Sensors & Transducers, Vol. 156, Issue 9, September 2013, pp. 111-115

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Sensors & Transducers

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Increasing Geometric Resolution of Data Supplied by Quickbird Multispectral Sensors

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Received: 8 August 2013 /Accepted: 25 August 2013 /Published: 30 September 2013

Abstract: On board of Quickbird satellite two types of sensors are present: panchromatic and multispectral. The first acquires earth images within spectral range 0.405 µm – 1.053 µm; the second acquires simultaneously four images of the same scene, each of them within shorter range of spectrum (Blue, Green, Red, Near-Infrared). Panchromatic images present geometric resolution 0.60 m while multispectral ones 2.40 m. For many applications, detailed data are welcome, so in the last decades several methods have been elaborated in Remote Sensing to transfer pixel dimensions of pan images into multispectral images. Included in data fusion techniques, they are named pan-sharpening methods and one of the principal problems they are called to resolve is to define weights to attribute to each multispectral component in fusion operations. The aim of this paper is to consider the application to Quickbird imagery of two efficient pan-sharpening methods, IHS and Brovey transformation, demonstrating that multispectral weights can be easily derived by analysis of sensors relative spectral radiance response. *Copyright © 2013 IFSA.*

Keywords: Quickbird images, Panchromatic and multispectral sensors, Geometric resolution, Pan-sharpening, Relative spectral radiance response.

1. Introduction

The successful launch of the first very high resolution (VHR) satellites, such as IKONOS in September 1999 or Quickbird in October 2001, marked the beginning of a wholly new age in remote sensing; in fact, VHR satellites are able to capture images of the earth's surface with a ground sample distance (GSD) of 1 m and even less [1].

Because of their high resolution, those images are used for many applications: IKONOS scenes (pan: 1 m x 1 m, multispectral 4 m x 4 m) are used to establish accurately variation of shorelines in presence of coastal erosion [2].

Recently cell size of 50 centimeters has been achieved for panchromatic data, such as in the cases of GeoEye-1 and WorldView-2 [3].

To reduce effects of noise on signals, multispectral sensors capture data with lower resolution than panchromatic ones. For consequence intense research activities in the last decades have been focused on the possibilities for integrating different images to produce more information than that can be derived from a single sensor [4].

Multispectral (MS) images are conducted to higher spatial resolution by exploiting panchromatic ones that frequently are acquired simultaneously by sensors on the same satellite. This fusion process is called pan-sharpening of MS images [5].

A large number of pan-sharpening methods are present in the literature: in this work the attention was focused on IHS (Intensity-Hue-Saturation) and Brovey transformation, remarking the possibilities to enhance quality of results using for both methods weights that were derived by operative characteristics of panchromatic and multispectral sensors.

2. Data and Methods

2.1. Quickbird Sensors

Launched on October 18, 2001, Quickbird satellite has a polar sun-synchronous orbit at an altitude of 450 km with a period of 93.6 minutes. On board of it there are two types of sensors (both with a swath width of 16.8 km) that respectively supply at nadir 61 centimeters panchromatic images (0.405 µm – 1.053 µm) and 2.44 meters multispectral images (Blue: 0.430 µm – 0.545 µm; Green: 0.466 µm – 0.620 µm; Red: 0.590 µm – 0.710 µm; Near-Infrared: 0.715 µm – 0.918 µm). Pixel dimensions become respectively 0.66 and 2.64 meters when images are collected with an acquisition angle of 15°. Commercially data are supplied with geometric resolution of 0.60 m for panchromatic and 2.40 m for multispectral ones. Radiometric resolution for both is 11 bit (BV=0÷2047) [6-7].

2.2. Study Area and Data

Pan-sharpening methods were applied to a clip of Quickbird imagery concerning San Francisco (Fig. 1), courteously supplied by Digital Globe as product samples available for download. Set includes panchromatic as well as multispectral data and was collected on June 8, 2012 [3].

Fig. 1. The RGB true color composition of the considered area (San Francisco, California).

The clipped scene extends 1,800 m × 1,800 m. In reference to UTM-WGS84 cartographic system (10 S zone), limits for East and Nord coordinates are: E_1=545,474.4 m, E_2=547,274.4 m, N_1=4,182,511.2 m, N_2=4,184,311,2 m. For consequence the original panchromatic image consists of 3,000 columns and 3,000 rows, while for the other four bands matrices are constituted by 750 x 750 pixels because of lower geometric resolution (2.4 m x 2.4 m rather than 0.6 m x 0.6 m).

