

# COLOR ENHANCEMENT OF REMOTE SENSING IMAGERY USING USING IHS TRANSFORMATIONS AND DECORRELATION STRETCH METHODS

Luciano V. Dutra \*  
Paulo R. Meneses \*\*  
Waldir R. Paradella \*

\* Instituto de Pesquisas Espaciais-INPE  
P.O. Box 515 - 12201 - São José dos Campos - SP  
Brazil

\*\* Universidade Brasília - UnB  
70910 - Brasília - DF  
Brazil

COMISSION III

## I - INTRODUCTION

Photointerpretation of multispectral remote sensing images, requires a good presentation of the data in order to utilize the information offered, which is based on textural and color aspects of the targets.

Color is achieved by assigning each one of three channels of a multispectral image to one RGB input of a color monitor. To enhance color distinction among targets, making the photointerpretation task easier, several techniques can be used, but special attention will be payed here to the IHS color transformation and the decorrelation stretching technique.

## II - IHS TRANSFORMATION

Any color vector based on the primary colors Red, Green, and Blue, can be also represented by three perceptually independent attributes: intensity (I), hue (H) and saturation (S). Intensity is the attribute used for black and white images and is linked with the total energy that reaches the eye. Hue gives the common sense of pure color and saturation is a measure of how much white a natural color does not have.

There are many models to explain how I, H and S can be inferred from RGB measurements (Pratt, 1978; King et al, 1984). A simple method is presented by Haydn (1982), where H (Figure 1) is defined piecewise running counterclockwise around the periphery of the RGB triangle (valued between 0 and 3). S is defined as 1 on the triangle and 0 at the center. The equation (1) defined for the interval  $0 \leq H < 1$  can be extended to the interval  $1 \leq H < 3$ .

$$I = R + G + B$$

$$H = (G - B)/(I - 3B) \quad (1)$$

$$S = (I - 3B)/I$$

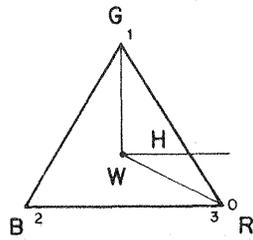


Fig.: 1 - The IHS triangle

Once in IHS space one can process the IHS attributes. Contrast stretching of I component ensures that the same brightness contrast modification is done without changing the hue of the resulted image (obtained by IHS inverse transformation).

With respect to the Hue contents, it is possible to expand its range by linear stretching or even histogram equalization. Care must be taken because this procedure modifies the colors of scene objects, in some cases causing confusion. Also using IHS transformation one can make Hue rotation (Dutra and Meneses, 1987) allowing a controlled changing of relative color of objects. This procedure may be suitable for false colors compositions in order to achieve more agreeable results or enhance details by changing borders colors like changing a magenta/red transition to red/yellow. Hue rotation is defined in degrees. If  $\theta$  is the desired rotation angle, new values  $S(h)$  for H can be achieved by:

$$S(h) = \begin{cases} h - d & d \leq h < 3 \\ h - d + 3 & 0 \leq h < d \end{cases} \quad (2)$$

where  $d = \frac{3 \cdot \theta}{360}$

Saturation of color can be enhanced by adding an offset or stretching the S component.

Using the inverse IHS transformation, one can see the IHS manipulated image back to screen.

### III - DECORRELATION STRETCHING

Decorrelation stretching was introduced by Soha and Schwartz (1978). Several authors have been using this technique since then, which is based on a whitening transformation (Fukunaga, 1972) of the acquired data. The purpose of this procedure is to produce a new multichannel image whose histogram occupies the entire feature space, maximizing the number of possible color features, without altering hue considerably.

Gillespie et al (1986) compared the use of IHS transformation and decorrelation stretching method reporting stimulating results. In this paper the comparison is made introducing another kind of IHS transformation and other type of H

manipulation, hue rotation, which is applied also after the decorrelation transform.

Let  $x$  be a zero mean  $N$ -dimension random vector ( $E(x) = 0$ ) representing the original channels feature coordinates.

