# Using a Wavelet Based Method for High Resolution Satellite Image Fusion

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## Abstract

The number and quality of commercially available multispectral sensors and the data they provide are continually improving, but there is always compromise between achieving high spatial resolution, necessary for those applications that require high degree of detail, and high spectral resolution when a better feature discrimination level is needed. However, there are some situations that simultaneously require high spatial and spectral resolutions in a single image. The techniques of data fusion, or data merging, provide an alternative to that constraint, being used to combine low-resolution multispectral satellite imagery with higher resolution panchromatic or radar imagery, improving their visual quality and interpretability. Many algorithms and software tools have been developed for fusing panchromatic and multispectral datasets in remote sensing. Wavelet techniques are increasingly being used for the processing of images. The algorithm used in this paper was based on multiresolution wavelet decomposition. The image is decomposed into multiple channels based on their local frequency content, obtaining new images each one of them with different degree of resolution. A simple Wavelet Transform is used, which is implemented in the ERDAS Imagine Software package ver. 9.2. The procedure was based upon the wavelet transform is to improve the spectral quality of high resolution image acquired by LANDSAT 7 ETM+.

**Keywords:** image fusion, merging, wavelets, multiresolution.

# استخدام طريقة المويجة لدمج صورة القمر الاصطناعي عالية الدقة

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## الخلاصة

إن عدد ونوعية المتحسسات متعددة القنوات والمتوفرة تجاريا والبيانات التي تجهزها تتحسن باستمرار ولكن هناك دائما مساومة بين تحقيق قابلية تحليل مكانية عالية والتي تعتبر ضرورية للتطبيقات التي تتطلب دقة عالية من التفاصيل ودقة طيفية عالية حيث تحتاج إلى مستوى أفضل لتمييز الخاصية, على أي حال توجد بعض المواقف التي تتطلب في نفس الوقت دقة مكانية وطيفية عالية في صورة منفردة.إن تقنيات دمج البيانات تزودنا ببديل لذلك المحدد حيث تستخدم صور الأقمار الاصطناعية ذات قابلية قليلة لمتعدد القنوات مع قابلية تحليل عالية أحادية اللون أو صور رادارية وبالتالي تؤدي إلى تحسين النوعية البصرية وقابلية التفسير. تم تطوير عدة خوارزميات وأدوات برمجية لدمج البيانات المتعددة القنوات والأحادية في التحسس النائي. يزداد استخدام تقنيات المويجة في معالجة الصور. إن الخوارزمية المستخدمة في هذا البحث تستند على طريقة تجزئة المويجة ذات قابلية التحليل المتعددة, حيث يتم تجزئة الصورة إلى عدة قنوات مستندين على محتوى التردد الموضعي للحصول على صور جديدة كل واحدة منها بقابلية تحليل مختلفة الدرجة. تم استخدام تحويل المويجة البسيط والمطبق في حزمة برمجيات ايرداس النسخة 9.2 .تستند الطريقة على تحويل المويجة لتحسين النوعية الطيفية للصورة ذات قابلية التحليل العالية.

**كلمات مفتاحيه :** دمج الصورة , الدمج , المويجات , قابلية التحليل المتعددة .

## Introduction:

There are many different algorithms for spatial feature manipulation of satellite imagery. Enhancement techniques include spatial filtering to sharpen or blur an image, convolution using a moving window, edge enhancement to enhance linear features without eliminating low frequency brightness, and Fourier analysis that operates in the frequency domain [1]. Image enhancement is the improvement of digital image quality (wanted e.g. for visual inspection or for machine analysis), without knowledge about the source of degradation. If the source of degradation is known, one calls the process image restoration. Image Enhancement techniques are instigated for making satellite imageries more informative and helping to achieve the goal of image interpretation. The term enhancement is used to mean the alteration of the appearance of an image in such a way that the information contained in that image is more readily interpreted visually in terms of a particular need. The image enhancement techniques are applied either to single-band images or separately to the individual bands of a multiband image set. This operation seeks to improve the appearance of image data as a way of assisting in visual interpretation and analysis. Remote sensing data has been use widely for land cover identification and classification of various features of the land surface from satellite or airborne sensor. Application of remotely sensed data for land cover and land use mapping and its changes is a key to many diverse applications such as environment, forestry, hydrology, agriculture, geology[2]. Image enhancement is the process of making an image more interpretable for a particular application. Enhancement makes important features of raw, remotely sensed data more interpretable to the human eye. Enhancement techniques are often used instead of classification techniques for feature extraction—studying and locating areas and objects on the ground and deriving useful information from images[3],[4].

