Simulation of a Panchromatic Band by Spectral Combination of Multispectral ETM+ Bands

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Abstract – The simulation of one or more bands of a multispectral sensor by combination of other bands is a useful tool as an image processing technique. This work presents a simulation technique for the ETM+ panchromatic band based on linear combination of ETM+ multispectral bands. The simulation method takes into account the spectral overlapping between the simulated band and the bands that are linearly combined. First, the spectral bands are restored in a grid size of 15 meters. The restoration process improves the effective spatial resolution and therefore, produces an image with better visual quality. Afterwards, the restored spectral bands are combined to simulate the panchromatic band.

Keywords: image simulation, panchromatic band, ETM+, interpolation, restoration.

1. INTRODUCTION

The simulation of one or more bands of a multispectral sensor by combination of other bands is useful in many remote sensing applications. One could mention at least two applications (Mascarenhas et al, 1991): (1) the large sizes of remote sensing images impose a severe burden on the communications link between the satellite and the ground. Therefore, the simulation of an image by ground processing could decrease the data rate; (2) in sensor feasibility studies, it is common practice to develop simulation procedures before the actual sensor is built, so that many technical aspects can be predicted in advance.

The objective of this paper is to present a simulation technique of the ETM+ panchromatic band by linear combination of the ETM+ multispectral bands. This method can be applied for other sensors such as Landsat-TM-5 and Spot.

2. METHODOLOGY

The simulation approach is possible if there is a substantial spectral overlapping between the simulated band and the bands that are combined (Mascarenhas et al, 1991).

The Landsat 7 Enhanced Thematic Mapper-Plus (ETM+) provides multispectral coverage for seven spectral bands in the visible, near-infrared, shortwave infrared and thermal portions of the electromagnetic spectrum. The data also provides an additional spectral band with better spatial resolution than the others known as panchromatic band. Table 1 presents information on band characteristics and spatial resolution. One can observe that panchromatic band (0.52 - 0.90) spectrally covers the bands 2

(0.53 – 0.61), 3 (0.63 – 0.69) and 4 (0.78 – 0.90). So, a study of the simulation of panchromatic band (15 m) by linear combination of these three bands 2, 3 and 4 (30 m) will here be presented.

Table 1. ETM+ bands characteristics

Band number	Spectral range (μm)	Spectrum area	Ground resolution (m)
1	0.45 – 0.52	Blue	30
2	0.53 – 0.61	Green	30
3	0.63 – 0.69	Red	30
4	0.78 – 0.90	NIR	30
5	1.55 – 1.75	SWIR1	30
6	10.4 – 12.5	LWIR	60
7	2.09 – 2.35	SWIR2	30
8	0.52 – 0.90	PAN	15

Fig. 1 presents the spectral curves for each band: 2, 3, 4, and panchromatic. Hachured areas under the curves are used to calculate the simulation parameters.
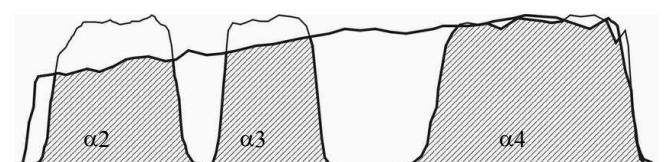

Figure 1. Spectral curves for B2, B3, B4 and panchromatic bands.

Since bands 2, 3 and 4 have a sampling rate of 30 m, the 15 m panchromatic band is simulated according to the following steps:
   a) step 1: interpolate the ETM+ spectral images in a grid of 15 m using the restoration filter developed for ETM+ (Fonseca, 1993; Giovanni, 2003);
   b) step2: calculate the value for each pixel of the simulated panchromatic band according to Eq. 1.

