Urban Remote Sensing Image Enhancement Using a Generalized IHS Fusion Technique

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Abstract

To improve observation quality, many approaches have been developed to combine the information coming from multiple images to create fused ones where the content is more suitable for human perception. IHS is one of the widespread image fusion methods in the remote sensing community. This method causes color distortion, therefore many papers have investigated modifications that can be made to attenuate the problem. Nevertheless, for some applications, the color distortion is not a great problem. Besides, the standard IHS methods accept just three bands. This paper proposes a new methodology for dimensionality reduction using multiple input images with a Generalized IHS transformation. The main objective is to produce urban images where the objects are clearly identified. The fusion method integrates, in three components (IHS), the most important information provided by multiple inputs. Experimental results are presented and discussed when applying the Generalized method to synthetic, IKONOS and QuickBird images.

1. Introduction

Data fusion is a formal framework in which data originating from different sources combined in one synthetic visual product. It aims at obtaining information of greater quality; the exact definition of 'greater quality' will depend upon the application [1]. A particular case of data fusion is image fusion. A general definition of image fusion is given as "Image fusion is the combination of two or more different images to form a new image by using a certain algorithm" [2].

In optical remote sensing, with physical and technological constraints, some satellite sensors supply the spectral bands needed to spectrally, but not spatially distinguish features. Other satellite sensors supply the spatial resolution for distinguishing features spatially but not spectrally [3]. Then, in order to improve observation quality, many approaches have been developed to combine the information coming from multiple images to create fused images where the content is more suitable for human perception.

IHS is one of the widespread image fusion methods in the remote sensing community and has been employed as a standard procedure in many commercial packages [4]. The pan-sharpening IHS image fusion, basically, consists of transforming three input channels from RGB to IHS, replacing the original intensity component by a high resolution image, and transforming the replacement component, hue and saturation back to RGB by inverse IHS transform. Although many other techniques have been applied to fuse multi-sensor data, the IHS technique is popular and easy to use.

However, the problem of color distortion, sometimes, appears at the analyzed area after it is transformed by using IHS fusion methods. To reduce the spectral distortion many papers have investigated some modifications that can be made to attenuate the problem.

A new look at IHS-like image fusion methods was introduced by [5]. They investigate the color distortion that happens in the popular image fusion methods, presenting a relatively detailed study indicating that the color distortion problem arises from the change of the saturation during the fusion process. [6] also indicate some reasons for the color distortion. Afterwards, [7] introduced a fast IHS fusion method. Besides its fast computing capability for fusing images, this method can extend traditional three-order transformations to four-order. It can also reduce the spectral distortion by a simple spectral-adjusted scheme which they integrated into a fast IHS method. Based on the previous Tu et al. paper, a new approach was proposed by [8] trying to minimize the spectral distortion inherent in image fusion methods based on IHS fusion. In his paper, a parameter is used to appropriately control the trade-off between the spatial and spectral resolution of the image to be fused. However, parameters are manually and not automatically adjusted. Therefore, optimal results are not achieved. Recently, [9] have presented a tunable IHS-Brovey method. IHS-Brovey method for image fusion was based on Choi's method. The resulting images not only keep the same spectral quality but also present higher spatial information than that by Choi's method, which is limited by the selection of the appropriate trade-off parameters.

Nevertheless, for some applications the color distortion is not a great problem. On image classification, for example, if trees are red, the classification algorithm will find them. The color distortion starts to be a problem when objects with different spectral characteristics have similar colors after image fusion.

Considering previous observations, this paper proposes a new methodology to reduce dimensionality using multiple input images with a Generalized IHS transformation (Section 2.). The method integrates, in three components (IHS), the most important information provided by multiple input images. Experimental results are presented in Section 3. when applying Generalized IHS transformation to synthetic, IKONOS and QuickBird images. The main objective of this results is to produce urban images that are more visual suitable and can be applied to some applications particularly visual interpretation of multispectral scenes of Remote Sensing. Finally, conclusions are posted in Section 4..

2. Proposed Generalized IHS Transformation

The human visual system can distinguish only about 20 to 30 shades of gray under a given adaptation level. Under the same conditions it discriminates a much larger number of color hues. Thus, the use of color provides a dramatic increase in the amount of information that can be displayed. When display devices, having slightly different sets of primary colors, are employed, a transformation may be necessary to obtain color consistency.

The IHS color space is useful because of two factors: intensity component is detached from the color information; hue and saturation components are very close to human color perception. These characteristics make IHS color space an ideal tool for image processing algorithm development.