## Resolution Merge:

Many types of satellite imagery include some bands that differ in spatial resolution from others. An example is the Landsat ETM+ with 6 reflective bands at moderate resolution (30 m) and a panchromatic band at higher spatial resolution (15 m). Several techniques allow us to combine data of different spatial resolutions to get some of the advantages of higher spatial resolution while not losing spectral resolution. Collectively these techniques are called “resolution merging” and in the case of combining a panchromatic band with multispectral bands it is called “pan sharpening.” These methods can be applied to combine bands from a single satellite with multiple spatial resolutions, like the ETM+, or to combine bands from multiple satellites with different resolutions. In the latter case one could combine, for example, a SPOT image with a Landsat TM image. The author will combine the ETM+ panchromatic and multispectral bands to create new pseudo high resolution bands (pan sharpened) of the study area. Image sharpening refers to algorithms designed to increase image resolution through the merging of co-registered multi-resolution datasets. The merge is achieved through the use of relatively high resolution imagery, frequently panchromatic, to enhance the visible details of a lower resolution multispectral color image. In the ERDAS Imagine interface, this type of spatial enhancement is called a resolution merge. Some image sharpening algorithms produce as many output bands as are contained in the multispectral dataset; others only produce three-band RGB composites. Data inputs can be from the same data source or from different sources. Satellite sensors such as SPOT, Landsat 7 ETM+, Quickbird, and Ikonos were designed to collect a high resolution sharpening band simultaneously with multispectral bands. Several new algorithms have been added to the Spatial Enhancement tools in ERDAS Imagine since version 8.7. This is encouraging since the three Resolution Merge options available in the previous version of the software were not optimal [5],[6],[7].

## Wavelet Transform:

Wavelet techniques are increasingly being used for the processing of images. The algorithm used in this paper was based on multiresolution wavelet decomposition. The image is decomposed into multiple channels based on their local frequency content, obtaining new images each one of them with different degree of resolution. Spatial and spectral qualities are the two important indices that are used to evaluate the quality of any fused image. Although some methods have been developed to assess the spatial quality, this is still a difficult topic to evaluate. The standard data fusion techniques distort the spectral characteristics of the multispectral data. The additive wavelet method improves the spatial quality of the multispectral image while preserving its spectral content to a greater extent. The Wavelet Transform method is appropriate to use for the sharpening of images collected by different sensors, such as active and passive systems, as well as for conventional image sharpening of contemporaneous high- and low-resolution bands. The ERDAS Imagine Field Guide, which offers a comprehensive explanation of the algorithm, mentions the possibility to merge radar with SPOT. The general principal of the wavelet transform method is that an image can be decomposed into its high-pass and low-pass components. Conversely, when added together, the high-pass and low-pass components can be used to reconstruct the original image. Through the use of pixel-based wavelets, a high resolution image is decomposed into a low-pass representation of the low-resolution image to be sharpened, retaining all generated high- and low-pass components. The process is reversed, with the actual low-pass input band, to construct a high-resolution multi-spectral image. Wavelet-based processing is similar to Fourier transform analysis. In the Fourier transform, long continuous (sine and cosine) waves are used as the basis. The wavelet transform uses short, discrete "wavelets" instead of a long wave. The ERDAS IMAGINE Wavelet Resolution Merge allows multispectral images of relatively low spatial resolution to be sharpened using a co-registered panchromatic image of relatively higher resolution. A primary intended target dataset is Landsat 7 ETM+. Increasing the spatial resolution of multispectral imagery in this fashion is, in fact, the rationale behind the Landsat 7 sensor design[8].

**Wavelet Theory:**

Wavelet-based image reduction is similar to Fourier transform analysis. In the Fourier transform, long continuous (sine and cosine) waves are used as the basis. The wavelet transform uses short, discrete "wavelets" instead of a long wave. In image processing terms, the wavelet can be parameterized as a finite size moving window. A key element of using wavelets is selection of the base waveform to be used; the "mother wavelet" or "basis". The "basis" is the basic waveform to be used to represent the image[9].

