

Improved Pansharpening Method

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Abstract: Among various image fusion methods, several efforts have been done to improve the resolution of multispectral images using panchromatic images and fusion based on high pass filtering is one among that. In this study, we proposed a modified panchromatic sharpening method which calculates the histogram matching of the missing high frequency components in Multispectral images and post processing technique also added for deduction of noise and color distortions. Experimental analysis illustrates that the proposed method produced the better results both visually and objectively.

Keywords: High Pass Modulation (HPM), histogram matching, image fusion, panchromatic and multispectral images, post processing

INTRODUCTION

In remote sensing techniques, most earth resource satellites such as IRS, RESOURCESAT, CARTOSAT, IKONOS and QUICKBIRD provide data in a variety of spatial, spectral and temporal resolutions. It contains both panchromatic images at a higher spatial resolution and multispectral images at a lower spatial resolution. To obtain the high spatial and spectral information is significant for an image. It is intricate to acquire the image of high-spatial and high-spectral resolution at the same time. Image fusion technique is the method to solve this problem which incorporates the high resolution panchromatic (single-band raster dataset) and low resolution multispectral images (multiband raster dataset) of the same scene to get the fused high resolution multispectral Image. Image fusion technique is also called as panchromatic sharpening. It increases the spatial resolution and provides better visualization and also improves reliability and robustness of an image. Many image fusion techniques have been proposed for merging High Resolution Panchromatic Image (HRPI) and Low Resolution Multispectral Image (LRMI). The well-known image fusion methods are Intensity-Hue-Saturation (IHS) based fusion (El-Mezouar *et al.*, 2011; Varghese *et al.*, 2012), Principal Component Analysis (PCA) based fusion, Brovey transform based on Arithmetic combinations, High-passfiltering (Alparone *et al.*, 2007) and Pyramid method based on Multiscale transform based fusion and Wavelet transform based fusion. In IHS technique, color distortion has often occurred. In PCA image fusion, dominant spatial information and weak color information is a frequent problem. In Brovey Transform, color distortion is obvious and it varies depending on the band combinations being fused. In wavelet based fusion, loss of spectral content is observable. In DWT method, the result appears like a High pass filtering method but in practical applications

(Lee and Lee, 2008) DWT method is not applicable for panchromatic sharpening method due to memory and computational cost requirements (Zhang, 2002). High pass filtering, High pass modulation have resolved some of these problems and created good results (Lee and Lee, 2010) The notion of HPF (*High pass filtering*) is to combine the high-frequency components from the High Resolution Panchromatic Image (HRPI) to the Low Resolution Multispectral Images (LRMI) to obtain the High resolution Multispectral Images (khan *et al.*, 2008). The high-frequency components is obtained by filtering the HRPI. The authors in this study Wang *et al.* (2002) has introduced modulation coefficient and is termed as High Pass Modulation (HPM). In Fast and efficient pansharpening method, it estimates the missing high frequency components. Then post processing technique also added to remove the color distortion (Lee and Lee, 2010). In this study, we proposed a modified panchromatic sharpening method which was partially published in Lee and Lee (2010).

In this study we calculated the histogram matching between the difference of panchromatic high and low frequency components and the matched histogram values is added with low resolution multispectral images. Then post processing technique also supplemented so it produced the better results comparing the existing method.

IMPROVED PAN SHARPENING BASED ON HPF

In general high resolution and low resolution images includes both low and high frequency components:

$$IMAGE^{\Omega} = IMAGE^{\Omega}_L + IMAGE^{\Omega}_H \quad (1)$$

$IMAGE^{\Omega}$ represents an Image with resolution Index $\Omega \in \{LR, HR\}$ Pansharpening method is the basis of

acquiring the missing high frequency components of the high resolution multispectral images using the spatial information of high resolution panchromatic images. We first utilize the Gaussian low-pass filter to the panchromatic image and acquired the high frequency components.

The mathematical model is:

$$MS^{HR} = MS^{LR} + (PAN^{HR} - PAN^{LR}) \quad (2)$$

Then apply histogram matching on the difference of panchromatic high and low frequency components i.e. $(PAN^{HR} - PAN^{LR})$. Then the histogram matched output produces missing high frequency components which is downsampled so that it could be modulated with low frequency multispectral image:

$$MS^{HR} = MS^{LR} + \text{Matched Histogram} \cdot \frac{(PAN^{HR} - PAN^{LR}) \cdot MS^{LR}}{PAN^{LR}} \quad (3)$$

Equation (3) shows the resultant high resolution multispectral image. The low resolution multispectral (MS^{LR}) is added with matched histogram of panchromatic missing high frequency components and MS^{LR} / PAN^{LR} represents the modulation coefficient which is equal to the ratio between low resolution multispectral and panchromatic images.