2.3. IHS Method

IHS method [8-10] transforms RGB colour composite of bands into Intensity-Hue-Saturation colour space. Similarity of Intensity component (I) to panchromatic image is used to produce data fusion preserving the higher spatial resolution and radiometric resolution. The Intensity component is replaced by the pan image and the scene is reverse transformed: for consequence R'G'B' composition with higher geometric resolution is produced.

Because Quickbird multispectral images are four, Intensity is supplied by the mean of them. Better results can be achieved introducing weights:

$$I = \frac{a*B + b*G + c*R + d*NIR}{a+b+c+d} \qquad (1)$$

Weights can be established in universal way considering series of images that cover different areas. In this application we propose to use coefficients that can be derived by Relative Spectral Radiance Response (RSRR) of the Quickbird system (Fig. 2): it was determined by the producer using analysis of laboratory measurements [11].

In this work the contribution of each multispectral band in percentage to the sum of the contributions of all multispectral bands to panchromatic one was calculated considering the areas of the respective polygons in the RSRR. Every polygon is generated by the correspondent graph and X-axis. The resulting weights are reported in Table 1.

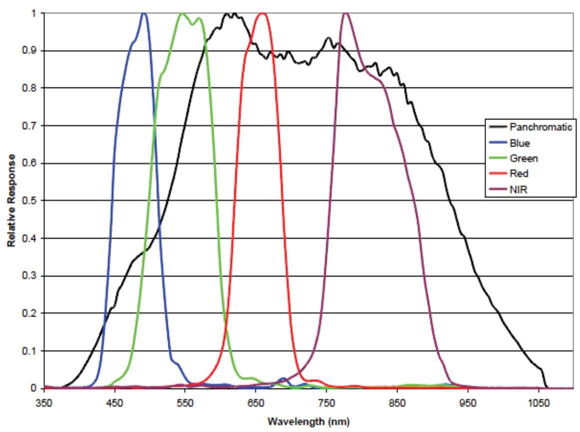


Fig. 2. Relative Spectral Radiance Response (RSRR) of QuickBird sensors.

Table 1. Weights that were derived by Relative Spectral Radiance Response.

Bands	Blue	Green	Red	NIR
Weights	0.11	0.26	0.24	0.39

2.4. Brovey Transformation

Brovey transformation [12] is included in *Modulation-based fusion methods* (MBFM) that research spatial details multiplying the multispectral (MS) data by the ratio of the pan image to a synthetic image which generally presents lower resolution [13]. The fused image is supplied by:

$$fusion_i = \frac{Pan}{Syn_p} \cdot Mul_i, \tag{2}$$

where $fusion_i$ is the fused ith band; Mul_i is the original MS ith band; Syn_p is the synthetic band; *Pan* is the higher resolution panchromatic band.

Particularly with Brovey transformation the synthetic image is the average of the multispectral bands that are included in panchromatic one:

$$Syn_p = \frac{\sum_{i=1}^{n} Mul_i}{n} \tag{3}$$

Similarly to IHS method, weights may be introduced, so the fused image is supplied by the following formula:

$$Syn_p = \frac{\sum_{i=1}^{n} p_i Mul_i}{\sum_{i=1}^{n} p_i} \tag{4}$$

In this work we used the same weights above mentioned for IHS and derived by RSRR.

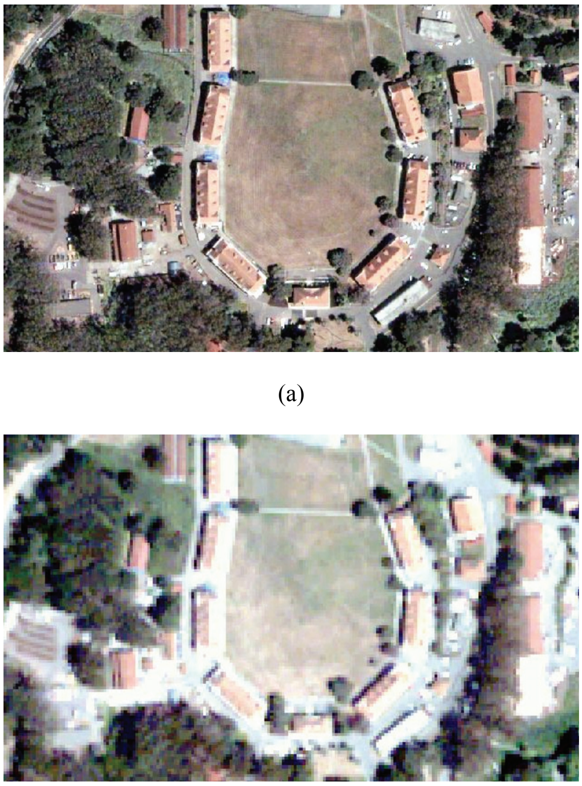
3. Results and Discussion

In Fig. 1 a particular of the RGB composition with pan-sharpened bands by IHS with weights is shown in comparison with the analogous supplied by the original imagery.