An IHS transform approach was proposed by [10], where each band has a determined angle on the hue space (*e.g.* for 3 bands, we have $\phi_1 = 0°$, $\phi_2 = 120°$, and $\phi_3 = 240°$). Moik describes this transformation just with three input images, considering orthogonal angles to each one, although it accepts more than three. Equations 1, 2, and 3 show how [10] transforms the input images in three IHS bands.

$$I(i,j) = \frac{max\ f_k(i,j)}{K} \tag{1}$$

$$H(i,j) = tan^{-1}\left[\frac{\sum_{k=1}^{n} f_k(i,j)\sin\phi_k}{\sum_{k=1}^{n} f_k(i,j)\cos\phi_k}\right] \tag{2}$$

$$S(i,j) = 1 - \left[\frac{min\ f_k(i,j)}{max\ f_k(i,j)}\right] \tag{3}$$

where i is the counter of lines ($i = 0, \ldots, M-1$) and M the number of lines; j is the counter of columns ($j = 0, \ldots, N-1$) and N the number of columns; k is the counter of input images ($k = 0, \ldots, n-1$) and n the number of input images; K is the maximum possible intensity value of the original component images (for 8 *bits* images, $K = 2^8 = 256$).

The angles ϕ_k determine the image axis components directions in a polar coordinate system and are calculated by Equation 4 (*e.g.* for $n = 3$, we have $\phi_1 = 0°$, $\phi_2 = 120°$, and $\phi_3 = 240°$).

$$\phi_k = k\left(\frac{360°}{n}\right) \tag{4}$$

In this paper, we consider non uniform color primaries based on the calculation of hue values. It means that we can determine any angle for each band. However, this process is empirical, depending on the application, and demands user knowledge to have successful results. One way to make this process automatic is to determine the angles based on spectral response function ranges.

A modification in Equation 2 is essential. The sun radiates all the frequencies; when an object reflects all these frequencies we see white. If, equally, 50% is reflected we see gray. When we work with satellite images, sensors don't "see" all frequencies. In standard IHS transformation these "unseen" frequencies are discarded. They exist, but we don't have the information. An white amount adjustment is introduced to compensate this effect (Equation 5) through the minimum pixel value subtraction.

$$H(i,j) = tan^{-1} \left\{ \frac{\sum_{k=1}^{n} [f_k(i,j) - min\ f_k(i,j)] \sin \phi_k}{\sum_{k=1}^{n} [f_k(i,j) - min\ f_k(i,j)] \cos \phi_k} \right\} \quad (5)$$

Hue is an angle, therefore we have to check to which quadrant each hue value belongs. To control this, we can use the numerator and denominator signals which correspond to sines and cosines, respectively.

With non orthogonal characteristic, we can use multiple images to finally reduce to IHS space, using the proposed Generalized IHS transformation. However, the high resolution satellite that are available today, frequently, have four multispectral bands.

If the angles are not well selected, the fused image will have color distortion. Nevertheless, when we have more than three input images the color distortion is inevitable.

The Generalized IHS transformation can be applied to any image set. The transformation objective is dimensionality reduction from input images to provided fused images that can be visualized after the inverse IHS to RGB transformation. To transform IHS to RGB a simple transformation presented in [11].

After all these steps, we have, a RGB three band fused image. It is important to point out that, like all IHS transformations, Generalized IHS is empirical. They are based on psychobiological experiments. IHS is more or less similar to rectangular and cylindrical coordinates transformation. In this sense Generalized IHS transformation can be thought as an extension of N-dimension coordinate systems to 3-Dimensional cylindrical coordinates (dimensionality reduction). The sole existence of many IHS transformations is a proof of its empirically.

In the next Section we demonstrate several experimental results produced by this methodology.

3. Experimental Results

First, we consider that the color information is important to show the results of the Generalized IHS transformation, so the images are presented colored.

Synthetic images were produced to demonstrate how an user can change hue angles to get an appropriate result. Figure 1 shows five input bands that simulate a satellite sensor behavior. Each band is sensitive to some kind of object.

a) b) c) d) e)

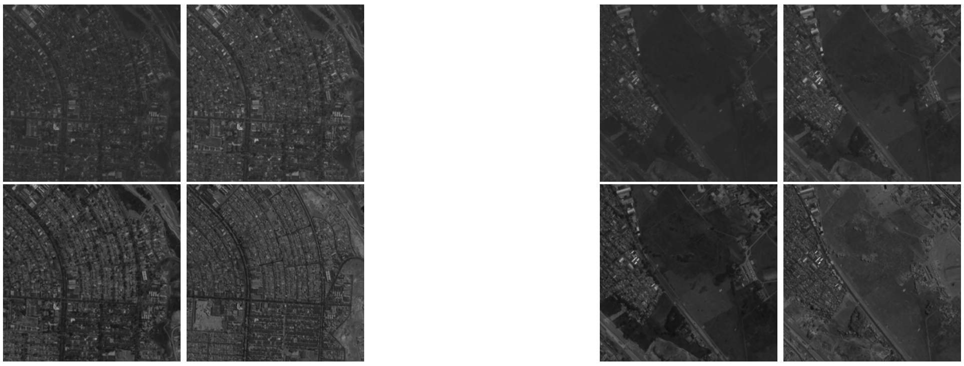
Figure 1: High response for: a) Linear [B1], b) Irregular [B2], c) Circular [B3], e) Elliptical [B4], and f) Rectangular [B5] objects.

