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Comparison of Several Fusion Rule Based on Wavelet in The Landsat ETM Image

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Abstract

Remote sensing image quality and the improvement of remote sensing image position accuracy on Landsat ETM satellite is highly needed in term of remote sensing. Therefore, it is required one way or more to obtain the quality and accuracy of the image which uses image processing. Fusion technique is one of the image processing example that is using an existing descriptions to catch the result of image that can provide better information in the content. In this final task, multispectral images have high spectral information content and low spatial, also high spatial information content in panchromatic image that it is needed to do the image fusion in order to have a spectral information content and high spatial to compare the performance of some fusion rules wavelet-based on the multispectral image fusion and panchromatic imagery. The image used is Landsat ETM. The performance of image fusion rules is compared with the mean gradient parameters, mutual information, mean square error and correlation coefficient. Based on the test results, image fusion has an influence on the information content of multispectral imagery and panchromatic imagery, which is the spectral and spatial information content are getting better, the ratio of the 6 image fusion rules have inconsistent values of the three image testings to the mean gradient parameters, mutual information and mean square error and the results of image fusion of the fifth fusion rules on the correlation coefficient have a consistent value of the three image testings.

Key words: remote sensing, image fusion, fusion rules, wavelet, Landsat ETM

1. Introduction

Remote sensing on Landsat ETM is one of the areas of knowledge about how to obtain information that is useful for mapping activities and observing the environment or landscape. Remote sensing image quality and the accuracy improvement of satellite positioning on Landsat ETM imagery is highly needed in any distance sensing. Improving the quality of Landsat ETM can be done by using the image processing. Fusion technique is one of the image processing by utilizing existing images to get the Landsat ETM that can provide better information.

Wavelet method is one of the example of the way that can be taken in order to obtain the image fusion. In this study, multispectral image contains spectral information of high and low spatial and high spatial information content of the panchromatic image, so it is necessary for every image fusion to obtain a spectral information of content and high spatial while comparing the performance of several wavelet-based on the fusion rules for multispectral fusion image and panchromatic image. The performance of image fusion rules are compared by using the mean gradient parameters, mutual information, the mean square error and coefficient of correlation. By comparing several fusion rules based on wavelet method on Landsat ETM satellite image, so the image fusion have an influence on the content of multispectral image and panchromatic image information, where the spectral and spatial information content are getting better.

2. Basic Theory

Aerial photographs and satellite imagery consist of recording the details of the state of the earth at the time of the data acquisition. Interpretation is made for the physical properties of objects and phenomena that appear in the image. Level of complexity might be come up while we are interpretating the image from the simplest object recognition on the earth's surface to the origin of the detailed information about the complex interaction between the surface of the earth and under the earth's surface [1].

2.1. Landsat Satellite Imagery

Landsat 7 ETM was launched on 15 April 1999 which was made by *Raytheon Santa Barbara Remote Sensing* in Santa Barbara, California. Landsat ETM aims for

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producing a series of data across the land and coastal areas of the earth with the image recording using visible wavelengths (visible) and a high quality of infrared signal while continuing the Landsat database that already exists. ETM + is a kind of radiometer scanning consists of 8 channels, namely TM1, TM2, TM3, TM4, TM5, TM6, TM7 and TM8, 30 meters of spatial resolution channels 1,2,3,4,5, and 7, while the channel 6 has 60 meters of spatial resolution. Channel 8 is a panchromatic channel, with 15 meters of spatial resolution. Landsat ETM has facility of radiometric correction.

2.2. Multispectral Imagery

In the satellite image there are several channels that collect and store the information on each wavelength called adjacent layers (bands). The collection of some spectral layers at the same time and area are called multispectral image [1].

