SCENES CHANGE ANALYSIS OF MULTI-TEMPORAL IMAGES FUSION

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ABSTRACT

Image fusion and subsequent scene analysis are important for studying Earth surface conditions from remotely sensed imagery. The fusion of the same scene using satellite data taken with different sensors or acquisition times is known as multi-sensor or multi-temporal fusion, respectively. The purpose of this study is to investigate the effects of the multi-sensor, multi-temporal fusion process when a pan-sharpened scene is produced from low spatial resolution multispectral (MS) images and a high spatial resolution panchromatic (PAN) image. It is found that the component substitution (CS) fusion method provides better performance than the multi-resolution analysis (MRA) scheme. Quantitative analysis shows that the CS-based method gives a better result in terms of spatial quality (sharpness), whereas the MRA-based method yields better spectral quality, i.e., better color fidelity to the original MS images.

Key Words— *Multi-sensor, Multi-temporal fusion, Component substitution, Multi-resolution analysis*

1. INTRODUCTION

Following the rapid advancements of new and greatly improved remote sensing (RS) sensor systems, various kinds of remote sensing data were acquired and applied in many interdisciplinary Earth observational applications. A low spatial resolution multispectral (MS) and high spatial resolution panchromatic (PAN) imaging sensors are the systems usually used for earth change observation, each one having its own specific advantage. Most of the operating earth observation very high resolution (VHR) imagery (WorldView, QuicBird, GeoEye, and Orbview, etc), it was very useful issues various RS problems such as image sharpening, land classification, change detection, and object identification, visualization purposes etc.[1]. Besides that, PAN sensors provides an image in the visible band, which is characterized by high spatial information content well suited for intermediate scale mapping applications and urban analysis [2]. In image fusion observed scene analysis and RS application, the observed scene information fusion can be available in the following cases [3]: data recorded by different sensors (multi-sensor image fusion), data recorded by the same sensor scanning the same scene at different dates (multi-temporal image fusion), data recorded by the same sensor operating in different spectral bands (multi-frequency image fusion), data recorded by the same sensor at different polarizations (multi-polarization image fusion), and data recorded by the same sensor located on platforms flying at different heights (multi-resolution image fusion). A Multi-sensor, multi-temporal, multi-resolution and multi-parameter image data from operational Earth observation satellites are available and therefore possibly give a more complete view of observed objects [4]. In this research, objectives of the study is analyses and assess the capability of scene changes multi-temporal images using multi-resolution analysis (MRA) and component substitution (CS) algorithm. The goal of the present paper is to propose both an approach and some criteria for a quantitative assessment of the quality. In doing this, we assume that the main demand of the user concerns the quality of the transformation of the multispectral content when increasing the spatial resolution.

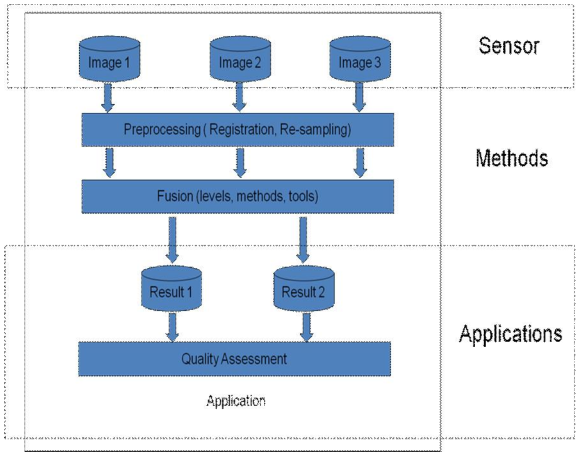


Fig 1. Concept image fusion [5]

2. STUDY AREA AND SATELLITE IMAGERY

2. 1. Study area

The study site for this work is located in over the downtown of San Francisco, California (US) with geographical coordinates 122°23'1.08"W, 37°42'38.81"N. San Francisco is located on the West Coast of the United States at the tip of the San Francisco Peninsula and includes significant stretches of the Pacific Ocean and San Francisco Bay within its boundaries (Fig.2).

