Comparatively Study of An IHS-Based Color Distortion Reduction for Vegetation Extraction in IKONOS Imagery

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***Abstract*—High-resolution imagery, such as IKONOS imagery has both multispectral (MS) and panchromatic data are provided, with different spatial resolutions. IKONOS images can be fused or pan-sharpened for the visual interpretation of large-area-scale applications. In particular, the intensity-hue-saturation (IHS)-based methods are well known in quick image pan-sharpening. However, most of these processes produce color distortion due to the unnatural spectral response of IKONOS sensors, particularly in vegetated areas. Hence, many recent methods make use of vegetation enhancement in order to correct the unnatural color appearance. Generally, this enhancement is accomplished using vegetation indexes (VIs). A new fusion approach that produces images with natural colors is proposed. Moreover, in this technique, a high-resolution normalized difference VI is also proposed and used in delineating the vegetation. The procedure is performed in two steps: MS fusion using the HIS technique and vegetation enhancement.**

Vegetation enhancement is depends on the considered application.

Index Terms—IKONOS imagery, image fusion, Intensity-Hue-Saturation (IHS) transform, vegetation enhancement, Vegetation Index (VI).

I. INTRODUCTION

The fusion of a PAN image that has high spatial but low spectral resolutions with MS images that have low spatial but high spectral resolutions is a key issue in many remote sensing applications that require both high spatial and high spectral resolutions. The fused image may provide feature enhancement and classification accuracy increase. The design of a sensor to provide both resolution requirements is limited by the tradeoff between spectral resolution, spatial resolution, and signal-to-noise ratio of the sensor. The spectral and spatial resolutions have an inverse relationship. These image processing techniques are known as pan-sharpening or resolution fusion techniques. Intensity-Hue-Saturation (IHS) technique is suitable when exactly three MS bands are concerned. When more than three bands are available, a good solution is to use all of the MS bands located within the PAN band, particularly the near infrared (NIR) band. Moreover, for vegetation visualization applications, recent methods make use of vegetation enhancement to improve color quality. using a vegetation index (VI). EARTH observation satellites provide multispectral (MS) and panchromatic (PAN) data that have different spatial, spectral, temporal, and radiometric resolutions.

LITERATURE SURVEY

A useful technique in various applications of remote sensing involves the fusion of panchromatic and multispectral satellite images. Recently, Tu et al. introduced a fast intensity- hue-saturation (IHS) fusion method. Aside from its fast computing capability for fusing images, this method can extend traditional three-order transformations to an arbitrary order. It can also quickly merge massive volumes of data by requiring only resampled multispectral data. However, fast IHS fusion also distorts color in the same way as fusion processes such as the IHS fusion technique. To overcome this problem, the minimization problem for a fast IHS method was considered and the method proposed by González-

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Audícana et al. is presented as a solution. However, the method is not efficient enough to quickly merge massive volumes of data from satellite images. The author therefore uses a tradeoff parameter in a new approach to image fusion based on fast IHS fusion. This approach enables fast, easy implementation. Furthermore, the tradeoff between the spatial and spectral resolution of the image to be fused can be easily controlled with the aid of the tradeoff parameter. Therefore, with an appropriate tradeoff parameter, the new approach provides a satisfactory result, both visually and quantitatively.

II. Spectral Response of IKONOS

Figure 1 shows the spectral responses of IKONOS. The MS and PAN bands are different.

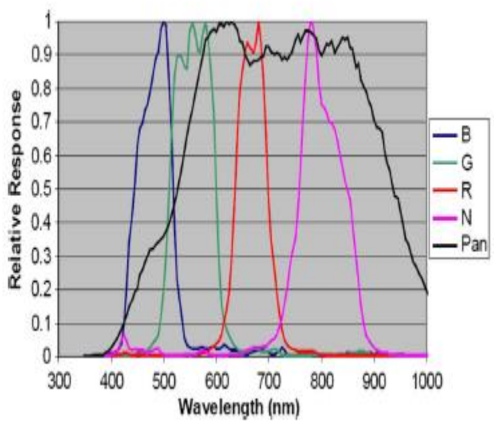

Figure. 1 Ikonos spectral response.

Obviously, the color distortion in the fusion process results from these mismatches. Generally speaking, if the spectral responses of the MS bands do not lay perfectly within the PAN band, as it happens with the most advanced very high resolution imagers, namely, IKONOS, then the IHS-based methods may yield poor results in terms of spectral fidelity. Therefore, in order to improve the fused results, the spectral response must be considered in the merging process.

III.IHS Fusion Technique

The IHS transform is widely used as an image fusion technique to exploit the complementary nature of multi-sensor image data. Before conducting an IHS fusion, the color image should be registered with the high-resolution PAN image and should be resampled to the same pixel size with the PAN image. Next, the three bands (R, G, and B) of a color image have to be transformed from the RGB space into the IHS space.