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Table 1
Characteristic of Landsat ETM satellite image

System	Landsat
Orbit	705 km 98.2º, *sun-synchronous*, 10:00 AM *crossing*, 16 days of rotation (*repeat cycle*).
Censor	ETM+(*Enhanced Thematic Mapper*)
Swath Width	185 km (FOV=15º)
Off-track viewing	Not Available
Revisit Time	16 days
Spectral Bands (μm)	0.45 -0.52 (band1), 0.52-0.60 (band2), 0.63-0.69 (band3), 0.76-0.90 (band4), 1.55-1.75 (band5), 10.4-12.50 (band6), 2.08-2.34 (band7), 0.50-0.90 (PAN)
Pixel Size (Data Resolution)	15 (PAN), 30 m (band 1-5, 7), 60 m band 6

Fig 1. Multispectral image *Band* 123 in Landsat 7 (Paris, USGS, 2002)

Fig 2. Panchromatic image in Landsat 7 (Paris, USGS, 2002)

2.3. Panchromatic Imagery

Panchromatic image is an image that shows higher spatial resolution compare to the image in every spectral layer so the detail of image can be clearly shown (Lillesand et al., 2008)

2.4. Image Fusion

Image fusion is defined as the merging process of multiple images of relevant informations into a single composite or an image results. It aims for creating the collection input of image into a single output image that contains a better place description than the description that has provided by the individual input. The image results will have more information than the information that the input images have and those are more useful for human visual perception or machine perception [3].

2.5. Discrete Wavelet Transformation

Discrete wavelet transform is a representation of a signal from a time region (time domain) to the frequency region (frequency domain). Discrete wavelet transform is using the *low-pass filter* and *high-pass Filter* and sub sampling operations. If the decomposition is performed in a sub dimension, so that in every level of decomposition, each of the signal is separated into high and low component of frequency. Each of the low components frequency can be decomposed again until it's reached the desired resolution [3].

This study uses wavelet transformation of Wavelet Haar method. There are two processes that should be carried, those are *forward transformation* (decomposition) and *Inverse transformation* (reconstruction). This procedure can be applied into 2-dimensional image. Where is the approximation value at the previous level are decomposed again into the high and low frequency. Image 3 is the example of 2 Dimension Wavelet decomposition.

2.6. Rule of Fusion based on Wavelet Method

Related to the methode of multispectral image and panchromatic image that are decomposized in the first stage so that those will produce the output that can divide the image into some sub bands , LL, LH, HL, and HH. Every coefficient approximation and the detail of every image are used for combining both images. This combining process is done by using Fusion Rule, where it's comparing 6 fusion rule [2].
Mathematically, the comparison of Fusion Rule that is used in this study are:

1. Combination of Wavelet coefficient approximation and the maximum detail of image sources, the equation is:
$F(x,yy) = \max [A(x,y),B(x,y)]$ (2.3)

2. Combination of Wavelet coefficient approximation and the maximum detail of image sources
$F(x,y) = \min [A)x,y),B(x,y)]$ (2.4)

3. Combination of maximum Wavelet coefficient approximation and minimum detail of Wavelet coefficient
$F_{approximation}(x,y)= \max[A_{approximation}(x,y), B_{approximation}(x,y)$ (2.5)

. $F_{detail}(x,y) = \min [A_{detail}(x,y), B_{detail}(x,y)]$ (2.6)

4. Combination of minimum Wavelet approximation and Wavelet maximum detail

5. $F_{approximation}(x,y) = \min [A_{approximation} (x,y), B_{approximation}(x,y)]$ (2.7)

$Fdetail(x,y) = \max [Adetail(x,y), Bdetail(x,y)]$(2.8)

6. Average combination of image sources Wavelet coefficients
$F(x,y)=[\frac{A(x,y)+B(x,y)}{2}]$ (2.9)

6. Combination average approximation of Wavelet coefficient and maximum detail of Wavelet coefficien
$F_{approximation}(x,y) = [\frac{A_{(x,y)}+B_{(x,y)}]}{2}$ (2.10)

$F_{detail}(x,y) = \max [A_{detail}(x,y), B_{detail}(x,y)]$ (2.11)

3. Method

3.1 Implementation and simulation of Fusion Rules

Several stages need to be done in order to obtain the implementation and simulation of fusion rules

3.1.1 Collecting Data

This research is using the image of landsat ETM satellite that is taken from www.usgs.gov. This research is using the data from Shenyang in August 2001, Paris in September 2002, and Berlin in February 2003 and all those data are using 1024x1024 pixel of image resolution. Landsat ETM satellite has the multispectral image that consist of band1, band2, band3, band4, band5, band6, band7, and band8 of panchromatic image.

