A SIMPLIFIED IMAGE FUSION TECHNIQUE WITH SENSOR SPECTRAL RESPONSE

Qiang Zhou, Peng Gong, Ziqi Guo, Caixia Liu, Wei Fu, Baogang Zhang*

State Key Laboratory of Remote Sensing, Jointly Sponsored by the Institute of Remote Sensing Applications of Chinese Academy of Science and Beijing Normal University, Beijing, 100101, China
*Corresponding author. Email: xl_zhq@163.com

1. INTRODUCTION

In optical remote sensing, many satellites provide comparatively high-resolution panchromatic (HRP) and low-resolution multispectral (LRM) images both. There are many image fusion methods which have been used to combine these two data into high-resolution multispectral images. In these methods, intensity-hue-saturation (IHS), Brovey transformation (BT), and principal component analysis (PCA) methods may cause the spectral distortion in fused image with original multispectral image [1][2][3]. The wavelet-based image fusion methods are developed to solve this problem [4]. The wavelet-based methods extract the features from the HRP images to inject them into the LRM images by wavelet decomposition. But many wavelet-based image fusion methods only focused on the image processing's mathematical algorithms, not considering the essential principle of the image-forming. To quantitate the features extracted from the HRP images to inject into the LRM images, Xavier et al. [5] introduce the sensor spectral response into the wavelet-base image fusion in WiSpeR algorithm, which makes the image fusion procession more precisely. As all the wavelet-based image fusion methods, WiSpeR algorithm is something complex because of the wavelet decomposition.

This paper simplified the WiSpeR algorithm by using the relationship between high resolution pixel and low resolution pixel of the same sensor. The simplified method need not to do the wavelet decomposition, which makes the image fusion procession simpler and gets a good image fusion quality.

2. SENSOR SPECTRAL RESPONSE FUNCTION

Sensor's spectral response function (SRF) is defined as the probability of a photon in a frequency is detected by the sensor. The SRF is already used for image fusion by [5][6][7]. QuickBird-2 satellite has a panchromatic and four multispectral sensors. Let the panchromatic sensor's SRF be $\phi(\nu)$, the multispectral sensor's SRF be $\varphi_i(\nu)$, i=1, 2, 3, 4 represent the blue (B), green (G), red (R), and near infrared (NIR) band respectively. The SRFs of QuickBird-2 are shown in figure 1.

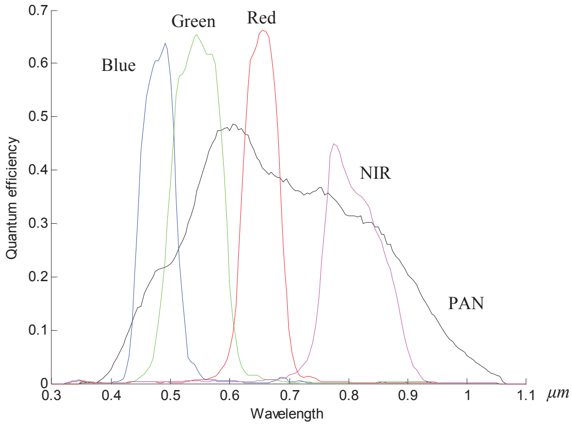

Fig. 1. SRFs of QuickBird-2

By the definition of SRF, the probability of a photon detected by the sensor can be understood as the area enclosed by the SRF curve and the abscissa axis. Let the detection event of LRM band i be m_i, the probability of m_i be $P(m_i)$. As the same, p and P(p) are those of HRP band's. The complete expression of merged LRM_i band in WiSpeR algorithm is

$$LRM_i^f = LRM_i + s_i \cdot \frac{\alpha_p \cdot P(m_i \mid p_m)}{P(p_m \mid m_i)} \cdot \left(1 - \frac{\beta_i}{2}\right) \cdot \sum_{k=1}^{n_\omega} \omega_k \tag{1}$$

In (1), p_m is the event corresponding to an HRP photon simultaneously below the $\phi(\nu)$ and $\varphi_i(\nu)$ functions, β_i is the fraction of the area of the LRM_i SRF shared with its adjacent LRM_j SRF, ω_k is the wavelet plane of HRP band decomposed by *à trous* wavelet decomposition. α_p is

$$\alpha_p = \frac{\int \min(\phi(\nu), \max(\varphi_1(\nu), \varphi_2(\nu), \cdots, \varphi_i(\nu)))d\nu}{\int \phi(\nu)d\nu} \tag{2}$$

and s_i is

$$s_i = \frac{\rho_{p,i}}{\overline{\rho}_p} \tag{3}$$

$\rho_{p,i}$ is the number of photons below both the $\phi(\nu)$ and $\varphi_i(\nu)$ functions divided by the common area below these curves. $\overline{\rho}_p$ is the mean of all $\rho_{p,i}$. It seems that (1) is something complex, including many kind of factors from SRF and wavelet decomposition.

3. DATA AND METHODS

The QuickBird-2 0.61 m resolution panchromatic (450-900 nm) band image, and 2.44 m resolution blue (450-520 nm), green (520-600 nm), red (630-690 nm), and NIR (760-900 nm) bands images were used here. These data were acquired on September 13, 2003, covering an area of the Hoqiying Bridge of Beijing, China. All the images were geometrically registered to each other. The image size is 512×512 pixels.