1) The RGB images to the PAN pixel size, and then, convert them to the IHS components

$$\begin{bmatrix} I \\ v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} 1/3 & 1/3 & 1/3 \\ -\sqrt{2}/6 & -\sqrt{2}/6 & 2\sqrt{2}/6 \\ 1/\sqrt{2} & -1/\sqrt{2} & 0 \end{bmatrix} \times \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

where R, G, and B represent the corresponding values in the original RGB image and v1 and v2 are the intermediate components used to calculate the H and S components.

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} R+\delta \\ G+\delta \\ B+\delta \end{bmatrix}$$

where δ = PAN-I and I = (R+G+B)/3.

The first scheme consists of the GIHS method, where the intensity component is simply the average of the four MS images, i.e., I = (R + G + B + NIR)/4. The second algorithm uses the SAIHS method with another weighting for I : I = (R + aG + bB + NIR)/3. The values of 0.75 and 0.25 corresponding to a and b, respectively, are found to be suitable in fusing the IKONOS images.

IV.IKONOS High-Resolution

The NDVI is the most used VI for a variety of remote sensing applications. It was generally developed for coarse resolution imagery, and it is rarely used to directly generate high-resolution vegetation maps. On the other hand, in some applications, the IKONOS imagery can be used to map a vegetation cover or to validate a vegetation cover classified from other remote sensing images. In addition, the IKONOS PAN images provide more details of buildings and individual trees, while vegetation structural variations can be well detected with 1-m spatial resolution images. However, the vegetation zones of the MS images are much darker because the vegetation appears to have a relatively low reflectance in the RGB bands.

Fig. 1 shows the difference between the NDVI [Fig. 1(b)] and HRNDVI [Fig. 1(c)] obtained from the MS and PAN images. High frequency is

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obviously apparent in Fig. 1(c), especially in the dense vegetation (top and middle boxes). The HRNDVI preserves more detailed vegetation areas than the conventional NDVI. In the bottom box in Fig. 1(a), the oblique structure, which is not a vegetation area, appears in Fig. 1(b) in white, corresponding to false vegetation detection, while it can be noticed that this false detection does not occur in Fig. 1(c).

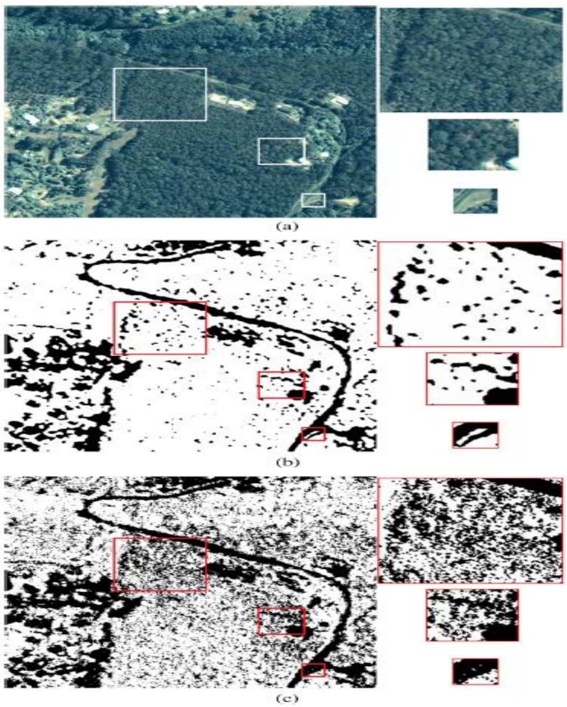

Figure 1. (a) GIHS fused image. (b) NDVI with a threshold of 0.35. (c) HRNDV with a threshold of 0.3.

The contribution of the PAN image in detecting vegetation is obviously apparent in the VI and HRNDVI maps. NDVI, and it guarantees less confusion in the vegetation detection process.

Principal Components Analysis

Principal Components Analysis (PCA) is a linear transformation technique related to Factor Analysis. Given a set of image bands, PCA produces a new set of images, known as components, that are uncorrelated with one another and are ordered in terms of the amount of variance they explain from the original band set. PCA has traditionally been used in remote sensing as a means of data compaction. For a typical multispectral image band set, it is common to find that the first two or three components are able to explain virtually all of the original variability in reflectance values. Later components thus tend to be dominated by noise effects.

PCA Method:

The PCA technique is a decorrelation scheme used for various mapping and information extraction in remote sensing image data. The procedure to merge the RGB and the PAN image using the PCA fusion method is similar to that of the IHS method.