3.1.2 Selecting the Band Combination

In order to get the desired band image, the coeeficient correlation calculation and Optimum Index Factor (OIF) in every band are needed. Optimum Index Factor (OIF) is the value that is used to select the optimum combinationof the three band in the satellite that need to be combined. Optimum combination in every possible combination that might occur is the combination with the high information (amount of the highest standard deviation from three bands) and the lowest duplication amount (coefficient correlation between the lowe bands).

$$OIF = \frac{std_i + std_j + std_k}{|corr_{(i,j)}| + |corr_{(i,k)}| + |corr_{(j,k)}|} \quad (2.12)$$

Stdi : Standard Deviation of band i
Stdj : Standard Deviation of band j
Stdk : Standard Deviation of band k
Corr(i,j) : Coefficient correlation of band i and j
Corr(i,k): Coefficient correlation of band i and k
Corr(j,k): Coefficient correlation of band j and k

3.1.3 Image Registration

Linier Stretching needs to be done to every image for getting the maximum greyness effect form each of image. The linier stretching process is using "imadjust" in matlab 2010.

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3.1.4 Simulation Process

This process is calculated by using matlab 2010. The stages that need to be taken consist of the way in the image. The existing landsat ETM image holds the rule as the input image in the implementation system process. Input image includes the multispectral image and panchromatic image. In landsat ETM image, it selects 3 band from every image to be combined into multispectral image, every band selecting is based on the composition of RGB image, where the band recovery stage is needed to be done in multispectral image. input image is being process in the wavelet transformation by using six fusion rules: Combination of wavelet maximum image source coefficients, Combination of wavelet minimum image sources coefficients, Combination of wavelet maximum approximation and wavelet minimum detail coefficients, Combination of wavelet minimum approximation and wavelet maximum detail coefficients, Combination of average wavelet approximation coefficient and coefficient of wavelet maximum detail and Combination of average wavelet image sources coefficients. Spectral and spatial parameter calculation are being done after applying image fusion technic to each of the output image.

3.2 Comparison Stage

In this stage, the parameter value of every fusioned image is calculated, data comparison anylisis from every fusion rules that is involved is being applied. Parameters for analyzing the fusioned images are: mean gradient, mutual information, mean square error and coefficient correlation. Mean square error and coefficient correlation parameters need to compare image fusion result with the value of multispectral and panchromatic image in every fusion rule.

4. Comparison Of Several Image Fusions Based On Wavelet In Landsat Etm Image

4.1 First Result of Image Fusion

3 bands are selected in every image test to be combined as multispectral image in landsat ETM image. Every band selection is based on the composition of RGB color image and the combination of multispectral image is being settled before any wavelet transformation. Multispectral image and Panchromatic image that are used in the first experiment is shown in the Fig. 6. Fig. 7 is the image fusion result which is using 6 fusion rules image. for analyzing the right fusion method for fusion image, researcher needs to compare some parameters.

It is better to use mean gradient of second fusion rule in the first image. Fourth fusion rule has better information result in mutual information parameter while in the mean square error, fourth fusion rule has better value and better value of coefficient correlation is occuring in the fifth fusion rule.

Fig 3. multispectral image band 457

Fig 4. Panchromatic image

First image fusion result:

Fig 5. Fusion Rule1

Fig 6. Fusion Rule 2

Fig 7. Fusion Rule 3

Fig 8. Fusion Rule 4

Fig 9. Fusion Rule 5

Fig 10. Fusion Rule 6

Table 2:
Comparison of fusion rule image by using several parameters in the first image test