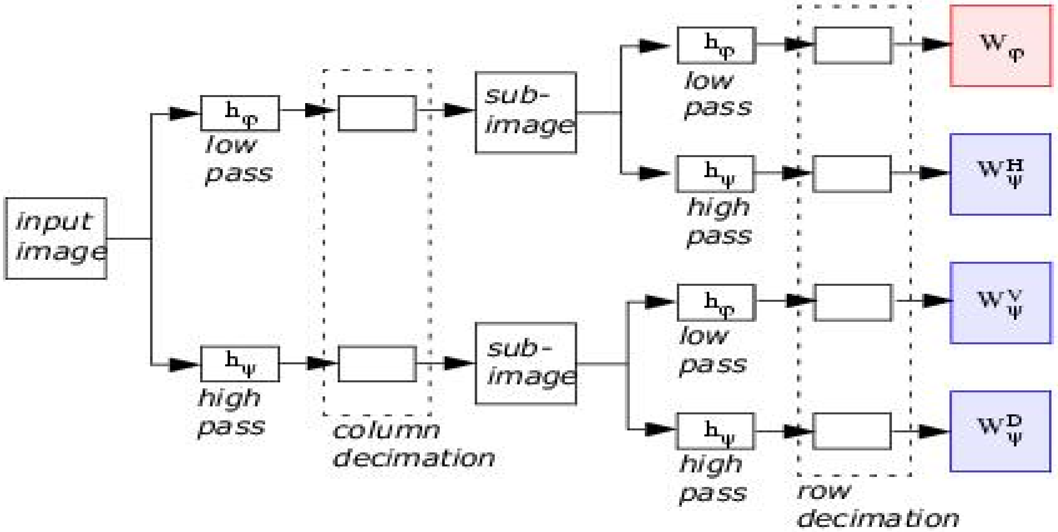

**Figure 1-** Schematic Diagram Of The Discrete Wavelet Transform.

The input signal (image) is broken down into successively smaller multiples of this basis. Wavelets are derived waveforms that have a lot of mathematically useful characteristics that make them preferable to simple sine or cosine functions. For example, wavelets are discrete; that is, they have a finite length as opposed to sine waves which are continuous and infinite in length. Once the basis waveform is mathematically defined, a family of multiples can be created with incrementally increasing frequency. For example, related wavelets of twice the frequency, three times the frequency, four times the frequency, etc. can be created. Once the waveform family is defined, the image can be decomposed by applying coefficients to each of the waveforms.

