A Survey of Satellite Image Enhancement Techniques

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***Abstract*- Satellite image enhancement is the technique which is most widely required in the field of satellite image processing to improve the visualization of the features. Satellite images are captured from a very long distance, so they contain too much noise and distortion because of atmospheric barriers. After capturing the image, some radiometric and geometric corrections are carried out on it but they are not sufficient for all the applications. It is very important to enhance the restored image before using it. In this paper, different methods for satellite image enhancement viz. contrast enhancement, resolution enhancement, edge enhancement, density slicing, digital mosaics and synthetic stereo images are discussed in detail, as well as experimental results of two techniques viz. contrast enhancement of multispectral color composite and IHS (Intensity, Hue, Saturation) transformation are shown.**

Keywords-Remote Sensing, Satellite Images, Satellite Image processing

I. INTRODUCTION

Over past few years, satellite remote sensing data have played an important role in different scientific and need based applications in the field of agriculture, geology, forestry, biodiversity conservation, regional planning, education and warfare etc. Multispectral satellite data (e.g. Landsat TM) combined with high resolution data (e.g. aerial photographs, SPOT satellite panchromatic data) reveal the surface geology in arid areas where the vegetation cover can be neglected and the landscape is dominated by extensive outcrops of different rock types. In contrast to the classical, time consuming geological field work with its expensive and complex logistics, remote sensing techniques offer an efficient and low cost addition to preliminary geological investigations.

Satellite image enhancements are used to make it easier for visual interpretation and understanding of imagery. The advantage of digital imagery is that it allows us to manipulate the digital pixel values in an image. Although radiometric corrections for illumination, atmospheric influences, and sensor characteristics may be done prior to distribution of data to the user, the image may still not be optimized for visual interpretation. Remote sensing devices, particularly those operated from satellite platforms, must be designed to cope with levels of target/background energy which are typical of all conditions likely to be encountered in routine use. With large variations in spectral response from a diverse range of targets (e.g. forest, deserts, snowfields, water, etc.), no generic radiometric correction could optimally account for and display the optimum brightness range and contrast for all targets. Thus, for each application and each image, a custom adjustment of the range and distribution of brightness values is usually necessary.

II. REMOTE SENSING

"Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information."

The information needs a physical carrier to travel from the objects/events to the sensors through an intervening medium. The electromagnetic radiation is normally used as an information carrier in remote sensing. The output of a remote sensing system is usually an image representing the scene being observed. A further step of image analysis and interpretation is required in order to extract useful information from the image. The human visual system is an example of a remote sensing system in this general sense. In a more restricted sense, remote sensing usually refers to the technology of acquiring information about the earth's surface (land and ocean) and atmosphere using sensors onboard airborne (aircraft, balloons) or spaceborne (satellites, space shuttles) platforms.

A. Electromagnetic Spectrum

The sensors onboard remote sensing platforms record energy transmitted as electromagnetic radiation. The sensors contain detectors to record specific wavelengths within the Electromagnetic Spectrum (EMS). In remote sensing terminology, portions of the EMS are often called bands, or spectral bands.

The electromagnetic spectrum (figure 1) can be divided into several wavelength (frequency) regions, among which only a narrow band from about 400 to 700 nm is visible to the human eyes. The NIR (Near Infrared: 0.7 to 1.5 µm.) and SWIR (Short Wave Infrared: 1.5 to 3 µm.) are also known as the Reflected Infrared, referring to the main infrared component of the solar radiation reflected from the earth's surface which is sensed by the satellite.