Suppose that a satellite sensor observe the same area $\Omega(x, y)$ in high and low resolution modes respectively, it can get a low resolution pixel $DN_b^l(\Omega(x, y))$ and n high-resolution pixels $DN_b^h(\Omega_n(x, y))$, where the subscript b denotes the band b and the superscripts l and h denote low and high resolution respectively. Then the ratio of $DN_b^h(\Omega_n(x,y))$ to $DN_b^l(\Omega(x,y))$ is independent of the sensor band [8]

$$\frac{DN_b^h(\Omega_n)}{DN_b^l(\Omega)} = K(\Omega_n) \tag{4}$$

Let HRP and HRP^l be the panchromatic sensor's high and low resolution image respectively. Correspondingly, let LRM_i^f and LRM_i be the multispectral sensor's high and low resolution image respectively in band i. Then (6) can be rewrote as

$$\frac{HRP}{HRP^l} = \frac{LRM_i^f}{LRM_i} \tag{5}$$

Now we have HRP and LRM_i, only need knowing HRP^l to computer LRM_i^f as the image fusion result. We can get HRP^l by *à trous* wavelet decomposition [9]

$$HRP = HRP^l + \sum_{k=1}^{n_\omega} \omega_k \tag{6}$$

From (1), (5) and (6), we can get HRP^l

$$HRP^l = \frac{LRM_i}{s_i \cdot \frac{\alpha_p \cdot P(m_i \mid p_m)}{P(p_m \mid m_i)} \cdot \left(1 - \frac{\beta_i}{2}\right)} \tag{7}$$

Now we can find that the part of $\sum_{k=1}^{n_\omega} \omega_k$ is eliminated. Taking (7) into (5) and using the formulas on SRF in [5] to simplify the expression of LRM_i^f. The final merged LRM_i band is expressed as

$$LRM_i^f = \frac{n \cdot \left(1 - \frac{\beta_i}{2}\right) \cdot LRM_i}{\sum_{b=1}^{n} k_b \cdot LRM_b} \cdot HRP \tag{8}$$

Here, n is the number of multispectral bands, $k_b = P(p)/P(m_b)$, k_b and β_i can be calculated by sensor's SRFs. This is the simplified remote sensing image fusion technique based on SRF, SRSIFS.

4. EXPERIMENTAL RESULTS

The images merged by the simplified method proposed in this paper, WiSpeR and Brovey methods respectively. The scene of this remote sensing image contains many kinds of objects, including buildings, vegetation, roads, vehicles and rivers. It can be seen that the buildings with red roofs at the left corner of the scene are clear and truly in the simplified method merged image. The other objects, such as vegetation, road, vehicle and rivers are all enhanced and the color preserved fine in the simplified method merged image. The objective assess indexes of image fusion are calculated in table I.

Table I Image Fusion Objective Assess Indexes

Method	Simplified method	WiSpeR	Brovey
CC	0.8364	0.9615	0.7270
UIQI	0.7858	0.9593	0.7723
SCC	0.9726	0.9529	0.9754

The Correlation Coefficients (CC) and the universal image quality index (UIQI) [10] have been used to measure the similarity between two images. It can be seen that the WiSpeR is the best in these three methods in color preservation, and the simplified method is better than Brovey method. The high spatial correlation coefficient (SCC) [4] indicates the spatial information of the initial high resolution panchromatic image is present in the merged image. It can be seen that the simplified method preserve spatial information well in these three methods.

5. CONCLUSIONS

Image fusion methods are used to produce high-resolution multispectral images from high-resolution panchromatic images and low-resolution multispectral images. A simplified image fusion technique based on the WiSpeR algorithm by using the relationship between high resolution pixel and low resolution pixel of the same sensor is presented in this paper. The simplified method provides good performance both in processing speed and image fusion quality.

6. REFERENCES

[1] C. Paul and J. L. Van Genderen, "Multi-sensor image fusion in remote sensing: concepts, methods, and applications," Int. J. Remote Sens., 19(5), pp. 823-854, 1998.

[2] W. J. Carper, T. M. Lillesand, and R. W. Kiefer, "The use of Intensity-Hue-Saturation transform for merging SPOT panchromatic and multispectral image data," Photogramm. Eng. Remote Sens., 56(4), pp. 459-467, 1990.

[3] P. S. Chavez, S. C. Sides, and J. A. Anderson, "Comparison of three different methods to merge multi-resolution and multi-spectral data: Landsat TM and SPOT panchromatic," Photogramm. Eng. Remote Sens., 57(3), pp. 295–303,1991.

[4] J. Zhou, D. L. Civco, and J. A. Silander, "A wavelet transform method to merge Landsat TM and SPOT panchromatic data," Int. J. Remote Sens., 19(4), pp. 743-757, 1998.

[5] Xavier Otazu, María González-Audícana, Octavi Fors, et al., "Introduction of Sensor Spectral Response Into Image Fusion Methods," IEEE Transactions on Geoscience and Remote Sensing, 43(10), pp. 2376-2385, Oct. 2005.

[6] María González-Audícana, Xavier Otazu, et al., "a low computational-cost method to fuse IKONOS images using the spectral response function of its sensors," IEEE Transactions on Geoscience and Remote Sensing, 44(6), pp. 2376-2385, 2006.

[7] Chen SH, Zhang RH, et al., "Introducing object reflectance property and sensor spectral response into empirical mode decomposition based MODIS and TM image fusion," Canadian Journal of Remote Sensing, 34(6), pp. 585-595, Dec. 2008

[8] Zhijun Wang, Djemel Ziou, CostasArmenakis, et al., "A Comparative Analysis of Image Fusion Methods," IEEE Transactions on Geoscience and Remote Sensing, 43(6), pp. 1391-1402, June, 2005.

[9] Jorge Núñez, X. Otazu, O. Fors, et al., "Multiresolution-based image fusion with additive wavelet decomposition," IEEE Transactions on Geoscience and Remote Sensing, 37(3), pp. 1204-1211, May. 1999.

[10] Z. Wang and A. C. Bovik. "A universal image quality index," IEEE Signal Process. Lett., 9(3), pp, 81-84, Mar. 2002