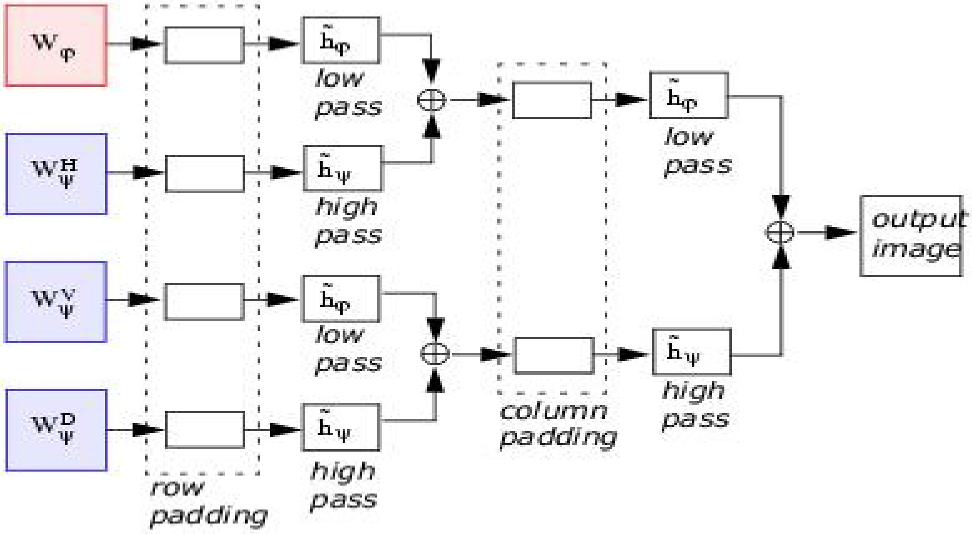

**Figure 2-** Inverse Discrete Wavelet Transform.

Consider two images taken on the same day of the same area: one a 5-meter panchromatic, the other 40-meter multispectral. The 5-meter has better spatial resolution, but the 40-meter has better spectral resolution. It would be desirable to take the high-pass information from the 5-meter image and combine it with the 40-meter multispectral image yielding a 5-meter multispectral image. Using wavelets, one can decompose the 5-meter image through several iterations until a 40-meter low-pass image is generated plus all the corresponding high-pass images derived during the recursive decomposition. This 40-meter low-pass image, derived from the original 5-meter pan image, can be replaced with the 40-meter multispectral image and the whole wavelet decomposition process reversed, using the high-pass images derived during the decomposition, to reconstruct a 5-meter resolution multispectral image. The approximation component of the high spectral resolution image and the horizontal, vertical, and diagonal components of the high spatial resolution image are fused into a new output image[4],[10],[11].

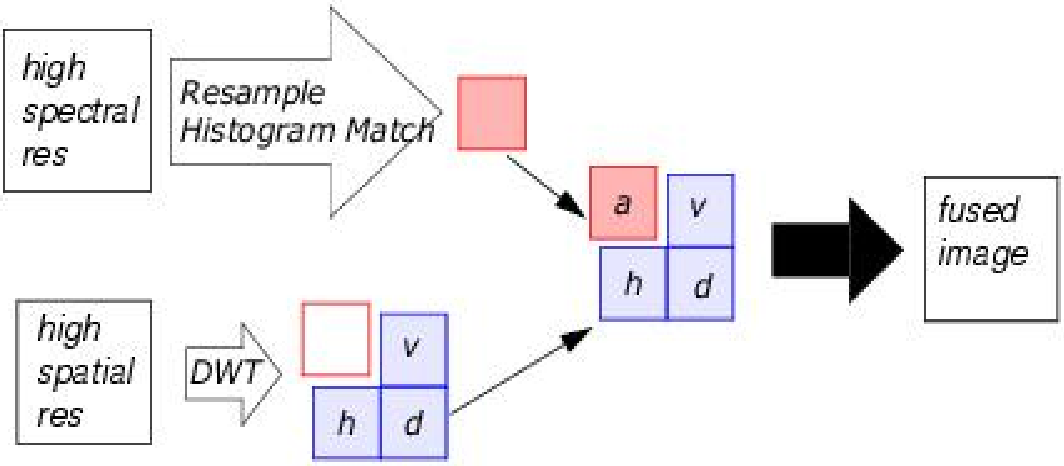

**Figure 3-** Wavelet Resolution Merge

**Study Area:**

For the single-sensor/single-date fusion of Landsat ETM+, a panchromatic image, recorded on 13/3/2005 is fused with its equivalent multispectral image. The study area is located in Iraq in the region of Al-Razzaza Lake in Karbala governorate. Figure (4) shows the panchromatic image of the study area with spatial resolution 15 meters, while figure (5) represents the multispectral image (6 bands) for the same area having resolution 30 meters.

**Figure 4-** Panchromatic Image.

**Figure 5-** The Multispectral Image.

## Results And Discussion:

A simple Wavelet Transform is used, which is implemented in the ERDAS Imagine Software package. For image fusion, a wavelet transform is applied to the panchromatic image resulting in a four-component image: a low-resolution approximation component (LL) and three images of horizontal (HL), vertical (LH), and diagonal (HH) wavelet coefficients which contain information of local spatial detail. The low-resolution component is then replaced by a selected band of the multispectral image. This process is repeated for each band until all bands are transformed. A reverse wavelet transform is applied to the fused components to create the fused multispectral image. Generally, wavelet fused images produce good spectral preservation but poor spatial improvement. A 30-meter resolution color composite is shown in Figure (5) illustrate the detail available before the resolution merge. The 15-meter resolution panchromatic band for this region is shown in Figure (4). The 15-meter image provides a clearer definition of the features such as the water, different soil types. Also apparent is a brighter and clearer rendition of sparsely vegetated surfaces around the area. Figure(6) represent the fused image with resolution 15 meters, while improved resolution (15 meters instead of 30 meters) did not increase our ability to discriminate finer thematic classes of vegetation, it did allow us to map smaller landscape features thereby avoiding some of the mixed pixel problem experienced with 30-meter imagery. Automated image classification requires multispectral bands to offer sufficient information to characterize land cover. In order to exploit the finer resolution of the panchromatic band for mapping at the local scale as well as the regional scale, the pan data must be merged with the multispectral data. While several merging techniques have been developed and finer resolution images rendered, their use for image classification has not been thoroughly investigated.