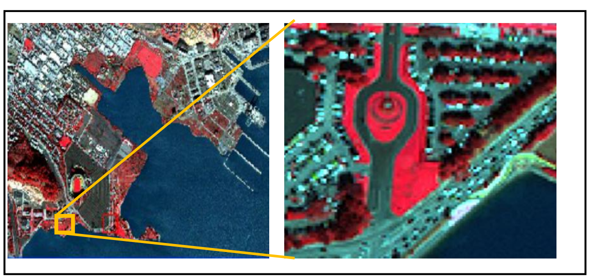


Fig 2. Subset study area in downtown San Francisco

2. 1. Satellite images

For this work, two temporal optical images acquired by QuickBird (QB) and WorldView-2 (WV) on 11 November 2007 and 9 October 2011, respectively, were used for investigating the performance of multi-sensor multi-multi temporal fusion. A QB images consists of one PAN and four MS with a spatial resolution of 0.7 m and 2.8 m at nadir and WV-2 image consists of one PAN and eight MS was placed on the altitude of 770 km with the revisit frequency of 1.1 days at 1 meter GSD (Ground Sample Distance) or less and 3.7 days at 20° off-nadir or less (0.52 meter GSD). The optical temporal images used in this study were made available from Digital globe, organized by IEEE GRSS in data fusion contest 2012. The characteristics of both images are summarized in Table 1.

2. 1. Spectral response of sensor

Significant spectral distortion in the fusion product image can occur due mainly to the wavelength extension of the new satellite PAN sensors. In image fusion techniques, it is important to properly include the sensor spectral response information [6].

3. METHODS

3.1. Pre-processing

3.1.1. Image correction and registration

The most important prerequisite for accurate data fusion is precise geometric correction. In image fusion needs commons control point on both the input images since different images of the same area used together. The common geometric correction is image to image registration. Registration can be done in various methods. A one of methods is image to image registration. An image to image registration is translation and rotation alignment process by which two images of like geometry on the same geographic area (Chen and Lee, 1992). In registration processing, the most accurate way is to register the input images separately by establishing geometric relationship between the image and the ground using rigorous photogrammetric methods (Lee and Bethel, 2001). Two bgeometrically corrected mages, of the same area, size, and imaging band, are used as reference images. They were geometrically corrected using maps (image-to-image) registration (Figure 4.16). In this study, the first order polynomial transformation method is used for registration refinement of multispectral images by taking the PAN WV-2 image as the reference. The cubic convolution re-sampling method is used to calculate the pixels gray level values of the rectified output image. The accuracy of the correction process is evaluated by calculating the RMS error at every GCP. The RMS error is the difference between the desired output coordinate for a GCPs (common ground control points) and the actual output coordinate for the same point, when the point is transformed with the geometric transformation. RMS error in X, Y directions and total (T) RMS error at the GCPs are calculated according to the following equations. The result of GCPs on both images are selected carefully such that they produce an RMS error smaller than 0.5 pixels .

Table 1. Characteristics of VHR optical sensors.

Sensor	Band Name	Wavelength (μm)	Resolution (m)	Date Acq.
QB	B1(Blue)	0.45-0.52	2.44-2.88	11 Nov. 2007
	B2(Green)	0.52-0.60		
	B3(Red)	0.63-0.69		
	B4(NIR)	0.76-0.90		
	PAN	0.45-0.90	61 -72 cm	
WV-2	B1(NIR1)	0.77-0.89	2.07	9 Oct. 2011
	B2(Red)	0.63-0.69		
	B3(Green)	0.51-0.58		
	B4(Blue)	0.45-0.51		
	B5(R.Edge)	0.70-0.74	52 cm	
	B6(Yellow)	0.58-0.62		
	B7(Coastal)	0.40-0.45		
	B8(NIR2)	0.45-0.48		
	PAN	0.45-0.80		

