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16. Summary/Notes

The multispectral scanner (MSS) of the LANDSAT satellite contains six independent sensors, in each of the following four spectral bands 0 5 to 0 6 μm, 0.6 to 0.7 μm, 0.7 to 0 8 μm and 0 8 to 1 1 μm In each of these four bands, the six sensors collect data from adjacent scan lines across the ground scene. Theoretically, these sensors are supposed to be identical, however, in actual practice, they may have different gain settings and offset factors, which result in the effect known as 'stripping' (black lines at regular intervals) of the imagery ~~At INPE~~, a simple two parameter method to correct the gain settings and offset factors of each of the sensors with respect to one sensor, taken as reference, has been developed. This method assumes (1) the response of a detector varies linearly with the radiance of radiation received (2) the means, as well as the standard deviations, of a reasonably large number of pixels, in a given wavelength band, are equal for each of the detectors for the radiometrically corrected data. A look-up-table is generated to correct the response of each of the detectors Results of the application of the correction algorithm to LANDSAT images are presented

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RADIOMETRIC CORRECTION OF LANDSAT DATA

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ABSTRACT

The multispectral scanner (MSS) of the LANDSAT satellite contains six independent sensors, in each of the following four spectral bands 0 5 to 0 6 μm, 0 6 to 0 7 μm, 0.7 to 0 8 μm and 0.8 to 1 1 μm In each of these four bands, the six sensors collect data from adjecent scan lines across the ground scene Theoretically, these sensors are supposed to be identical, however, in actual practice, they may have different gain settings and offset factors, which result in the effect known as "stripping" (black lines at regular intervals) of the imagery At INPE, a simple two parameter method to correct the gain settings and offset factors of each of the sensors with respect to one sensor, taken as reference, has been developed. This method assumes (1) the response of a detector varies linearly with the radiance of radiation received (2) the means, as well as the standard deviations, of a reasonably large number of pixels, in a given wavelength band, are equal for each of the detectors for the radiometrically corrected data A look-up-table is generated to correct the response of each of the detectors. Results of the application of the correction algorithm to LANDSAT images are presented

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* *ITA student at the time when collaborating in this work*

INTRODUCTION

The Institute for Space Research (INPE) is one of the two non-U S institutions that receive and process data of the LANDSAT satellite series The multispectral scanner (MSS) of the LANDSAT-2 satellite has the following four wavelength bands 0 5 to 0.6 μm, 0 6 to 0 7 μm, 0 7 to 0 8 μm and 0 8 to 1 1 μm LANDSAT MSS data is received at the Data Receiving Station in Cuiabá, Mato Grosso and is processed at the Data Processing Station in Cachoeira Paulista, São Paulo, to produce 8 bit (256 gray levels) computer compatible tapes

This manuscript describes the radiometric correction algorithm developed at INPE and currently being used to correct the data of LANDSAT's computer compatible tapes

RADIOMETRIC CORRECTION ALGORITHM

Each of the four spectral bands of the LANDSAT multispectral scanner has six independent sensors In each of four bands, the six sensors get data from adjacent scan lines across the ground scene. Theoretically, these six sensors should be identical and there should be no discontinuity between consecutive lines. However, in actual practice the sensors have been presenting different gain settings and offset factors, producing a highly undesirable effect in the images

Let us assume that, for a given sensor j of any given band, the observed output signal, R(j), is given by

$$R(j) = a(j) + b(j)\,L(j) \qquad (1)$$

where

a(j) = the gain for sensor j, and

L(j) = radiance of radiation received by the detector (j = 1,2. 6),

R(i,j) represents the observed output signal for the pixel i and sensor j.