Then we apply a post processing technique to eliminate the peak noise at the edge regions of the high resolution multispectral image.

The phases involved are:

- Edge image is obtained using a conventional high pass filter
- Thresholding is employed to produce edge mask.
- Then we can get the noise removed multispectral image.
- This method will be used to upgrade the performance of other panchromatic sharpening methods.

EXPERIMENTAL ANALYSIS

In this study, we compared the proposed method with existing method using different parameters so that we can find the performance ratio between these methods. To analyze the accuracy of the fused images has to be evaluated with the original multispectral images. The relative bias is the discrepancy between the mean of original and merged images and variance analysis to examine the variance between actual and fused images.

- **Standard deviation:** It is evaluated to show how much it is deviated from the actual multispectral image and the lower value of standard deviation is the finest spectral value of the merged image.

- **Correlation coefficient:** Correlation indicates the resemblance between the original and the fused image and the CC for MXN image is calculated as follows where, x and y indicates original and fused images \bar{x}, \bar{y} stands for the mean value of the images:

$$CC(x/y) = \frac{\sum_{i=1}^M \sum_{j=1}^N (x_{i,j} - \bar{x})(y_{i,j} - \bar{y})}{\sqrt{\sum_{i=1}^M \sum_{j=1}^N (x_{i,j} - \bar{x})^2 \sum_{i=1}^M \sum_{j=1}^N (y_{i,j} - \bar{y})^2}}$$

The value ranges from -1 to 1 and the best correspondence between fused and original image data shows the highest correlation values.

- **SAM:** The Spectral Angle Mapper Classification (SAM) is broadly used method comparing spectral similarities between the images. The SAM for two given spectral vectors v and w is defined as:

$$SAM(v, w) = \cos^{-1} \left(\frac{\sum_{i=1}^L v_i w_i}{\sqrt{\sum_{i=1}^L v_i^2} \sqrt{\sum_{i=1}^L w_i^2}} \right)$$

where, v_i and w_i are the mean values of v and w .

- **ERGAS:** ERGAS is the abbreviation of Erreur Relative Globale Adimensionnelle de Synthèse (Relative global-dimensional error). It is a global quality measure of the trade-off between spatial and spectral quality, respectively. The lesser the value of the ERGAS index, the higher the spectral quality of the fused images:

$$ERGAS = 100 \frac{h}{l} \sqrt{\frac{1}{N} \sum_{i=1}^N \frac{RMSE^2(B_i)}{M_i^2}}$$

where, h is the resolution of the high resolution image, l is the resolution of the low spatial resolution image AND M_i is the mean radiance of each spectral band involved in the fusion, where h/l is the ratio between the pixel size of PAN and MS image:

- **UIQI:** UIQI is abbreviated as Universal Image Quality Index. It measures how much of the salient information contained in reference image (Wang and Bovik, 2002) UIQI is evaluated the transformation of loss of correlation, luminance distortion AND radiometric distortion. The range of this metrics varies from -1 to +1 and the best value is 1:

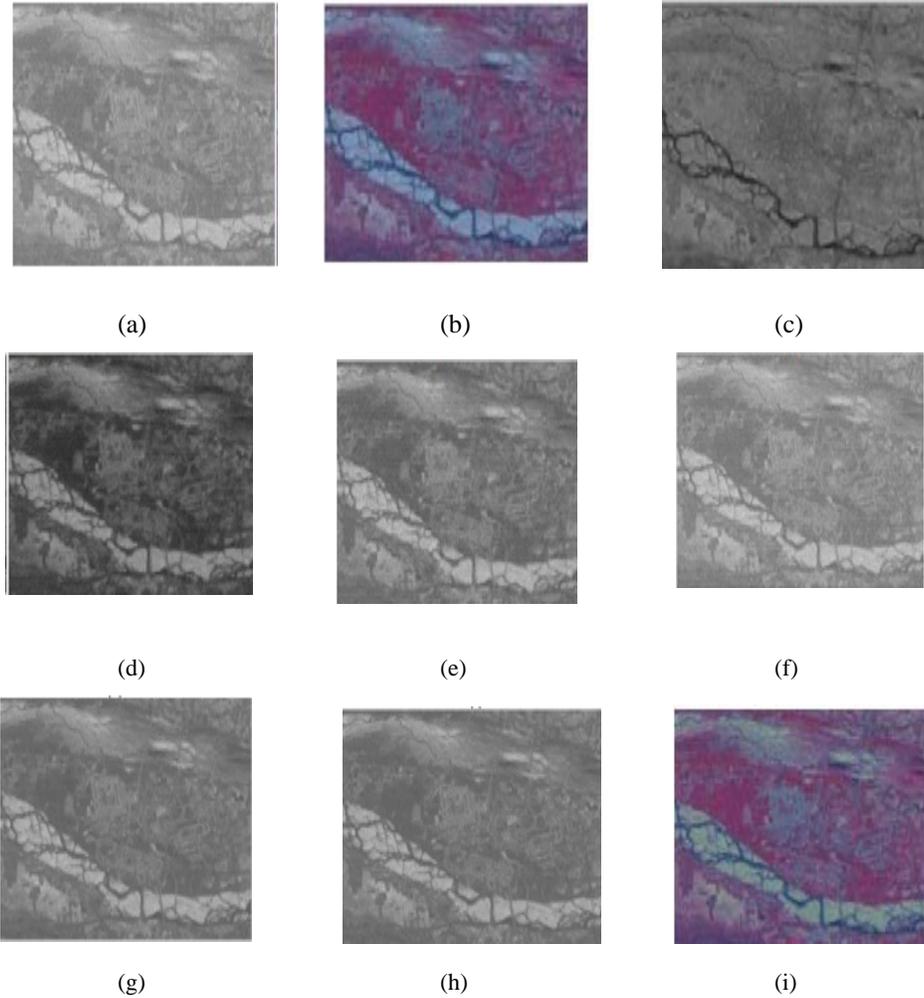


Fig. 1: CARTOSAT, (a) PAN, (b) MS, (c) pan low frequency, (d) LRP matched, (e) HRP matched, (f) MS post processed red band, (g) MS post processed green band, (h) MS post processed blue band, (i) MS sharpened

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

where, σ represents the standard deviation and μ represents the mean value. The first term in RHS is the correlation coefficient, the second term represents the mean luminance and the third measures the contrast distortion UIQI is also used to similarity between the two images:

- **RMSE:** The Root Mean Square Error (RMSE) indicates how much error between the fused and the actual image. It estimates the spectral and spatial quality of the high resolution multispectral images. Thus the lower value more likely resembles the ideal value i.e Zero. It is the difference of standard deviation and the mean of the fused and the original image.

The mathematical model is:

$$RMSE = \sqrt{\frac{\sum_{i=1}^M \sum_{j=1}^N (x_{i,j} - y_{i,j})^2}{M \times N}}$$

Quantitative evaluation: Apart from visual analysis, efforts were taken for quantitative evaluation. Figure 1 represents the Trichy region obtained from CARTOSAT, which has the clear view of Cauvery valley Srirangam temple and the entire city and the image provided by NRSC. For this data set, the input LRM (Low Resolution Multispectral) and HRP (High Resolution Panchromatic) image size is 1024×512. We have evaluated the spatial and spectral quality of the resulting images using metrics such as bias, variance, Standard Deviation, Correlation