3.1.2 Re-sampling

Next, we apply re-sampling, in which each data point (pixel) in the high-resolution base map is assigned with a value based on the MS image pixels. In order to achieve a good fusion result, low spatial spectral images should be re-sampled. At present, nearest neighbor re-sampling is often adopted which has some effects on the precision of new image. In this paper, an image fusion method is proposed with Cubic Convolution technique. In this way, PAN-MS images
with 0.5m, 2m and 0.7m, 2.8m spatial resolutions are produced from original GeoEye-1 and QuickBird images, respectively (Figure 4.16). The pixel size of WV PAN (0.5 m) is greater than that for QB PAN (0.6 m). Thus, in order to minimize the spectral difference, WV-MS, QB-MS and QB-PAN imaging are used, after being re-sampled at 0.5 m. To analyze the effect of different spatial resolution ratio images, re-sampling of the two images was done next as different resolution ration to create various set of images for fusion. The various resolution obtained due to such a re-sampling techniques are shown in Table 4.24, when the effective set of input image was generated for

Table 4.2 Multi-temporal fusion

Input Image	Spatial resolution (m)	Resolution ratio	Fusion techniques
QB_PAN + QB_MS QB_PAN + WV_MS WV_PAN + WV_MS WV_PAN + QB_MS	PAN= 0.5 m MS = 2 m (0.5:2)	1:4	CS, MRA

fusion using Component Substitution (CS) and Multi-Resolution Analysis (MRA) techniques.

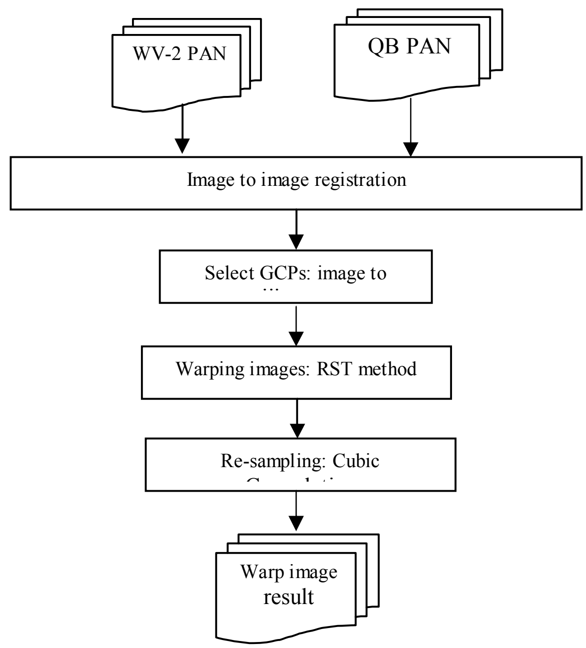


Figure 4.16 Image to image registration processing

3.1.3Band selection model by the OIF

Band selection is a key step of fusion techniques. For this purpose, values of optimum index factor (OIF) are useful for designating the most favorable band combination according to their information [7]. Generally, a larger standard deviation of an image infers that it involves more information. Thus, the OIF is defined [10] as

$$OIF = \sum_{i=1}^{3} \sigma_i / \sum_{j=1}^{3} \left| r_j \right| , \qquad (1)$$

where σ_i is the standard deviation of each of the three selected bands and r_j is the correlation coefficients (CCs) between any pair formed by these bands. From the original WV and QB, a total of 56 and 4 bands color combinations are produced and analyzed using the optimum index factor (OIF). The highest value of average OIF has been obtained for the band combination 3-5-7 and 2-3-4, both for WV and QB.