The whitening transformation (eq. 3) (Fukunaga, 1972), is transformation which promotes a rotation to the principal components coordinates and a changing of the scales in order to transform the original distribution of  $x$  to a circular one (Figure 2):

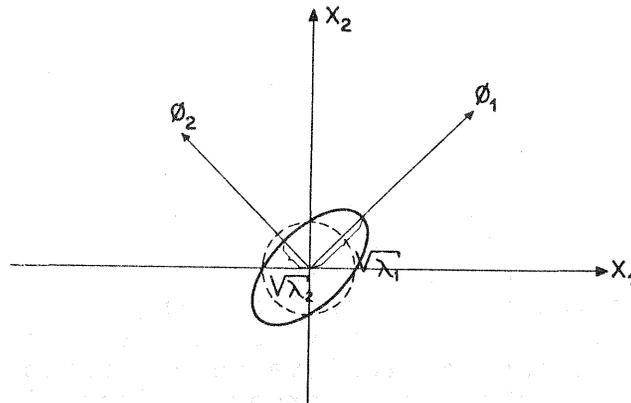


Fig. 2 - Whitening Transformation ( $N = 2$ )

$$y = \Lambda^{-1/2} \phi^T x \quad (3)$$

where

$$\Lambda^{-1/2} = \begin{bmatrix} \frac{1}{\sqrt{\lambda_1}} & & 0 \\ & \ddots & \\ 0 & & \frac{1}{\sqrt{\lambda_n}} \end{bmatrix}$$

$\lambda_1, \dots, \lambda_n$  are the eigenvalues and  $\phi$  the matrix of eigenvectors of the covariance matrix of  $x$ .

To process the decorrelation stretch method we have to subtract the input channels means from the original image to produce the zero mean random vector  $x$ , to apply the transformations  $\Lambda^{-1/2} \phi^T$  and the backward rotation  $\phi$ , and add a constant vector to get the whitened composition on the original coordinates.

An offset of 128 is added to each output channel (for a range of possible 256 gray levels). So the decorrelated image  $Z'$  of  $Z$  is (eq. 4):

$$Z' = K \phi \Lambda^{-1/2} \phi^T [Z - E(Z)] + \begin{bmatrix} 128 \\ \vdots \\ 128 \end{bmatrix} \quad (4)$$

where  $k$  is constant used to choose the scaling if the output (normally  $K = 42$ , corresponding to  $3\sigma_z$  within 128).

#### IV - RESULTS

To analyse these two techniques of color enhancement with purpose of lithologic discrimination, it was selected the subgroup of TM bands 4, 5 and 7 of an area comprising essentially carbonic rocks. In the original bands the lithologic facies appear with a very subtle spectral difference.

In the RGB color composition, only enhanced by linear contrast stretching (Figure 3) it can be noted a predominance of few colors, without significant contrasts, suggesting for the photointerpreter not much lithologic variation in the area. However, the IHS transformation for the some subgroups of bands show us a more detailed spectral difference. High contrast among arenitic rocks (magenta), shales (orange-yellowish) and the different carbonics facies identified by various tones of blue appears clearly in the IHS manipulation image of Figure 4. This image was obtained by a previous equalization of the mean the original bands to the higher mean value, to avoid the color concentration of the Hue component in 1/3 of the dynamic range. So, the Hue component pass to occupy all the dynamic range and then only the I and S components have to be stretched. Although it is noticeable an increase of color contrast in the IHS image, in relation to the RGB composition, it can be seen the absence of the complementary colors or even the basic green color. To try to eliminate such deficiency it was made an angular rotation in the Hue component with the intention to introduce new colors and to increase the visual contrast of the image. Different angles of rotation were tested. Specific for the test site, the positive rotation of 30° allowed a better equilibrium of complementary and basic colors, which became more suitable for visual interpretation. This can be seen in Figure 5, as indicated by the points A and B, where is noted a better spectral discrimination of some lithologic units. With this method the analyst can select the angle of rotation which will give him the best color combination to realize a profitable interpretation.