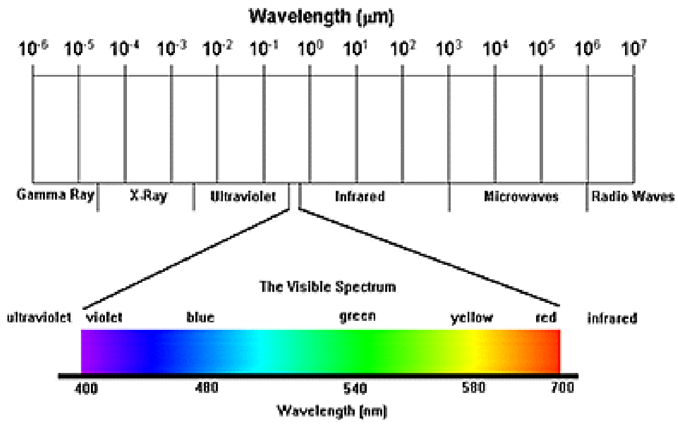

Figure 1. Electromagnetic Spectrum

B. Spectral reflectance signature

When solar radiation hits a target surface, it may be transmitted, absorbed or reflected. Different materials reflect and absorb differently at different wavelengths. The reflectance spectrum of a material is a plot of the fraction of radiation reflected as a function of the incident wavelength and serves as a unique signature for the material. In principle, a material can be identified from its spectral reflectance signature if the sensing system has sufficient spectral resolution to distinguish its spectrum from those of other materials. This premise provides the basis for multispectral remote sensing.

The following (figure 2) graph shows the typical reflectance spectra of five materials: clear water, turbid water, bare soil and two types of vegetation.

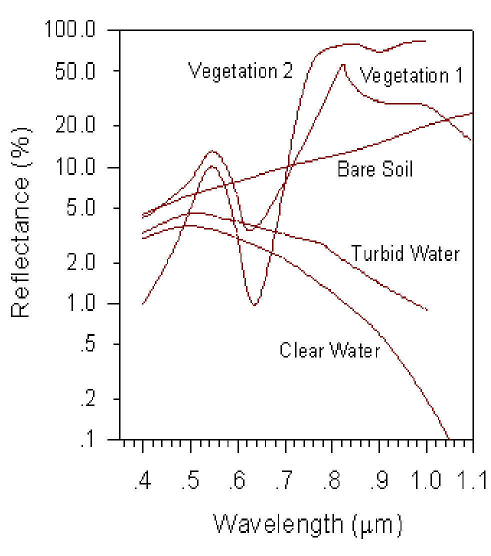

Figure 2. Reflectance Spectrum of Five Types of Landcover

III. STEPS IN SATELLITE IMAGE PROCESSING

Satellite images are used in various applications such as monitoring earth surfaces for land cover change detection, deforestation assessment, crop development, urban growth and natural disasters management. These images can be obtained from the data collected from various satellites. In all these applications, satellite image processing is required for easy interpretation of images and also to extract more information. Image Processing in its general form pertains to the alteration and analysis of pictorial information of image data. Satellite image processing can be divided into image acquisition, image restoration, image enhancement and information extraction.

A. Satellite Image Acquisition

Several remote sensing satellites are currently available, providing imagery suitable for various types of applications. Each of these satellite-sensor platforms is characterized by the wavelength bands employed in image acquisition, spatial resolution of the sensor, the coverage area and the temporal coverage, i.e. how frequent a given location on the earth surface can be imaged by the imaging system.

B. Satellite Image Restoration

Satellite image restoration compensates for data errors, noise and geometric distortions introduced during the scanning, recording, and playback operations. It includes,

- Restoring periodic line dropouts.
- Restoring periodic line striping.
- Filtering of random noise.
- Correcting for atmospheric scattering.
- Correcting geometric distortions.

C. Satellite Image Enhancement

Satellite image enhancement alters the visual impact that the image has on the interpreter in fashion that improves the information content. The techniques for satellite image enhancement are contrast enhancement, IHS (Intensity, Hue and Saturation) transformation, density slicing, edge enhancement, digital mosaics and synthetic stereo images.