Let *B2*, *B3* , *B4* and *Pan* be the observed values at each pixel of the multispectral and simulated panchromatic bands, respectively. One can estimate the panchromatic band value, *Pan*, by combining the multispectral bands as:

$$Pan = \left(\frac{\alpha_2}{\alpha_p} * B2 \right) + \left(\frac{\alpha_3}{\alpha_p} * B3 \right) + \left(\frac{\alpha_4}{\alpha_p} * B4 \right) \quad (1)$$

where:

α_2 , α_3 , α_4 = area under spectral curve for each band 2, 3 and 4, limited by panchromatic spectral curve (hachured areas in Fig. 1).

B2, *B3*, *B4* = value at each pixel of restored bands 2, 3 and 4, respectively.

$\alpha_p = \alpha_2 + \alpha_3 + \alpha_4$,

Pan = value at each pixel of simulated panchromatic band.

The spectral curves (Fig. 1) were digitalized and the area under the spectral curves, for each band, was calculated. This procedure was performed in order to obtain the contribution (α_i / α_p , *i=2,3,4*) of each spectral band in relation to the panchromatic band. The results are shown in Table 2.

Table 2. Contribution of each spectral band 2, 3 e 4

Parameters ratio	α_2 / α_p	α_3 / α_p	α_4 / α_p
Contribution	0.25	0.23	0.52

3. RESULTS AND DISCUSSION

The method was tested for ETM+ images of Rio de Janeiro city, Brazil, dated of 2002/06/09 (path/row 217/76), in two different regions called region 1 and region 2.

Fig. 2 and Fig. 3 display the original panchromatic (*Porig*) and simulated (*Pan*) images for region 1, respectively. The simulated and original images were processed so that their mean and standard deviation values are equal.

Figure 4 displays the absolute value of the difference image (*Porig – Pan*), through a linear contrast stretch that increases the maximum value of the difference image for visual purposes.

Fig. 5 and Fig. 6 display the original panchromatic (*Porig*) and simulated (*Pan*) images for region 2, respectively.

Figure 2. Original panchromatic band , Rio de Janeiro, Brazil, (region 1).

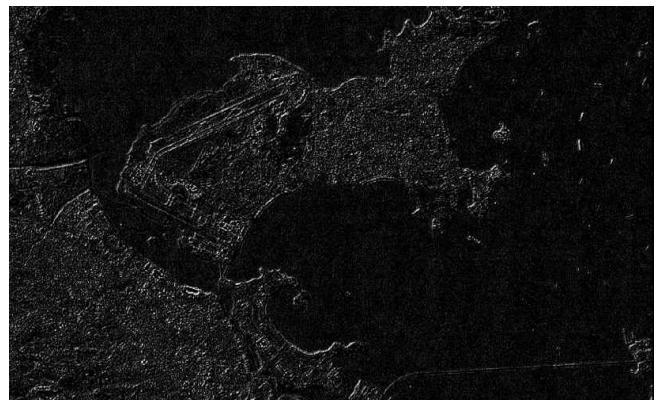Figure 3. Simulated panchromatic band (region 1).

Figure 4. Difference image (*Porig-Pan*).

Figure 7 displays the absolute value of the difference image (*Porig–Pan)*. The largest differences occur on edges between high contrast areas (airport runways, for example), as it can be seen in Fig. 4 and Fig. 7.

Table 3 presents the correlation coefficient and mean square error (m.s.e) values between original and simulated panchromatic images. It is observed that simulated images, *Pan,* are very close to the original images, *Porig,* in numerical and visual terms.

Table 3. Correlation coefficient and m.s.e. values

	Region 1	Region 2
correlation	0.97	0.95
m.s.e	11.9	13.2

Figure 6. Simulated panchromatic band (region 2).

Figure 5. Original panchromatic band , Rio de Janeiro, Brazil (region 2).

Figure 7. Difference image (*Porig-Pan*).

4. CONCLUSION

This work has presented a methodology to simulate a panchromatic band using ETM+ multispectral bands. Firstly, a restoration filter is used to interpolate the spectral bands in a grid that is finer than the original sampling grid. Therefore, an improvement in the visual quality of the image is obtained. Afterwards, the panchromatic band is estimated by combining linearly the multispectral bands.

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