Another experience was made with the IHS transformation, which consists in submitting the I component (still in the IHS space) to a high-pass filter, with the aim of enhancing some local details in the image. The value 0.2 is added to the saturation component S before the inverse IHS transform. Using a high-pass filter with a window size 3 x 3, a good result was obtained in relation to the enhancement of lithologic units which have some topographic features. Only by this aspect we can separate with more reliance various spectral units of carbonatic rocks (grading from blue to black) in the central part of the Figure 6.

With the decorrelation stretching technique it was obtained an effective contrast of colors, i.e., a real expansion of the range of chromaticness (hue and saturation), compared to the RGB or IHS images. In any portion of the decorrelated image (Figure 7) it is possible to note more detailed information by a large variation of complementary and basic colors. For the purpose of visual interpretation the most significant result of the decorrelation was the sensation of textural enhancement of the lithologic units provided by the higher contrast of color. A good example of this can be seen in the region A indicated in the Figure 7. An application of a hue rotation over the decorrelated image can still increase the color contrast (compare Figure 8 to Figure 7).

## V - CONCLUSION

The above test site has been used to show how much the techniques IHS and decorrelation are really effective to yield to good color enhancements for TM bands, mainly when these bands are highly correlated.

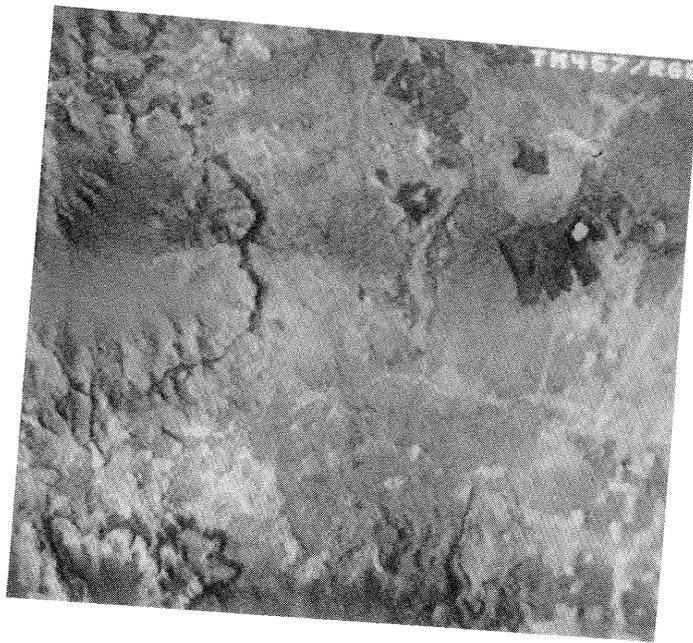


Fig. 3: Original color composition

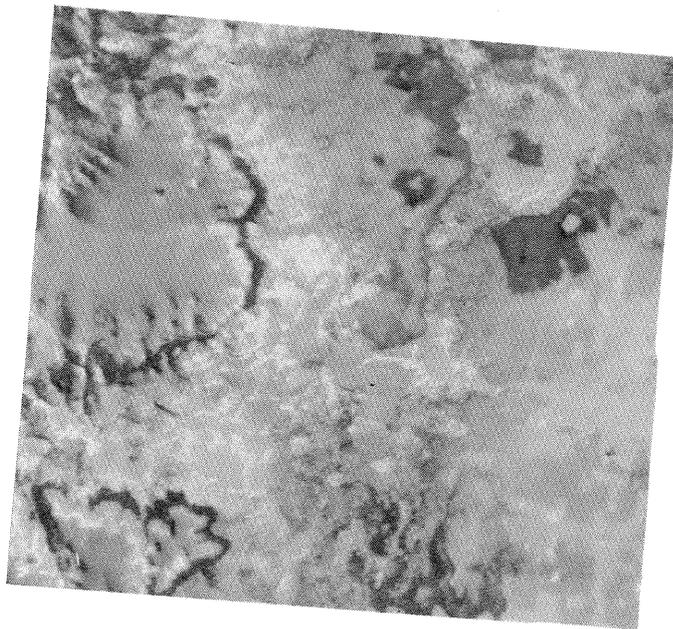


Fig. 4: IHS processed image with addition of 0.2 to S component and linear stretching of I.