Fusion Rule	Parameter							
	Mean Gradient			Mutual Information ($1x10^{13}$)	Mean Square Error		Coefficient Correlation	
	MS	PAN	Citra Fusi		MS	PAN	MS	PAN
I	8,094	18.789	14,481	2,4964	117,35	177,12	0,9394	0,9504
II			14,863	2,499	6,450	12,072	0,9328	0,9531
III			14,502	2,4969	117,308	177,10	0,9392	0,9505
IV			14,835	2,5018	6,331	11,991	0,9329	0,9529
V			12,105	2,4874	38,263	77,940	0,9585	0,9742
VI			14,342	2,4876	42,012	79,408	0,9481	0,9637

4.2 Second Result of Image Fusion

In the second test images, based on the parameters of the mean gradient, the third fusion rule is better used for image fusion. While based on the parameters of mutual information, the first fusion rule is better used. For the mean square error parameter, the second fusion rules have better value and the value of the correlation coefficient, the better the fifth fusion rules used.

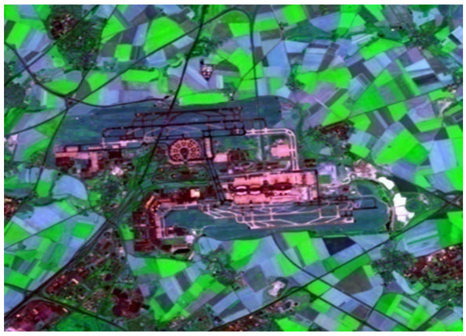

Fig 11. Multispectral image Band 457

Fig 12 Panchromatic Image

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Second Figure Fusion result:

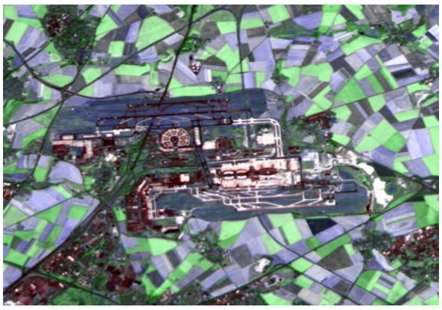

Fig 13. Fusion Rule1

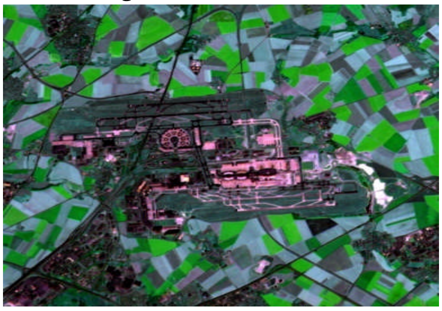

Fig 14. Fusion Rule 2

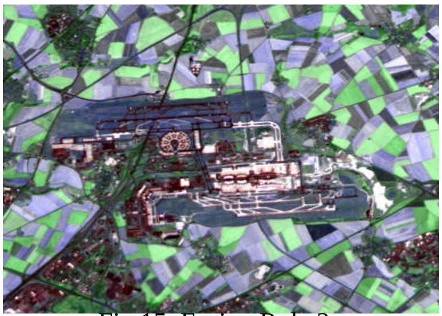

Fig 15. Fusion Rule 3

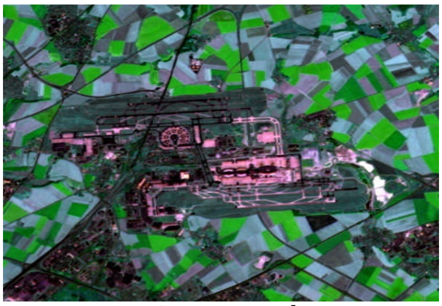

Fig 16. Fusion Rule 4

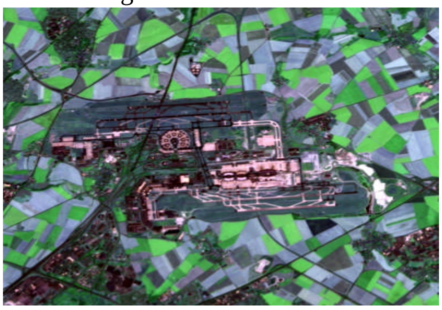

Fig 17. Fusion Rule 5

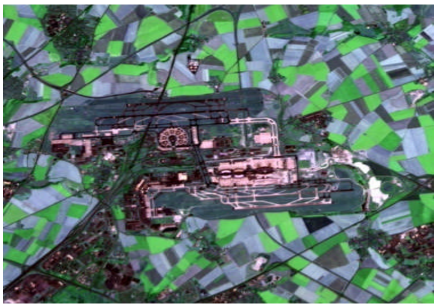

Fig 18. Fusion Rule 6

Table 2:
Comparison of Fusion Rule Image by using several parameters in the second image test

