced by the method is not similar with the input image. The brightness of the output image has been changed from the input image. The output image looks better than the input image. In this method, the component ratio of RGB at each pixel may be changed, since each R, G, B component image is enhanced independently. So the surface features are easier to recognize. A histogram of the 3 bands after applying a color enhancement method shown in Fig.6, shows that the data has been spread over much more of the available dynamic range.

CONCLUSION

This paper proposes a method for the effective visualization of the enhanced spectral features. An example on the methods to determine the color for visualization is also presented. Even if an image has a salient spectral feature in the invisible wavelength range or has a large number of spectral bands, the spectral feature can still be enhanced and effectively visualized with the proposed method. The method will be useful in exploring the spectral features masked in multispectral or hyperspectral images.

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