**Figure 6-** The Merged Image With Resolution 15 Meters.

Our objective was to compare the results of unsupervised classification for images, the original multispectral image and the resulting fused image. Sharpening an image to identify features that can be used for training samples requires a different set of enhancement techniques than reducing the number of bands in the study. You must have a clear idea of the final product desired before enhancement is performed. Many works have recognized the benefit of merging high spectral resolution (or spectral diversity) and high spatial resolution images, particularly in land mapping applications. Figures (7) and (8) display the result of unsupervised classification.

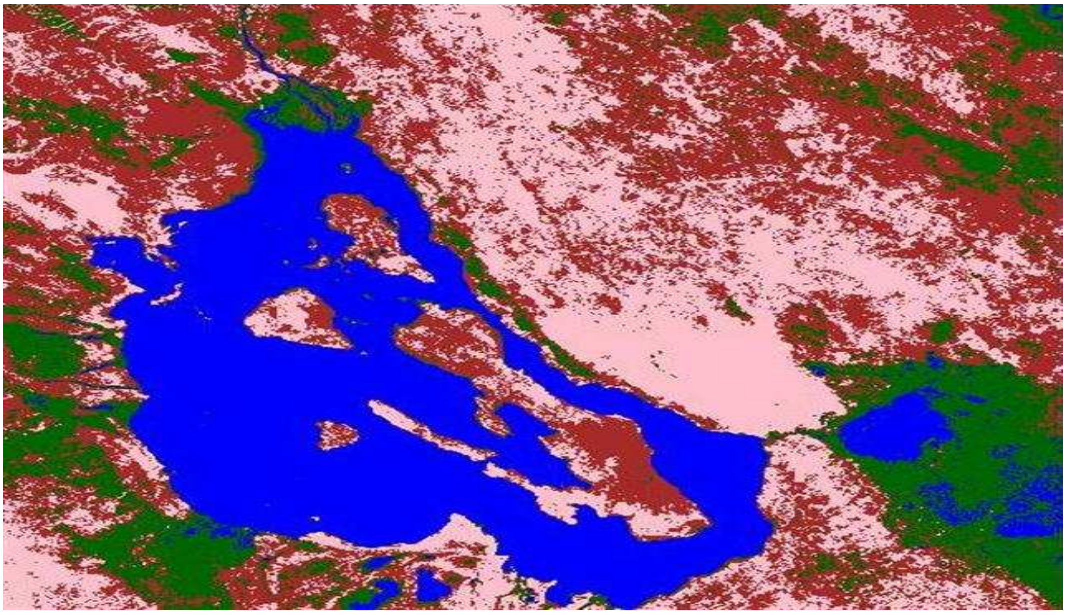

**Figure 7-** Unsupervised Classification Of The Original Multispectral Image.

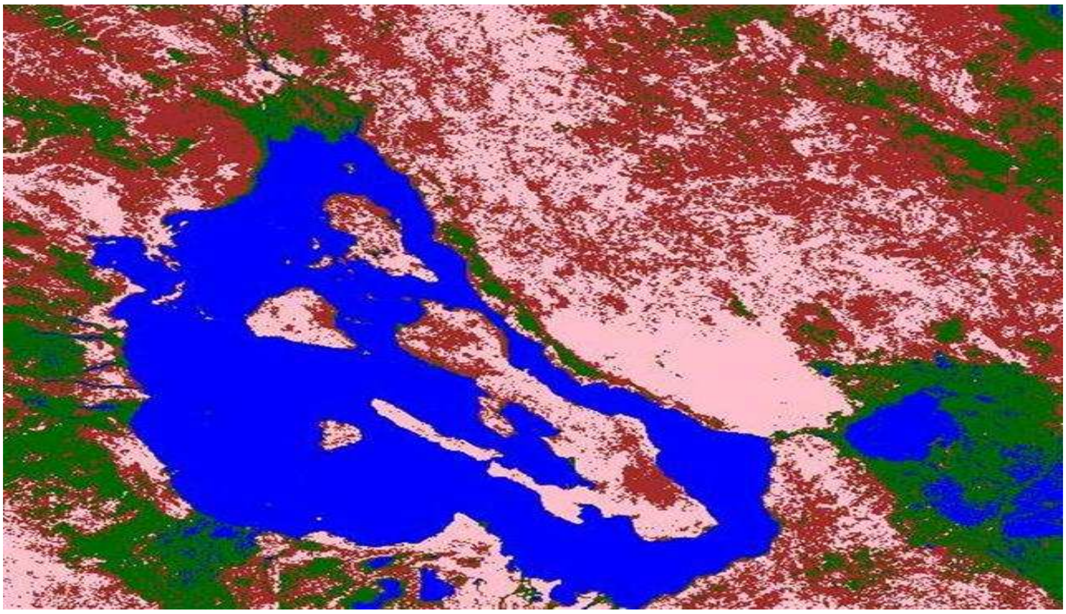

**Figure 8-** Unsupervised Classification Of The Merged Image.

There are small differences between the two thematic images; the results shown below represent the area of the four classes of the unsupervised classification method applied on both. For the image shown in figure (7) the area in hectares for the four classes are respectively as: Class (1): 98,060, Class (2): 60,000, Class (3): 144,100, Class (4): 120,070.

While for the image shown in figure (8) the area in hectares for the four classes are respectively as:

Class (1): 98,660, Class (2): 65,000, Class (3): 145,380, Class (4): 111,500.

**References:**

[1] Lillesand, Thomas M. and Ralph W. Kiefer, **2000**. Remote Sensing and Image Interpretation. 4th ed. New York, NY: John Wiley and Sons, Inc.

