

A NEW METHOD FOR THE INTEGRATION
OF LANDSAT TM AND SPOT PANCHROMATIC DATA

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Abstract

The integration of Landsat TM and Spot Panchromatic data is an important task in order to provide images with the spectral coverage of the former and the spatial resolution of the latter. From previous research, the methods based on Principal Component Analysis (PCA) and High Pass Filtering (HPF) have been proved to be the most efficient and straightforward for this purpose. Anyway, both these procedures suffer from some important drawbacks, which can lead to noticeable distortions in the spectral structure or spatial properties of the images obtained. In the present work a new, multi-step methodology is put forward which should join the advantages of the two basic techniques. The first step of the methodology is a PC transformation applied to the TM reflective bands. The resulting Principal Component 1 (PC1) is then subjected to a HPF which introduces the spatial resolution of the Spot data into this transformed variable. Finally, an inverse PC transformation is performed using the new PC1. The methodology has been tested in an agricultural area of Tuscany (Central Italy) with small fields. A first visual and quantitative evaluation of the high resolution images produced has been extremely encouraging. In particular, these images have been shown to be able of reducing the problems due to the presence of mixed, boundary pixels in TM scenes.

Key Words: Data integration, Spot PAN, Landsat TM.

1. INTRODUCTION

The availability of remotely sensed images taken from various sensors with different spatial resolutions has raised the need for procedures which can merge the complementary information acquired. The integration of data from different space platforms has therefore become an important field of research, and several investigations have been conducted on this subject (Cappellini, 1989, Chavez et al., 1991). The merging of Spot Panchromatic (PAN) and Landsat Thematic Mapper (TM) multispectral data has received a particular attention because of the very high spatial resolution of the former and the wide spectral coverage of the latter, which, when integrated, can provide images of extremely high quality. Several mathematical and statistical algorithms have been proposed, based on the similarity of the spectral range of the Spot sensor with some of the TM channels. Among these, three procedures have been found to be particularly interesting; these methods will be briefly reviewed here.

One of the first methods to integrate Spot PAN with TM multispectral data was based on the use of a Hue-Intensity-Saturation (HIS) transformation of the latter (Carper et al., 1990). Since the intensity component of TM data is generally spectrally similar to the PAN image, this can be substituted to the result of the transformation. A subsequent reverse rotation of the modified TM data set allows the generation of TM images with enhanced spatial resolution. The main drawback of the method lies in the spectral differences between the Intensity component of TM data and the Pan image, which can bring to noticeable distortions of the final product.

Better results has been achieved by a Principal Component Analysis (PCA) based on the same principle. The PC1 of TM data was in fact found to be related to scene brightness (Conese et al., 1988) and it is more spectrally consistent with the PAN data than the Intensity component of the HIS transformation (Chavez et al., 1991). Thus, the PAN image can be substituted to the first Principal Component of the TM data set (PC1), followed by a reverse transformation. Also in this case, however, some distortion persists, and the method can not be considered optimal.

Finally, good results were achieved by the use of a High Pass Filtering (HPF) to directly superimpose the spatial resolution of the PAN image on the TM original channels (Chavez et al., 1991). Nevertheless, this method can be expected to lead to some problems because of the remarkable spectral dissimilarity between some TM channels and the Spot Panchromatic band.

In this context, the present work proposes a new, multi-step approach for the integration of the two kinds of data. The method consists of a first PC transformation of the TM data, which extracts the PC1. Then, a HPF similar to that proposed by Chavez et al. (1991) is applied to this PC1, which is spectrally rather similar to the Spot PAN image. Finally, the modified TM PC1 is transformed back into the original TM feature space, so as to produce a new TM scene with enhanced spatial resolution. This strategy should avoid the spectral distortion of the PCA method while preserving only the high frequency spatial information of the PAN data which is consistent with the TM images.

The procedure has been tested in a case study. The first results have been evaluated visually and statistically by means of a correlation analysis.