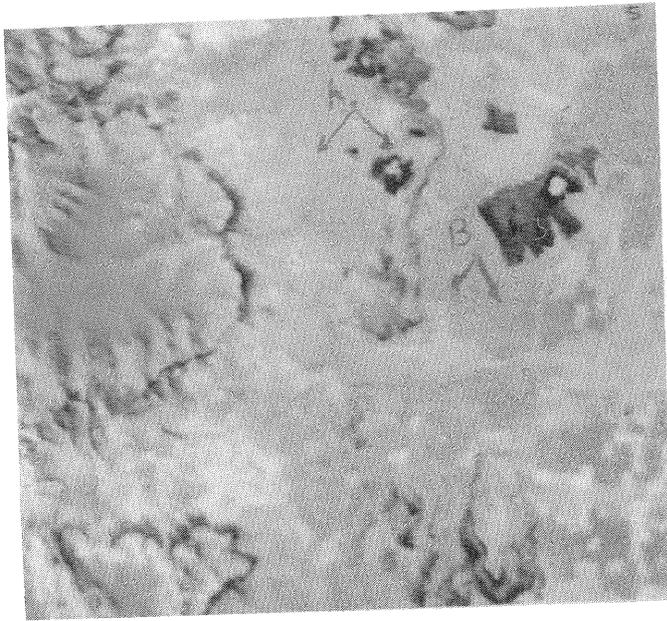


Fig. 5: Hue rotation ( $\theta = 30^\circ$ )

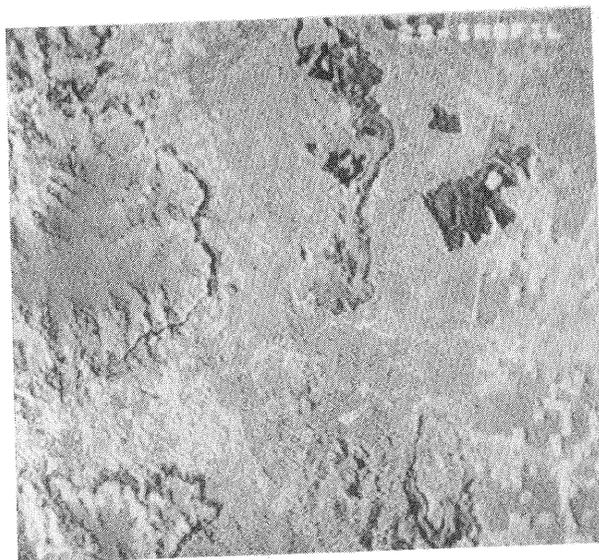


Fig. 6: IHS processed image with high pass filtering of I component.