Advantage of pan-sharpening is evident: more details are visible and the resulting imagery can support further studies. To establish the similarity of pan-sharpened bands to those obtainable by real sensors with same high resolution, quality indices must be considered. According with that reported in literature, to establish the quality of results and verify the efficiency of the calculated weights, two indices were considered:

Universal Image Quality Index (UIQI);

Relative Dimensionless Global Error in Synthesis.



(a)

(b)

Fig. 3. Particulars of comparison between RGB true color composition with pan-sharpened bands by IHS with calculated weights (a) and the correspondent one with original bands (b).

Universal Image Quality Index (UIQI) was introduced by Wang and Bovik (2002) [14] and can be calculated as:

$$UIQI = \frac{Cov_{AB}}{\sigma_A \sigma_B} \cdot \frac{2\mu_A \mu_B}{\mu_A^2 + \mu_B^2} \cdot \frac{2\sigma_A \sigma_B}{\sigma_A^2 + \sigma_B^2} \tag{5}$$

where: *A* is the original multispectral image; *B* is the correspondent multispectral image after pan-sharpening; σ_A is standard deviation of image A; σ_B is standard deviation of image B; Cov_{AB} is covariance between A and B; μ_A is the mean values of images A; μ_B is the mean values of images B.

In (5) the first term is the correlation coefficient, the second term is about mean shifting, and the third term is about contrast similarity. Good quality of Pan-sharpened images is certified by *Q* value close to one.

Relative Dimensionless Global Error in Synthesis is indicated as *ERGAS,* the abbreviation of Erreur Relative Globale Adimensionnelle de Synthèse. Introduced by Wald [15], it is supplied by the formula:

$$ERGAS = 100\frac{h}{l}\sqrt{\frac{1}{K}\sum_{k=1}^{K}\left(\frac{RMSE(k)}{\mu(k)}\right)^2}, \tag{6}$$

where *h/l* is the ratio between pixel sizes of pan and original multispectral images; *RMSE*(*k*) is the RMSE of the k^{th} band; $\mu(k)$ is the mean of the k^{th} band.

A small value of ERGAS means good image quality.

Values of those indices are shown in Tables 2, 3, 4, 5 in reference to each applied method.

Table 2. Quality indices for IHS.

	UIQI	ERGAS
Blue	0.838	5.420
Green	0.843	
Red	0.842	
NIR	0.929	

Table 3. Quality indices for IHS with weights.

	UIQI	ERGAS
Blue	0.907	4.242
Green	0.908	
Red	0.906	
NIR	0.935	

Table 4. Quality indices for Brovey transformation.

	UIQI	ERGAS
Blue	0.901	4.644
Green	0.885	
Red	0.887	
NIR	0.895	

Table 5. Quality indices for Brovey transformation with weights.

	UIQI	ERGAS
Blue	0.935	3.732
Green	0.931	
Red	0.929	
NIR	0.913	

Comparing results, advantages that are introduced by calculated weights are evident. Mean value of UIQI increases from 0.863 to 0.914 for IHS, and from 0.892 to 0.927 for Brovey transformation. ERGAS rises of about 27 % for IHS and 24 % for Brovey transformation.

4. Conclusions

Calculation of weights in consideration of RSRR of Quickbird pan and multispectral sensors is an efficient approach to effort IHS and Brovey transformation. In fact, introducing those weights in the calculation of Intensity as well as Synthetic image, improvement of results is generated as confirmed by both quality indices UIQI and ERGAS. In other approaches these weights are calculated considering series of images: in this application they are directly derived by RSRR and can be used in any case in presence of Quickbird data.

Acknowledgements

This paper synthesizes results of works performed within the project PRIN 2010-11 financed by *MIUR (Ministero dell'Istruzione, dell'Università e della Ricerca)* - Italy and developed at University of Naples "Parthenope" (Coordinator: Prof. Raffaele Santamaria).

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