[2] Mohd,H., Pakhriazad H., Shahrin M., **2009**. Evaluating Supervised And Unsupervised Techniques For Land Cover Mapping Using Remote Sensing Data. Malaysian Journal of Society and Space **5** issue 1 (1 - 10).

[3] Jensen J.R. , **2005**. Introductory Digital Image Processing: A Remote Sensing Perspective, Upper Saddle River, NY, Prentice Hall.

[4] Leica Geosystems GIS & Mapping, LLC. **2003**. ERDAS Imagine Field Guide. Chapter 6: Enhancement. ERDAS Imagine Version 9.1.

[5] Chavez P.S, Sides S.C., and Anderson J.A., **1991**, Comparison Of Three Different Methods To Merge Multi-resolution And Multispectral Data: Landsat TM and SPOT Panchromatic. Photogramm. Eng. Remote Sensing, vol. **57**, no. 3, pp. 295-303.

[6] Welch, R. and Ahlers W., **1987**, Merging Multiresolution SPOT HRV and Landsat TM Data., Photogrammetric Engineering & Remote Sensing, **53** (3), pp. 301-303.

[7] Vrabel, Jim. **1996,** Multispectral Imagery Band Sharpening Study. Photogrammetric Engineering & Remote Sensing, Vol. **62,** No. 9, pp. 1075-1083.

[8] Lemeshewsky, George P. **1999**, Multispectral Multisensor Image Fusion Using Wavelet Transforms, in Visual Image Processing VIII,S. K. Park and R. Juday, Ed., Proc SPIE 3716: 214-222.

[9] Daubechies I., **1988**, Orthonormal Bases Of Compactly Supported Wavelets. Communications on Pure and Applied Mathematics, **41**, 909-996.

[10] Li H., Manjunath B. S., Mitra S. K., **1995**, Multisensor Image Fusion Using The Wavelet Transform. Graphical Models and Image Processing, **57**(3), 235-245.

[11] Zhou, J., D.L. Civco, and Silander J.A., **1998**, A Wavelet Transform Method To Merge Landsat TM and SPOT Panchromatic data. International Journal of Remote Sensing, 19, no. 4, 743–757.