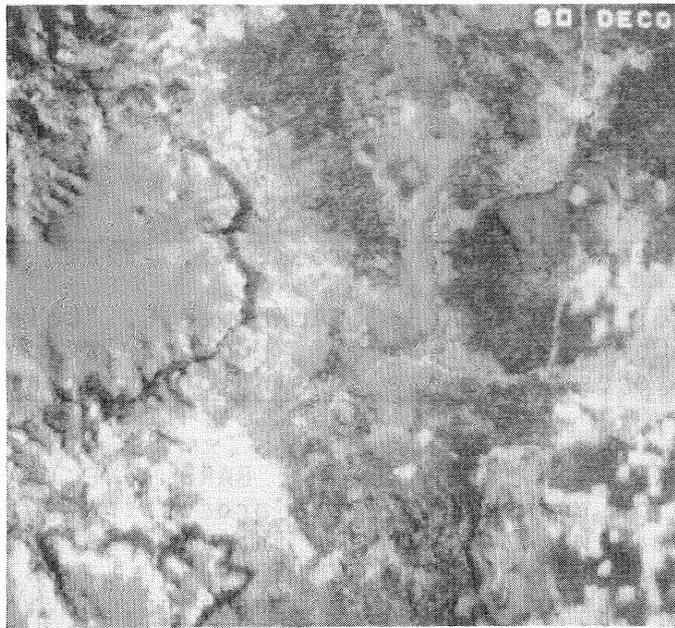


Fig. 7: Decorrelation stretching

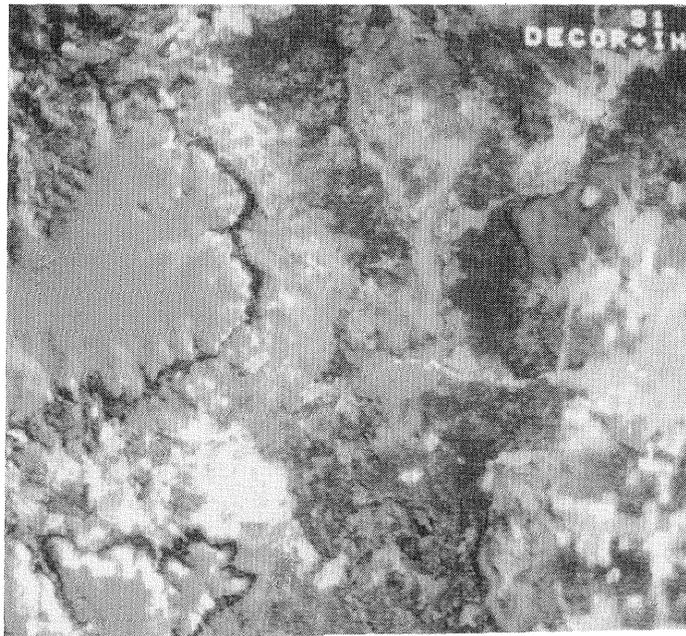


Fig. 8: Decorrelation stretching and  
- 30° Hue rotation.

## VI - REFERENCES

- DUTRA, L.V.; MENESES, P.R. "Realce de cores em imagens de sensoriamento remoto utilizando rotação de matiz do espaço IHS". In: 5o. SIMPÓSIO BRASILEIRO DE TELECOMUNICAÇÕES Anais, Campinas, SP, Brasil, 1987.
- FUKUNAGA, J. "Introduction to Statistical Pattern Recognition". Academic Press, New York, NY, 1972.
- GILLESPIE, A.R.; KAHLE, A.B.; WALKER, R.E. "Color Enhancement of High Correlated Image, I. Decorrelation and HSI Contrast Stretches". Remote sensing of environment, 20:209-235 (1986).
- HAYDN, R.; DALKE, G.W.; HENKEL, J.; BARE, J.E. "Application of the IHS color transform to the processing of multisensor data and image enhancement". In: INTERNATIONAL SYMPOSIUM ON REMOTE SENSING OF ARID AND SEMIARID LANDS, 2th Thematic Conference, Cairo, Egypt. Proceedings. Environmental Research Institute of Michigan Ann Arbor, Michigan, 1982.
- KING, R.W.; KAUPP, V.H.; WAITE, W.P.; MACDONALD, H.C. "Digital color space transformations". In: INTERNATIONAL GEOSCIENCE APPLICATION REMOTE SENSING SYMPOSIUM. Proceedings. Strasbourg, August 1984, F. 649-654.
- PRATT, W.K. "Digital Image Processing", Wiley, New York, NY, 1978.
- SOHA, J.M.; SCHWARTZ, A.N. "Multispectral histogram normalization contrast enhancement". In: Proceedings 5th CANADIAN SYMPOSIUM ON REMOTE SENSING, Victoria, BC, Canada, pp. 86-93, 1978.