D. Information Extraction

Information extraction utilizes the decision-making capability of the computer to recognize and classify pixels on the basis of their digital signatures. The common events in image processing are the capture, storage, enhancement and interpretation of information in an image. The common operations performed on satellite images are,

- Principal-component analysis
- Ratio images.
- Change-detection
- Multi-spectral image classification

IV. SATELLITE IMAGE ENHANCEMENT TECHNIQUES

A. *Resolution Enhancement*

Resolution of an image has been always an important issue in many image and video processing applications. Interpolation in image processing is a method to increase the number of pixels in a digital image. The interpolation-based image resolution enhancement has been used for a long time and many interpolation techniques have been developed to increase the quality of this task. There are three well-known interpolation techniques, namely, nearest neighbor, bilinear, and bicubic. Bicubic interpolation is more sophisticated than the other two techniques and produces smoother edges. Wavelets are also playing a significant role in satellite image processing applications. Wavelet Transform is used to decompose an input low-resolution satellite image into different subbands. Then, the high-frequency subband images and the input image are interpolated, followed by combining all these images to generate a new high-resolution image. The quantitative peak signal-to-noise ratio (PSNR) and visual results show the superiority of the technique over the conventional bicubic interpolation.

B. *Contrast Enhancement*

Contrast enhancement is frequently referred to as one of the most important issues in image processing. The problem is to optimize the contrast of an image in order to represent all the information in the input image. There have been several techniques to overcome this issue, some are listed below:

- General histogram equalization (GHE)
- Local histogram equalization (LHE)
- Decorrelation Stretching
- Linear Contrast Stretching
- Multiwavelets and singular value decomposition(SVD)
- Discrete Wavelet transform(DWT)
- DWT and SVD
- Discrete cosine transform(DCT) and SVD
- Gamma correction

C. *Intensity, Hue and Saturation Transformation*

The additive system of primary colors (red, green, and blue, or RGB system) is well established. An alternate approach to color is the intensity, hue and saturation system (IHS), which is useful because it presents colors more nearly as the human observer perceives them. The intensity (I) represents brightness variations and ranges from black (0) to white (255): no color is associated with it. Hue (H) represents the dominant wavelength of color. Saturation (S) represents the purity of color and ranges from 0 to 255. A saturation of 0 represents a completely impure color, whereas high values represent purer and more intense colors. When any three spectral bands of a sensor data are combined in the RGB system, the resulting color images typically lack saturation, even though the bands have been contrast-stretched. To overcome this problem, data need to be transformed from RGB system to IHS system and equalization is performed on saturation component then data is transformed back to RGB system for visualization.

D. *Density Slicing*

Density slicing converts the continuous grey tone of an image into a series of density intervals, or each corresponding to a specified digital range D. Slices may be displayed as areas bounded by contour lines. This technique emphasizes subtle grey-scale differences that may be imperceptible to the viewer.

E. *Edge Enhancement*

The effort on edge enhancement has been focused mostly on improving the visual perception of images that are unclear because of blur. In general, the popular edge enhancement filtering is carried out with the help of traditional filters, but these filters do have some problems, especially while enhancing a noisy image. Noise removal and preservation of useful information are important aspects of image enhancement. A wide variety of methods have been proposed to solve the edge preserving and noise removal problem. Recently, researchers have focused their attention on nonlinear smoothing techniques in the spatial domain. Most of these techniques are local smoothing filters, which replace the center pixel of the neighborhood by an average of selected neighbor pixels.

F. *Digital Mosaics*

Mosaics of images may be prepared by matching and splicing together individual images. Differences in contrast and tone between adjacent images cause the checkerboard pattern that is common on many mosaics. This problem can be largely eliminated by preparing mosaics directly from the digital CCTs, as described by Bernstein and Ferneyhough. Adjacent images are geometrically registered to each other by recognizing ground control points (GCPs) in the regions of overlap. Pixels are then geometrically adjusted to match the desired map projection. The next step is to eliminate from the digital file the duplicate pixels within the areas of overlap. Optimum contrast stretching is then applied to all the pixels, producing a uniform appearance throughout the mosaic.

G. Synthetic Stereo Images

A synthetic stereo model is superior to a model from side-lapping portions of adjacent Landsat images because

(1) The vertical exaggeration can be increased

(2) The entire image may be viewed stereoscopically

Two disadvantages of computer synthesized stereo images are that they are expensive and that a digitized topographic map must be available for elevation control. Simpson employed a version of this method to combine Landsat images with aero-magnetic maps. The digitized magnetic data are registered to the Landsat band so that each Landsat pixel has an associated magnetic value. The stereoscopic transformation is then used to produce a stereo pair of Landsat images in which magnetic values determine the vertical relief in the stereo model. Elevated areas represent high magnetic values and depressions represent low magnetic values.