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Obviously, in general

$$L\ (i,h)\ \neq\ L(i,k) \tag{2}$$

where $L(i,h)$ and $L(i,k)$ represent the values of L for pixel i and sensor k respectively In the algorithm developed at INPE, five sensors of each band are corrected with respect to the sixth one, regarded as a reference sensor, whose gain setting and offset factor are assumed to be zero. This method is essentially the same as that developed by Strome and Vishnubhatla[1] Obviously, $L(i,j)$ is then equal to the observed response for the reference sensor

Over a large number of pixels, it is reasonable to assume that the statistics of $L(i,h)$ and $L(i,k)$ will be the same In particular, the following assumptions are made:

$$\frac{1}{N}\sum_{i=1}^{N} L(i,h) = \frac{1}{N}\sum_{i=1}^{N} L(i,k) = C_1 \tag{3}$$

and

$$\frac{1}{N}\sum_{i=1}^{N} (L(i,h))^2 = \frac{1}{N}\sum_{i=1}^{N} (L(i,k))^2 = C_2 \tag{4}$$

Let

$$E(j) = \frac{1}{N}\sum_{i=1}^{N} R(i,j) \tag{5}$$

$$F(j) = \frac{1}{N}\sum_{i=1}^{N} (R(i,j))^2 \tag{6}$$

From Eqs. (1), (3), (4), (5) and (6), we have

$$E(j) = a(j) + b(j)C_1 \tag{7}$$

$$F(j) = a^2(j) + b^2(j)C_2 + 2a(j)\, b(j)C_1 \tag{8}$$

From Eqs. (7) and (8), we have

$$C_1 = (E(j) - a(j)) / b(j) \tag{9}$$

$$C_2 = (F(j) + a^2(j) - 2a(j)E(j)) / b^2(j) \tag{10}$$

From Eqs. (7) and (8), wr arrive at

$$b(j) = \sqrt{(E^2(j) - F(j)) / (C_1^2 - C_2)} \tag{11}$$

$$a(j) = E(j) - \sqrt{(E^2(j) - F(j)) / (1 - C_2/C_1^2)} \tag{12}$$

From Eqs. (9) to (12), we have

$$b(k) = b(j) \sqrt{(E^2(k) - F(k)) / (E^2(j) - F(j))} \tag{13}$$

and

$$a(k) = a(j) \sqrt{(E^2(k) - F(k)) / (E^2(j) - F(j))} + E(K) \tag{14}$$

$$- E(j) \sqrt{(E^2(k) - F(k)) / (E^2(j) - F(j))}$$

Knowing the values of E(j) and F(j) for all the sensors, we can calculate the corresponding values of a(k) and b(k) Thus, the corrected values of response R(i,j) can be calculated for each pixel in the image. At INPE, an algorithm has been developed on-line-mode in the Image-100 The observed response of the pixels of a "good" part of the image are used to calculate the values of E(j) and F(j). A look-up-table is generated and stored in the memory, for each sensor, to convert each of the 256 gray levels from its observed response R(j), to its corrected response L(j). This method considerably improves the quality of imagery in many cases and consequently improves the classification accuracy To illustrate the use of this algorithm, Figures 1 to 4 show uncorrected urban area of Brasilia in the channels 1 (0.5 to 0 6 μm), 2 (0.6 to 0 7 μm), 3 (0.7 to 0.8 μm) and 4 (0 8 to 1 1 μm) respectively Figures 5 and 6 show composite colored image in the channels (4, 5 & 7) and in the channels(4, 5, & 6), respectively.

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Figures 7 to 12 show the corresponding figures 1 to 6 after they have been corrected radiometrically, using this algorithm. It is clear from Figures 7 to 12 that this algorithm considerably improves the quality of the image.

Another method, known as "histogram matching technique" is being tested by Mr. Ricardo Cartaxo Modesto de Souza of INPE. This method chooses one of the six sensors of each wavelength band as a reference sensor and converts the histograms of all other sensors to its histogram, i.e., we have

$$\sum_{i=0}^{g} N_r(i) = \sum_{i=0}^{g} N_j(i), \; g = 0 \text{ to } 255 \qquad (15)$$

where $N_r(i)$, $N_j(i)$ represent the number of pixels having a gray level i for the reference sensor and the j^{th} sensor respectively. g denotes the gray level and varies from 0 to 255. In actual practice, one cannot obtain an equality, as required by Eq. (15), for all the gray levels. So, one tries to get as close to equality as possible. Obviously, this is a more powerful technique than the 'Radiometric Correction Algorithm' described previously in this manuscript. Preliminary tests show that the "histogram matching technique" gives slightly better results than the algorithm described earlier here. In the histogram matching technique, one reasonable approach seems to be to take the average of the histograms of all the six sensors as the reference histogram and then use Eq. (15). Work is in progress to compare these techniques systematically, in order to evaluate them with respect to their improvement of the data quality and consequently the percentage of correct classification.