Brovey Transform (BT)

BT is a simple image fusion method that preserves the relative spectral contributions of each pixel but replaces its overall brightness with the high-resolution PAN image. The fusion process is done by applying the following conversion type to each pixel:

$$\begin{bmatrix} Rfi_i \\ Gfi_i \\ Bfi_i \end{bmatrix} = \frac{\text{PAN}}{I} \times \begin{bmatrix} R_i \\ G_i \\ B_i \end{bmatrix}.$$

Here, Ri, Gi, and Bi are the pixel values of pixel i of each band, Rfii, Gfii, and Bfii are the pixel values of pixel i of each band that is obtained by fusion process, and I = (Ri +Gi + Bi)/3.

AWL Method

AWL method was originally defined for a three-band red–green–blue (RGB) multispectral image. In this method, the spectral signature is preserved since the HRP detail is injected into the luminance L-band of the original LRM image.

V. WiSpeR Algorithm

Knowing contributions from both the sensor spectral response and physical properties of the object, we combine these effects to obtain a final expression for the merged image. The simplified final expression to the contribution from the HRP band to each of the LRM bands is

$$n_i^f = s_i \cdot n_i^l$$

noting that in the n_i^l number, the n_pHRP photons are substituted by the wavelet coefficient obtained from the HRP band presented methods.

VI. Visual Evaluation

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The color distortion is apparent in the FIHS and GIHS results. However, the SAIHS and Choi results are better, but the vegetation appears unnatural. The results show an excessive greenness in the vegetated area. This is due to the use of the VI with a zero threshold. Normally, increasing the threshold value improves the results if the used images are natural. In fact, the VI is designed for the vegetation layer of GIS and military applications as camouflage. In any case, the proposed method provides good results. This method tries to solve the problems evoked in [18] and presented in Section II-A. Hence, the NIR band is used in computing the intensity component, and the contribution of the three bands is weighted according to the spectral response of the sensors. The use of a correction term in vegetated areas for the G and B bands has strongly improved the visual quality, and a natural color is obtained.

Color Enhancement

This area is chosen in order to demonstrate the improvement for the G and B bands. The proposed method produces the best results, as can be seen: the green and blue colors appear natural. In Fig. 2(c), (e), and (g), corresponding to the second case, the importance of using the new VI (HRNDVI) is highlighted. The fused results shown in Fig. 2(e) and (g) are obtained using the conventional NDVI and the HRNDVI, respectively.

Quantitative Evaluation

The quality assessment of pan-sharpened MS images is a difficult task. Even when reference MS images are available for comparisons with fusion results, the assessment of fidelity to the reference usually requires computation of a number of different indexes.

Quality Assessment Indexes

Recently, the authors proposed a categorization of indexes found in the literature based on their properties, complementarities, and redundancies.

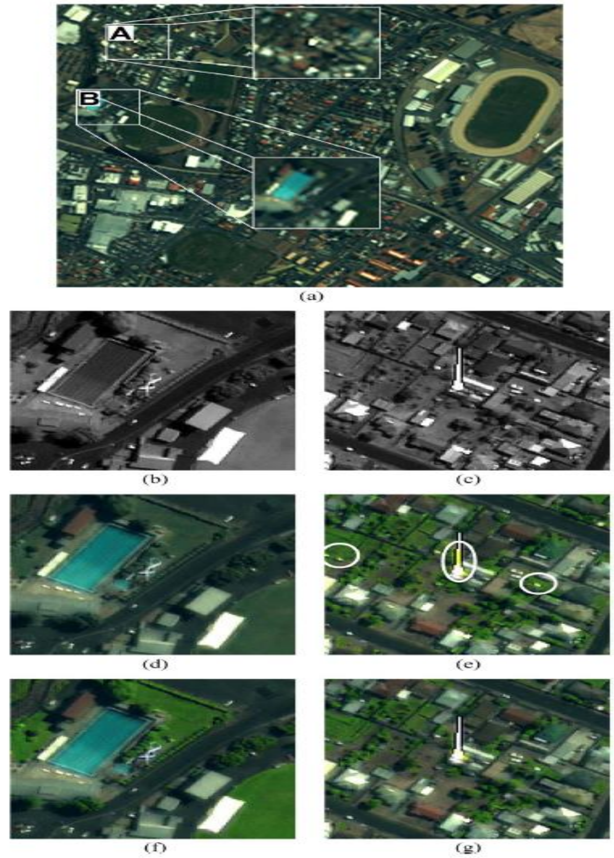

Figure 2. (a) RGB image with two zoomed areas (A and B). (b) PAN image for area A. (c) PAN image for area B. (d) Proposed method results using NDVI. (e) Proposed method results with B1 using HRNDV. (f) and (g) Proposed method results with B2 using HRNDVI.