As we can note, Figure 2 shows some examples for different choices of angles. In Figures 2a and 2c, the objects are correctly separated. Therefore, Figure 2b can not separate the irregular and regular objects.

a) b) c)

Figure 2: Bands angles: a) B1[0°] B2[72°] B3[144°] B4[216°] B5[308°], b) B1[320°] B2[160°] B3[140°] B4[80°] B5[0°], and c) B1[240°] B2[300°] B3[160°] B4[20°] B5[80°].

To illustrate the proposed Generalized IHS transformation with a real example, the data used for this experiment is an image scene of São José dos Campos, SP, Brazil, taken by the IKONOS satellite sensor in December 2005. The image size is 950×750. Two small images (256×256) are used for the experiment shown in Figures 3a and 3b. Figures 4a and 4b show a color composition to the two image sets presented in Figure 3.



a) b)

Figure 3: IKONOS bands: a) Region 1 and b) Region 2.

a) b)

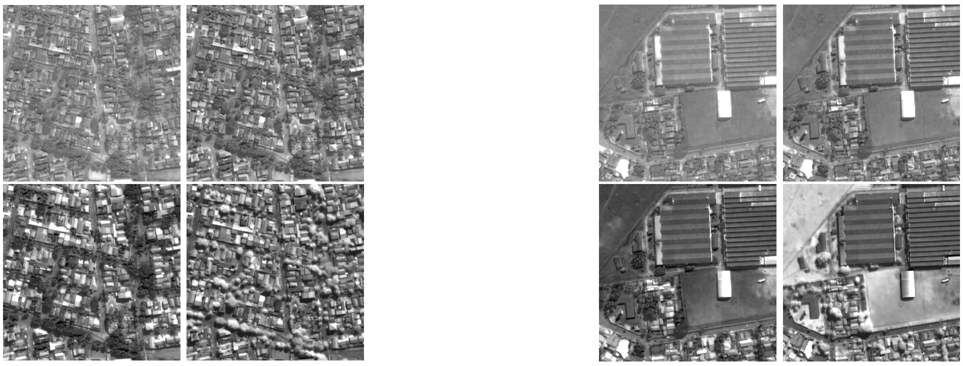
Figure 4: Color composition: a) R3G2B1 region 1 and b) R3G2B1 region 2.

Two Generalized IHS transformation application for 3-red, 4-nir, 2-green, and 1-blue IKONOS bands are shown in Figure 5. The angles used, in Figure 5a, to calculate the transformation were 0°, 120°, 90°, and 240°, respectively. In Figure 5b the angles used were 0°, 90°, 120°, and 240°. It is important to point out that when we have many input images (more than three) the color distortion is inevitable. These images can be used for classification, since all the objects in both images have different colors.

Another example with a real image scene in São José dos Campos, SP, Brazil, taken by the QuickBird satellite sensor in January 2004. The image size is 3334×1667. Two small images (512×512) are used for the experiment shown in Figure 6. Figures 7a and 7b show a color composition to the two image sets presented in Figure 6.

a) b)

Figure 5: Image fused by Generalized IHS transformation: a) IKONOS region 1 and b) IKONOS region 2.



a) b)

Figure 6: QuickBird bands: a) Region 1 and b) Region 2.

Figure 8 shows images resulting from Generalized IHS transformation applied to 3-red, 4-nir, 2-green, and 1-blue QuickBird bands, for the two regions presented before. The angles used in Figures 8a and 8b were $0°$, $140°$, $200°$, and $240°$, respectively. In Figure 8a, we can observe that trees and roofs are easily detected by any classifier while other objects are not as clear. In Figure 8b, the grass and trees are unclear, but roofs are clear. The angle selection is inherent to the application and each choice produces one different result.

We compare the classification using k-means classifier [12] to prove that the information provided from the four input images was improved. This classification method is unsupervised and works with two parameters: the number of classes and the number of iterations. An unsupervised classifier was chosen because it does not include a user interaction. The QuickBird images were chosen because they have higher spatial resolution, so we can see the objects clearly. The Figure 9 shows that so with four input images the classification is worse than one after Generalized IHS transformation.