Fusion Rule	Parameter							
	Mean Gradient			Mutual Information (1x1013)	Mean Square Error		Coefficient Correlation	
	MS	PAN	Citra Fusi		MS	PAN	MS	PAN
I	4,4863	9,5425	8,4801	2,5683	16,11	127,32	0,9394	0,9559
II			7,3816	2,5550	4,1178	2,3839	0,9198	0,9526
III			8,5350	2,5677	169,78	127,68	0,9602	0,9557
IV			7,4376	2,5543	4,5912	2,8937	0,9197	0,9526
V			6,2562	2,5423	67,697	26,033	0,9739	0,9858
VI			7,4793	2,5440	68,101	27,638	0,9705	0,9825

4.3 Result of the third fusion image

Multispectral and panchromatic image which are being used in the second test is shown in the Image.

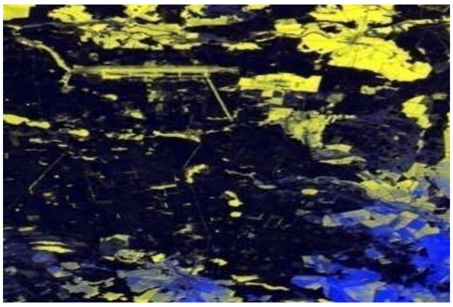

Fig 19. Multispectral image band 135

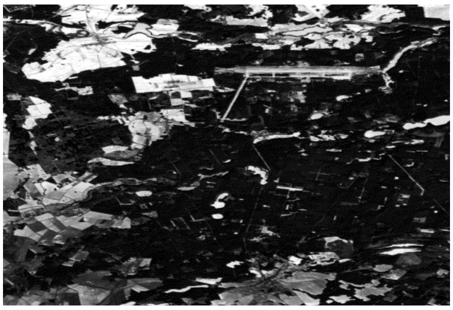

Fig 20. Panchromatic image

For analyzing the right fusion method for getting a better image fusion, comparing several parameters in Table 4 are needed.

For the third fusion test, based on the mean gradient parameter, the first fusion rule is better to use for image fusion. While for mutual information parameter, the second fusion rule is much more better to be used. Mean square error parameter is better in the fourth fusion and better image in the fifth fusion is related to the coefficient correlation parameter.

Table 4:
Comparison of fusion image rule using several parameters in the third image test

Fusion Rule	Parameter							
	Mean Gradient			*Mutual Information* *($1x10^{13}$)*	*Mean Square Error*		*Coefficient Correlation*	
	MS	PAN	Citra Fusi		MS	PAN	MS	PAN
I	4,4863	9,5425	8,4801	**2,5683**	16,11	127,32	0,9394	0,9559
II			7,3816	2,5550	**4,1178**	**2,3839**	0,9198	0,9526
III			**8,5350**	2,5677	169,78	127,68	0,9602	0,9557
IV			7,4376	2,5543	4,5912	2,8937	0,9197	0,9526
V			6,2562	2,5423	67,697	26,033	**0,9739**	**0,9858**
VI			7,4793	2,5440	68,101	27,638	0,9705	0,9825

5. Conclusion

The fusion image has an influence on the content of multispectral image and panchromatic image information, where the spectral and spatial information content is becoming better on Landsat ETM satellite image.

The comparison of 6 (six) image fusion has inconsistent values of the three test images to the mean gradient parameters, mutual information and mean square error. Results of the fifith image fusion rule (average incorporation of wavelet image sources coefficients) in the parameter correlation coefficient has a value that is consistent in the three test images.

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