V. EXPERIMENTAL RESULTS

Two methods of satellite image enhancement are implemented viz. contrast enhancement of multispectral color composite and IHS (Intensity, Hue, Saturation) transformation and their algorithm and results are shown below:

A. Method 1: Contrast Enhancement of multispectral color composite images

It uses Landsat thematic mapper imagery. Seven spectral bands are stored in one file in the Erdas LAN format (rio.lan).

- Step 1: Construct truecolor composite from a multispectral image :
- Step 2: Use histograms to explore un-enhanced truecolor composite
- Step 3: Use correlation to explore un-enhanced truecolor composite
- Step 4: Enhance truecolor composite with a contrast stretch
- Step 5: Check histogram following the contrast stretch
- Step 6: Enhance truecolor composite with a decorrelation stretch
- Step 7: Check correlation following the decorrelation stretch

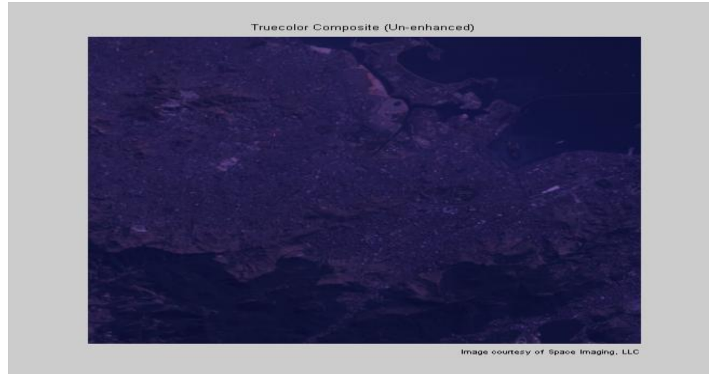

Figure 3.Truecolor composite of Image

Fig. 3 shows unenhanced truecolor composite and enhanced image is shown in fig. 4. Their respective histograms are shown in fig.5. Result of decorrelation stretch and scatterplots are shown in fig. 6 and fig.7 respectively.