The Principal Components Analysis (PCA) is an enhancement technique that reduce or remove the spectral redundancy [13]. The correlation between the spectral bands are transformed resulting separated bands. So, applying PCA we can produce a color composition improving some objects as the Generalized IHS transformation. Figure 10 shows a comparative between the result produced by Generalized IHS transformation and PCA . We can note that the objects enhanced by PCA also are enhanced by Generalized IHS transformation.

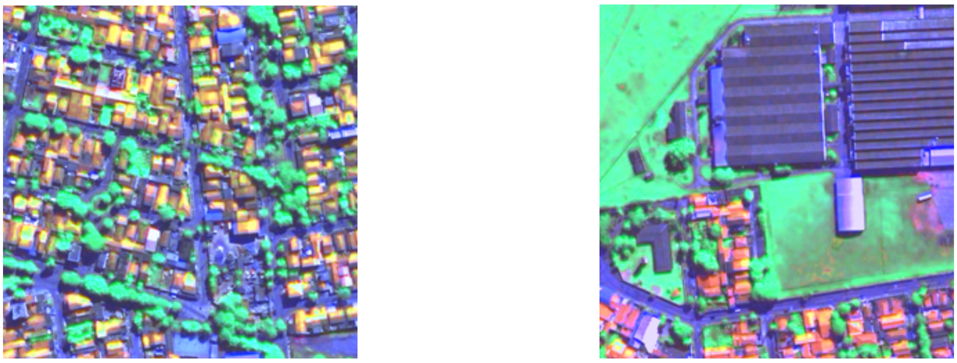
4. Conclusion

This paper proposes a new methodology to dimensionality reduction using multiple input images with a Generalized IHS transformation. This method integrates, in three components (IHS), the information provided from multiple input images, producing urban images where the object identification is more comfortable.

Color distortion, sometimes produced by the transformation, is not a great problem. In image classification, a

a) b)

Figure 7: Color composition: a) R3G2B1 region 1 and b) R3G2B1 region 2.



a) b)

Figure 8: Image fused by Generalized IHS transformation: a) QuickBird region 1 and b) QuickBird region 2.

good angle choice can produce images where each object set have a determined spectral range. Color distortion starts to be a problem when objects with different spectral characteristics have similar colors after image fusion. Angle determination in fusion process is empirical. It depends on application and requires user knowledge to have successful results. We intend to produce an automatic estimation of these angles based on input images spectral response functions.

Experimental results showed many urban examples with different satellite sensors proving that we can use Generalized IHS transformation to produce fused image with total color control using multiple source images. Through the classification test we prove that when the Generalized IHS transformation is used, the information are enhanced. When it is compared with PCA, we can show that Generalized IHS transformation improve the information provided from multiple input images as well as PCA. To produce such results we have implemented an algorithm using TerraLib Library available at `http://www.dpi.inpe.br/terralib`.

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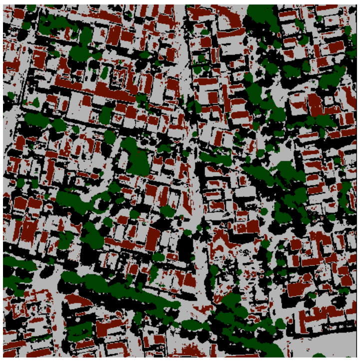

a)

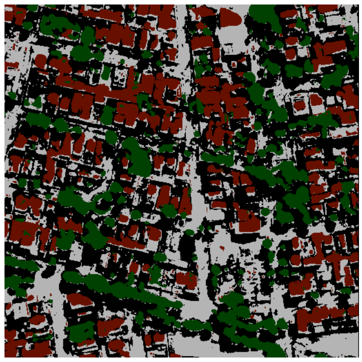
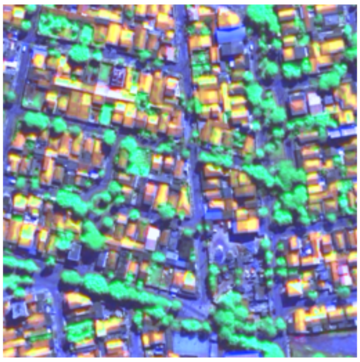

b)

Figure 9: Classification using k-means algorithm: a) Four input images and b) After Generalized IHS transformation.


a)

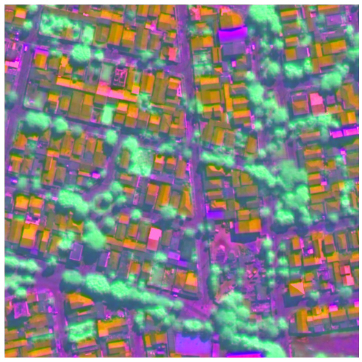

b)

Figure 10: Comparative between a) Generalized IHS transformation and b) PCA.

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