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Fig. 1 - Uncorrected Image in Channel 1

Fig. 2 - Uncorrected Image in Channel 2

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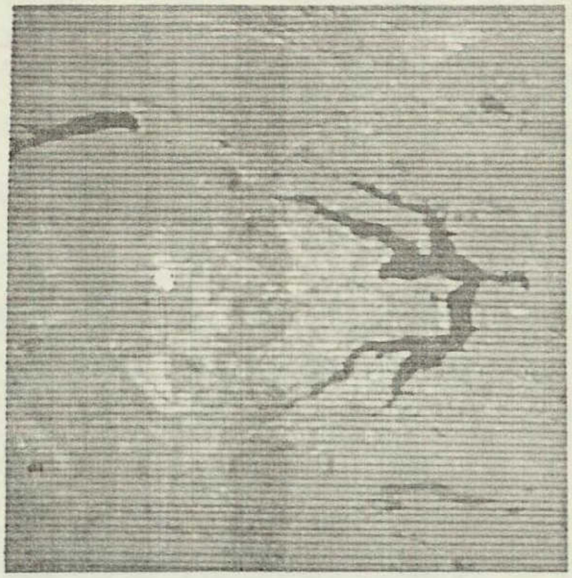

Fig. 3 - Uncorrected Image in Channel 3

Fig. 4 - Uncorrected Image in Channel 4

Fig. 5 - Uncorrected Image in Channels 4, 5 & 7

Fig. 6 - Uncorrected Image in Channels 4, 5 & 6

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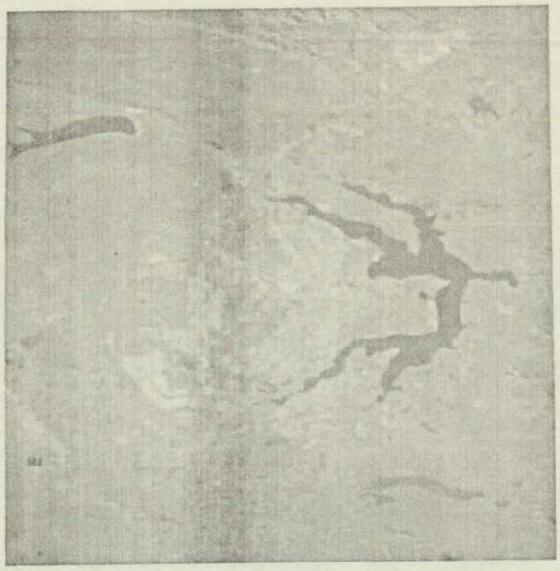

Fig. 9 - Radiometrically Corrected Image in Channel 3

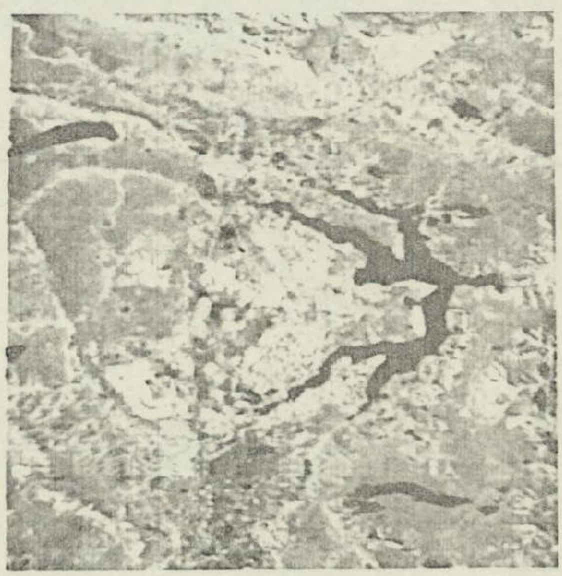

Fig. 10 - Radiometrically Corrected Image in Channel 4

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Fig. 11 - Radiometrically Corrected Image
in Channels 4, 5 & 7

Fig. 12 - Radiometrically Corrected Image
in Channels 4, 5 & 6

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