In the proposed method, enhancement is applied only in the vegetation areas. Therefore, if some errors are made in the vegetation detection process, the final result is affected. As shown in Fig. 2, the NDVI introduces some errors in the "monument" area. Then, enhancing these false vegetation areas introduces color distortions, where a white color pixel appears as yellow due to an increase in the G band and a decrease in the B band. One can notice that using the HRNDVI has eliminated the color distortions that are observed. Using the HRNDVI minimizes this error, especially in regions with sharp edges.

Bias, VAR, and SD

The bias is the difference between the mean of the original image and that of the fused one. In the relative value, the bias is divided by the mean of the

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original image. The relative VAR is the difference in VAR between the original and fused images, divided by the VAR of the original image. The ideal value for each of these measures is zero. The SD of the difference image in relation to the mean of the original image indicates the level of the error at any pixel. The lower the value of SD is, the better is the spectral quality of the fused image.

SAM

It has been widely used in MS and hyper spectral image analysis to measure the spectral similarity between substance signatures for material identification. To compute the SAM between two images, each having L bands B, two spectral vectors v and w are constructed, both having L components, where v = {v1, v2, . . . , vL}, with vk = $B^{(k)}$ (i, j) corresponding to pixel (i, j) in the kth original band, while w = {w_1, w_2, . . . , w_L}, with w_k = Fused_$B^{(k)}$(i, j) corresponding to pixel (i, j) in the kth fused band. The SAM takes the arccosine of the dot product between two spectral vectors: SAM(v,w) = cos−1(<v,w>/ ||v||. ||w||)

ERGAS and Q4

These indexes provide a single quantity synthesizing the quality of the fused data set. In image fusion, the index of the ERGAS (which means the relative global adimensional synthesis error) is as follows:

$$\mathrm{ERGAS} = 100\frac{h}{l}\sqrt{\frac{1}{L}\sum_{i=1}^{n}\frac{\mathrm{RMSE}^2(\mathrm{B}_i)}{\mu_i^2}}$$

where h is the resolution of the high spatial resolution image, l is the resolution of the low spatial resolution image, μi is the mean radiance of each spectral band Bi, and L is the number of bands involved in the fusion. RMSE is the root-mean-square error between a reference image x and a fused image y, with an M × N size, and it is defined

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(x_{i,j} - y_{i,j})^2}{M \times N}}.$$

The lower the value of the ERGAS is, the higher is the spectral quality of the fused image.

The authors proposed a reliable image quality index, namely, Q4, for MS images with four spectral bands. The Q4 index is a generalization of the Q index defined.

VII. CONCLUSION

A new method has been presented for both image fusion and vegetation visualization. It is based on the GIHS, with some G and B bands enhancement in the vegetated zones. In this context, a modified VI (HRNDVI) has been proposed for better vegetation detection. This new technique has been evaluated both subjectively and objectively and has been proven to be efficient in the process of pan-sharpening IKONOS images. For that reason, most classical evaluation indexes were used to assess the quality of the resulting images. The experimental results show that the method performs well on the images that contain mixed or mostly vegetated areas. The results were then compared with those obtained from other existing approaches. This comparison clearly shows that the new method gives very good visual results and produces non distorted and perfectly natural image colors. Moreover, in terms of quantitative indexes, this approach provides a global appreciable fusion quality and improves the spectral and spatial correlations in dense vegetation images. In addition to its performance, this method still remains as simple as the other IHS-based techniques.

FUTURE ENHANCEMENTS

This package has been developed in Mat Lab as Front end. This system is highly user friendly, interactive, easily implemental and modifiable. The system is flexible, adaptable to future modification and reliable.

A new method has been presented for both image fusion and vegetation visualization. It is based on the GIHS, with some G and B bands enhancement in the vegetated zones. In this context, a modified VI (HRNDVI) has been proposed for a better vegetation detection. This new technique has been evaluated both subjectively and objectively and has been proven to be efficient in the process of pan-sharpening IKONOS images.

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To obtain a color-enhanced image, the author proposed to use three different tradeoff parameters. The parameter used for the G band was greater than the parameter used for the B band. Decreasing the contribution of the B band reduces its effect in the vegetated area. To overcome this problem and to obtain a color-enhanced image, three different tradeoff parameters (t_R = 2.5, t_G = 3.5, and t_B = 2.0) are used. Each MS band was enhanced with a parameter reflecting its spectral response.

Therefore, when vegetation is the object of interest, an enhanced-vegetation fused result is the objective. In this case, usually, a VI is used in order to delineate the vegetated area where the enhancement is to be done. The author proposed a technique for IKONOS image fusion, where the main purpose of a specific image is vegetation visualization. The technique consists of a hue spectral adjustment scheme integrated into an IHS transformation.

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