Figure 4. Result of contrast stretching on satellite image

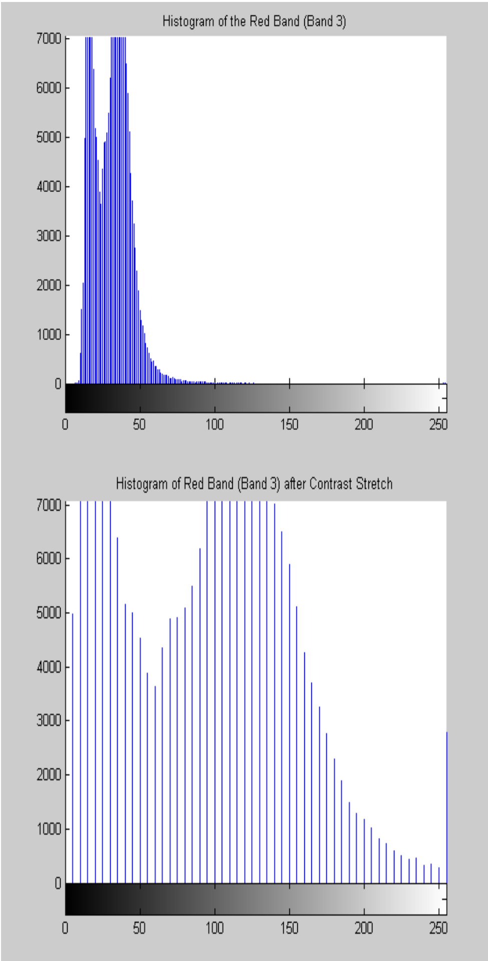

Figure 5 Histogram of the image before and after contrast stretch

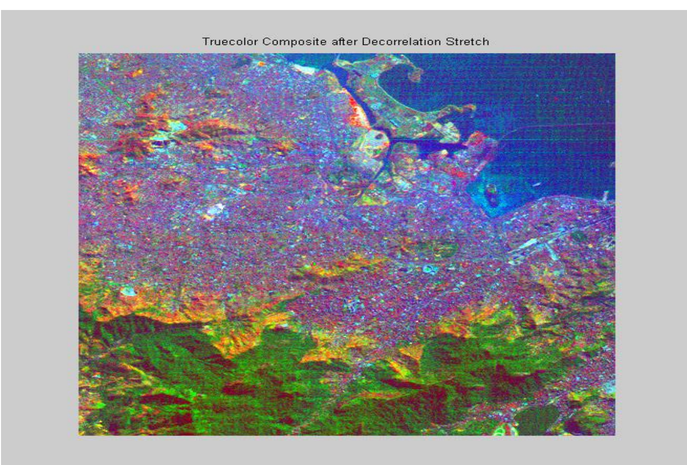

Figure 6 Result of decorrelation stretch

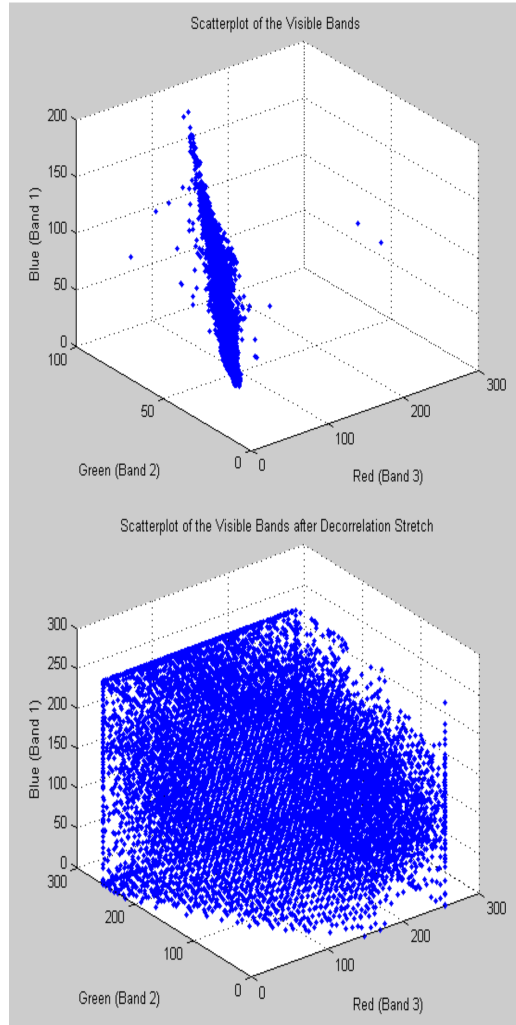

Figure 7 Scatterplot of visible bands before and after decorrelation stretch

B. Method 2: Enhance satellite images using IHS Transformation

The intensity, hue and saturation transformation can also be used for enhancing satellite images. In this case, we have to first separate the intensity component, hue component and saturation component from the RGB image and according to the requirement of the application we can enhance one or more components. After enhancing IHS image we have to convert it back to RGB for better visual perception.

- Step 1: Input RGB image
- Step 2: Separate the Intensity, Hue and saturation images.
- Step 3: Create IHS image

- Step 4: Histogram equalize the H, S and I images and the IHS image.
- Step 5: Then convert the HSI image back to RGB.

Figure 8. Result of Intensity equalization on satellite image

VI. CONCLUSION

There are different methods to implement each of the satellite image enhancement techniques. The selection of the method depends on the input image type, the sensor used to capture the image, the type of application for which it is to be used. These different methods for contrast enhancement, resolution enhancement, IHS transformation, density slicing, edge enhancement, digital mosaics, and synthetic stereo images are discussed and some are compared based on their performance. Among all above techniques, results of two techniques are shown viz. contrast enhancement of multispectral color composite and IHS (intensity, hue, saturation) transformation are shown and from these results, we can see that how satellite images get enhanced for better visual perception as well as for using them in various applications.

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