2. MATERIALS AND METHODS

2.1. Study Area, Ground and Satellite Data

An agricultural area of about 5x5 km was chosen for the research, located in Tuscany (Central Italy), at about 43° 40' North latitude, 12° 50' East longitude (figure 1). The terrain is rather flat, with a mean altitude of approximately 300 m. The climate of the area is mediterranean, and five main crops are grown: winter wheat, maize, tobacco, sunflower and alfa-alfa. The small size of the fields (0.5-5 ha) makes this zone particularly suitable for testing the method proposed.

A Landsat Thematic Mapper (TM) scene taken on 16 March, 1991 (frame 192/30, quarter 2) and a Spot Panchromatic (PAN) image acquired on 19 March, 1991 (KJ 063 262) were selected among those available and cloud-free. The two acquisitions were close enough to make sustainable the assumption of invariance in the conditions of the cover types. The TM and Spot images were registered on the same coordinate system (pixels of 10x10 m) by a bilinear interpolation method trained on ground control points. This georeferencing was carried out with extreme care, to avoid problems of misregistration which could disturb subsequent processing; in this way, a mean error of less than one PAN pixel was achieved. The registered TM images were also subjected to a 3x3 smoothing filter to eliminate the blockiness introduced by the digital enlargement. The georeferenced PAN image is shown in figure 2.

2.2. Data Processing

A Principal Component Analysis was first performed on the six reflective TM bands, and the PC1 was extracted (figure 3). A PCA was also carried out using only the 3 TM bands which are spectrally most similar to the PAN range (TM bands 2, 3, 4). The correlations between the PAN image and the six TM reflective bands plus the PC1s of the two data sets were calculated (table 1). The PC1s images were highly correlated with the the PAN one, and no significant difference resulted from the use of the restricted TM subset, which was therefore discarded for the subsequent analysis.

The high frequency information of the PAN data was added to the TM PC1 by means of a HPF (Chavez, 1991). In practice, this filter computes from the PAN data the difference between the mean grey value of the moving window and the grey value of the central pixel; this difference, multiplied by an enhancing factor, is then added to the digital count of the corresponding TM pixel. After some trials, a moving window of 7x7 pixels was selected, with an enhancing factor of 3. The output image, which is shown in figure 4, was then used in a reverse PC transformation, with six new TM images as final product.



Figure 1 - Geographical location of the study area.

3. RESULTS

From figures 2 and 3 it can be noticed that the Spot PAN and the TM PC1 images contained similar spectral information, and the former had clearly far higher spatial details. Table 1 brings support to this visual interpretation. While some original TM bands (especially bands 4 and 5) had rather low correlation with the PAN image, the TM bands 2 and 3 were highly correlated with this, as well as the PC1s of the complete and restricted TM data sets.

As can be seen from figure 4, the quality of the new TM PC1 with enhanced spatial resolution was quite high; the spectral properties of the image were fundamentally unmodified, because only the high frequency information of the PAN data had been added to the original TM PC1. At the same time, the spatial resolution was practically that of the PAN image, which considerably reduced the smoothness of the TM data especially for the boundary pixels. In table 2 the correlations between the new PC1 and the original PC1 and the PAN image are reported. The new image was highly correlated with both the original ones, which confirmed the results of the qualitative analysis.

Since the modified PC1 was inserted into the reverse transformation, the new TM bands were also of high quality. In particular, the spectral distortion which is common when directly using the PAN image for the substitution was mostly avoided. Contemporaneously, the spatial information of the PAN data was differently added to the TM bands depending on the PCA coefficients, which prevented the merging of non consistent types of information.