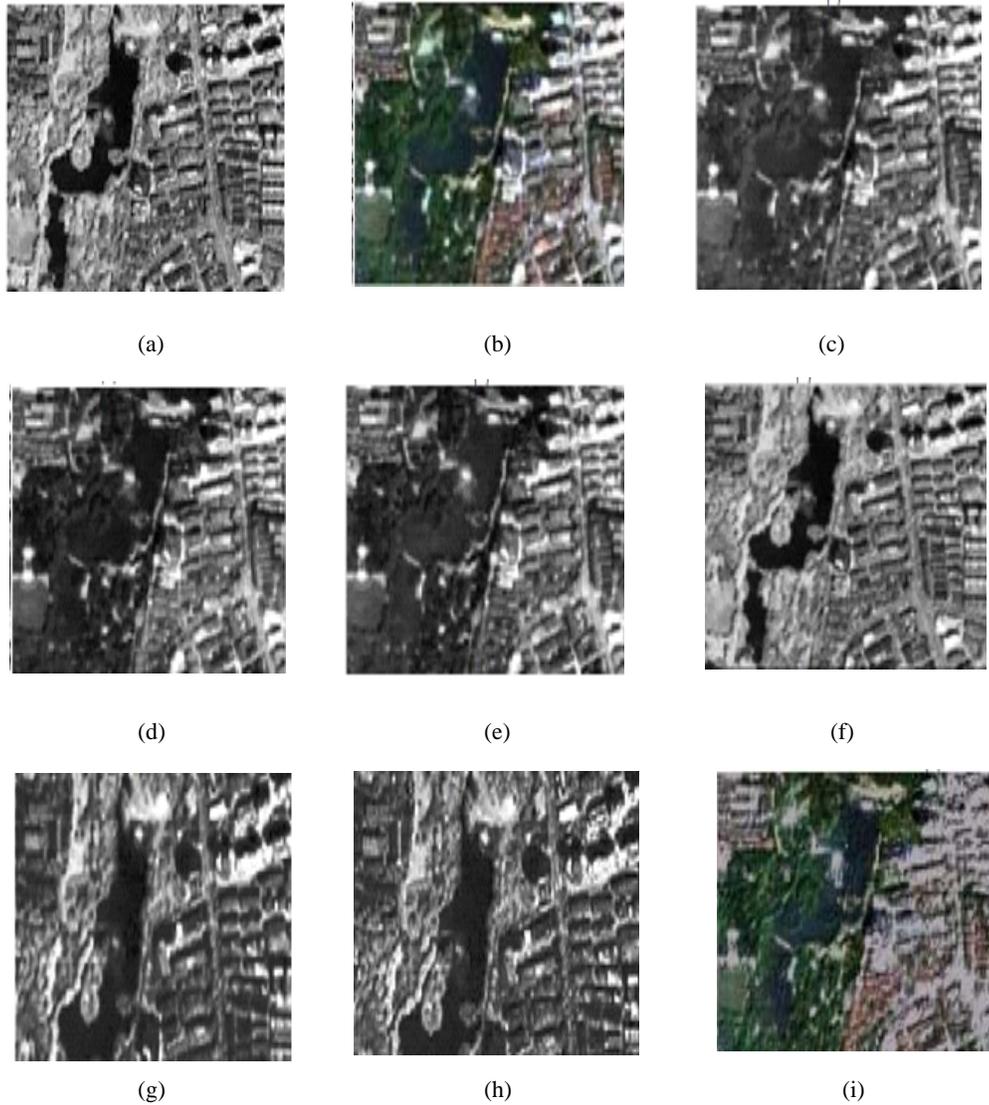


Fig. 2: QUICKBIRD, (a) PAN (b) MS, (c) pan low frequency, (d) LRP matched, (e) HRP matched, (f) MS post processed red band, (g) MS post processed green band (h) MS post processed blue band, (i) MS sharpened

Table 1: Objective indicators for fusing different visual images for CARTOSAT images

| Parameters | Propose Technique | Pansharpening |
|-------------------------|-------------------|---------------|
| Relative bias | 6.293350 | 6.186788 |
| Relative variance | 0.487820 | 0.051254 |
| Standard deviation | 0.018978 | 0.019452 |
| Correlation coefficient | 0.958245 | 0.953135 |
| SAM | 4.588675 | 4.631720 |
| ERGAS | 6.228200 | 6.664100 |
| UIQI | 0.998932 | 0.059118 |
| RMSE | 6.219400 | 6.768900 |

Coefficient, ERGAS, UIQI, SAM and RMSE. The values obtained are charted in Table 1.

Table 1 shows performance analysis between the proposed and the pansharpening technique. Higher values

Table 2: Objective indicators for fusing different visual images for CARTOSAT images

| Parameters | Propose Technique | Pansharpening |
|-------------------------|-------------------|---------------|
| Relative bias | 0.014611 | 0.014365 |
| Relative variance | 0.069767 | 0.065282 |
| Standard deviation | 0.027762 | 0.026854 |
| Correlation coefficient | 0.893599 | 0.859810 |
| SAM | 0.66576 | 0.46808 |
| ERGAS | 29.3503 | 33.0354 |
| UIQI | 0.019238 | 0.019145 |
| RMSE | 26.0672 | 29.3293 |

of Correlation Coefficient, UIQI indicates the better spatial and spectra l quality than the existing method. ERGAS, Standard deviation and the RMSE values in the first column denotes the lesser

value than the pansharpening technique so the proposed method proves to be better than existing.

Figure 2 represents the QUICKBIRD images and the final sharpened multispectral image. Table 2 depicts the performance of proposed method over the existing method.

CONCLUSION

In this study we have proposed the Improved pansharpening method that formed a high resolution multispectral images using histogram matching and filtering techniques. It is compared with the existing pansharpening technique and it gives the finer results in both visual inspection and quantitative results.

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