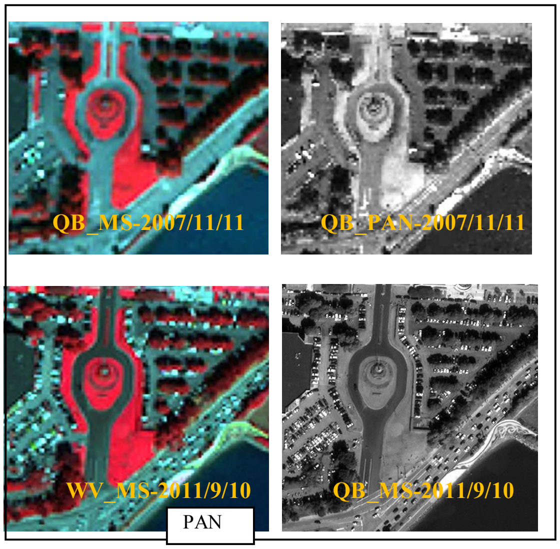


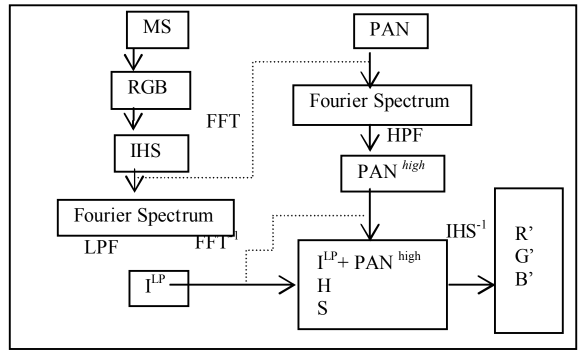
Fig 3. Remote sensing multi-temporal data used QB PAN and MS image obtained in 2007 and WV-2 PAN and MS images obtained in 2011.

3.2 Pan-sharpening Techniques

Two main approaches of pan-sharpening, namely MRA and CS, are compared in the present analysis.

3.2.1 Multi-resolution analysis (MRA)

MRA is an approach based on fast Fourier transform (FFT)-enhanced intensity-hue- saturation (IHS) transformation. Since this methods is capable of preserving the spectral characteristic, generally it is suitable for image analysis purposes [8-10].The re-sampled multispectral images are transformed from the RGB to IHS color space to obtain the intensity (I), hue (H), and saturation (S) components, and low-pass filtering (LPF) is applied to the intensity component. After high-pass filtering (HPF), the PAN image is added to the low-pass filtered intensity component by means of inverse FFT (FFT^{-1}). Finally, inverse IHS transformation (IHS^{-1}) is performed on the IHS image to create the fused image.



3.2.2 Component substitution (CS)

All fusion methods which do not make use of a filtering process to extract the high frequency details from the Pan image fall in the category of component substitution methods. The principle idea is to add the details of the Pan image into the MS images making use of some transformation. Gram-Schmidt (GS), Intensity-Hue-Saturation (IHS) based fusion methods, Brovey transform based fusion, PCA based fusion, all fall in the category of CS or Component Substitution Methods.

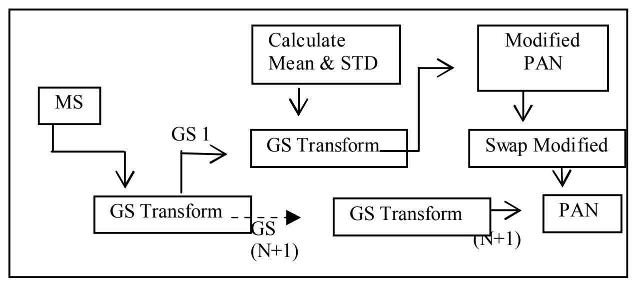


Figure 4.18 GS Techniques based on CS.

3.3 Multi-temporal analysis

For analyzing information from multi-temporal, the following combinations are employed here: (1) both PAN and MS images of November 2007 (QB-PAN, QB-MS), (2) PAN of November 2007 and MS of October 2011 (QB-PAN,W-MS), (3) both PAN and MS images of October 2011 (WV-PAN, WV-MS), and (4) PAN of October 2007 and MS of November 2011 (WV-PAN,QB-MS). For each of these choices, both MRA and CS pan-sharpening methods are applied.