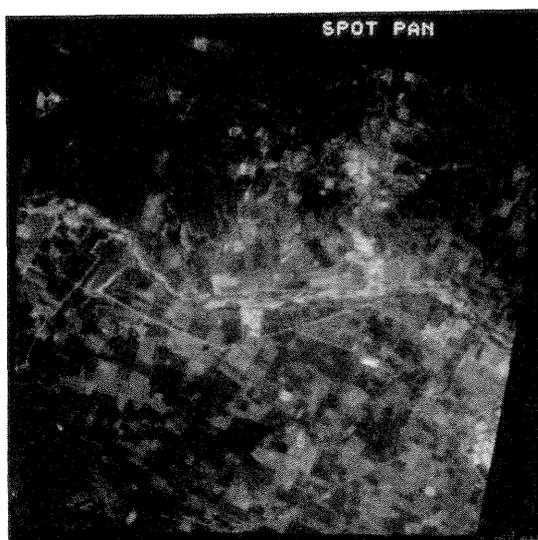


Figure 2 - Georeferenced Spot PAN image showing the study area.

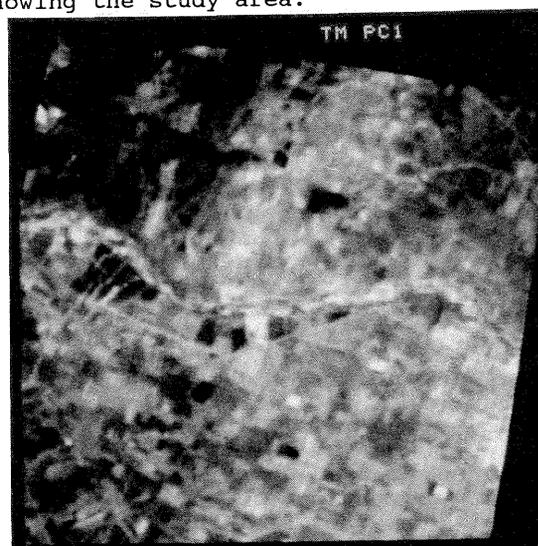


Figure 3 - Georeferenced TM PC1 of the study area.

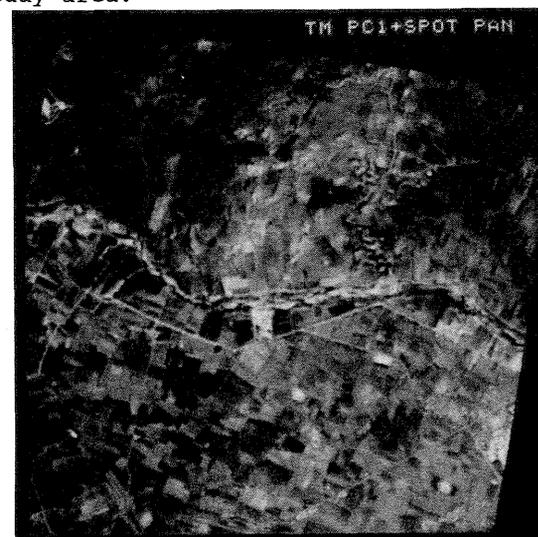


Figure 4 - New PC1 with enhanced spatial resolution obtained by the methodology proposed.

Table 1
Correlation coefficients of the Spot PAN data versus the original TM bands and the TM PC1s of the complete and restricted sets.

	TM1	TM2	TM3	TM4	TM5	TM7
PAN	.676	.741	.762	.179	.446	.571
	TM PC1(1-7)			TM PC1(2-4)		
PAN	.750			.779		

Table 2
Correlation coefficients of the new TM PC1 with enhanced spatial features and the original TM PC1 and Spot PAN images.

	TM PC1	PAN
TM PC1+PAN	.870	.846

4. CONCLUSIONS

In the present paper a new, multi-step procedure for merging Spot PAN and TM multispectral data is presented, which is aimed at avoiding most of the spectral and spatial distortions that are common to other methods. The methodology has been applied to a case study in Central Italy. A first visual and quantitative evaluation of the methodology has shown its good performance. Further research is underway for a more precise statistical evaluation of the results obtained, particularly relying on the available, accurate ground references which can be useful to quantify the effect of the procedure. Also, some comparisons with the results of other methods are being planned so as to estimate their different potentials.

Acknowledgements

Research supported by National Research Council of Italy, Special Project RAISA, Sub-Project N. 2, Paper N. 00.

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