3.4 Optimization of the parameter

A validation method is proposed based on a quality criterion, namely, the RASE and ERGAS parameter [11-12]. It is based on an RMSE estimation and chosen as a robustness criterion. This statistical parameter is often used for evaluation of fusion techniques. These parameters are defined as follows:

- Relative Average Spectral Error (RASE) is used to estimate the global spectral quality of the fused images.

$$RASE = \frac{100}{M}\left[\frac{1}{n}\sum_{i=1}^{n} RMSE^2(B_i)\right]^{1/2}$$

(2)

where M is the mean radiance of the n spectral bands (Bi) of the original MS bands; RMSE is the root mean square error computed as

$$RMSE(B_i) = Bias^2(B_i) + STD^2(B_i)$$

(3)

- Relative Dimensionless Global Error in Synthesis (ERGAS) was proposed by Wald as a multi-modal index to characterize the quality of process in terms of the normalized average error of each band of processed image. Increasing in ERGAS index may be the result of degradation in images due to fusion process. ERGAS index for the fusion is expressed as follow

$$ERGAS = 100\frac{dh}{dl}\left[\frac{1}{n}\sum_{i=1}^{n}\left(\frac{RMSE^2}{mean^2}\right)\right]^{1/2}$$

(4)

These formulae can be used for comparing errors obtained from different methods, different cases and different sensors. Where *dh/dl* is the ratio between the pixel sizes of the PAN and MS images (e.g., 1/4 for QB and WV data), and $\mu(i)$ is the mean of the i th band. Since ERGAS is a measure of distortion, its value must be as small as possible.

4. RESULT AND DISCUSSION

Figure 4 shows the fused images obtained with the CS and MRA fusion methods for the four choices of band combinations. In visual (quantitative) analysis, it is seen that CS fusion yields relatively sharp images for both PAN and MS images of October 2011 (WV-PAN, WV-MS) and PAN of October 2011 and MS of November 2007 (WV-PAN,QB-MS). Other results show somewhat blurred results due to temporal changes. For MRA fusion, the fusion of PAN and MS images of October 2011 (WV-PAN,WV-MS) gives better spectral quality (i.e., fidelity of colors to original) than other three combinations, which show color distortion as compared with origin
nal MS images. Table 2 and 3 summarize the values of RMSE, RASE, and ERGAS indexes based on the CS and MRA approaches. Smaller parameter values (ideally zero values) indicate better preservation of the original information. The resulting index values obviously depend on the MS images chosen as reference (see also Fig. 4).

In the case of CS fusion, when the reference is the PAN of October 2011 and MS of November 2007 (WV-PAN, QB-MS), a better result is obtained as manifested in smaller values of RMSE, RASE and ERGAS.

5. CONCLUSSION AND FUTURE RESEARCH

We have investigated the multi-temporal fusion by multi-resolution analysis (MRA) and component substitution (CS) algorithms. In both quantitative and qualitative results, it has been found that the CS based method leads to better spatial quality (sharpness), whereas the MRA based method better spectral quality (fidelity to the original color). In the future research, the methodology presented in this paper can be extended to include the multi-temporal fusion of optical and synthetic aperture radar (SAR) images from satellite remote sensing.

Table 2. Quality index based on CS fusion spatial resolution ratio 1:4

Index	Scene changes temporal fusion			
	Nov./Nov.	Nov./Oct.	Oct./Oct.	Oct./Nov.
RMSE	1.81	7.61	1.65	**0.90**
RASE	4.46	5.10	1.22	**1.07**
ERGAS	1.91	4.72	0.29	**0.08**

Table 3. Quality index based on MRA fusion spatial resolution ratio 1:4

Index	Scene changes temporal fusion			
	Nov./Nov.	Nov./Oct.	Oct./Oct.	Oct./Nov.
RMSE	16.60	11.57	**9.84**	14.98
RASE	15.55	7.19	**6.28**	13.78
ERGAS	2.01	0.59	**0.52**	1.14

6. ACKNOWLEDGEMENTS

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