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DWT – BASED IMAGE FUSION ON SATELLITE IMAGES

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***Abstract*—Satellite imaging system produces multisensory images. The sensors which are responsible for Red, Green, and Blue produce multispectral images and the pan sensor which produce grayscale image known as panchromatic images. To obtain true color image with high spatial and spectral resolution pan sharpening techniques are employed. Image fusion algorithms such as Hue Saturation Intensity method, Principal Component Analysis, Brovey Transform and Synthetic Variable Ratio are applied for panchromatic process. Though these techniques have high spatial resolution there is a problem of spectral distortion. To overcome this problem Discrete Wavelet Transform (DWT) based image fusion technique is proposed. This method extracts both spectral and spatial information from MS and PAN satellites images.**

***Index terms*— Multispectral (MS), Panchromatic (PAN), Spatial and Spectral Resolution.**

1. INTRODUCTION

Most of the earth observation satellite such as LANDSAT-7, IKONOS, SPOT-5, QUICKBIRD, GEO EYE-1, and WORLD VIEW-2 provide both PAN images with high spatial resolution and low spectral resolution and MS images with high spectral resolution and low spatial resolution. To make use of full spatial and spectral information image fusion techniques are applied in various remote sensing applications such as image classification, object detection and forest type mapping.

Image fusion is the process that combines information from multiple images of the same scene. The result of image fusion is a new image that retains the most desirable information and characteristics of each input image. The main application of image fusion is merging the gray level high-resolution panchromatic image and the colored low-resolution multispectral image. It has been found that the standard fusion methods perform well spatially but usually introduce spectral distortion. To overcome this problem DWT based image fusion method is proposed. This method extracts both spectral and spatial information from MS and PAN satellites images.

The overview of this paper consists of multisensor data fusion and its examples. Further the architecture of image fusion technique is explained.

A. MULTISENSOR DATA FUSION

This theme deals with combining different sources of information for intelligent systems. The information is signals delivered by different sensors and images from various modalities. The fusion concepts and methods gather tools like weighted average, neural networks, sub-band filtering, and rules based knowledge. More recently, fuzzy logic and graph pyramids have been used. The categories of Sensor Data are as follows

- One dimensional signals (analog, digital, logic)
- 2- or n-D arrays such as images or radiation field
- Procedural information, such as text, speech, software, behavioral rules

Table I: Examples of image fusion combination

Sensor1	Sensor2	Effect
TV	IR	Penetration, day/night
MMW	IR	Penetration, discrimination
TV	Laser(high-power)	Induced vibration signatures
IR	UV	Background discrimination
Multi-spectral	Panchro	Discrimination features and context
ALL	Digital terrain map	Discrimination and location
Laser(pulsed)	TV/IR	Thermal signature
TV	SAR	Mapping

The types of Multisensor Fusion are Signal-level fusion, Image-level fusion, Feature-level fusion and Symbol-level fusion. Produce a single image from a set of input images. The fused image should have more complete information which is more useful for human or machine perception. The development of wavelet theory, people began to apply wavelet multiscale decomposition to take the place of pyramid decomposition for image fusion. Actually, wavelet transform can be taken as one special type of pyramid decompositions. It retains most of the advantageous features for image fusion. Since wavelet transform provides space-frequency decomposition of images. By this property DWT allows energy compaction at the low-frequency subbands and the space localization of edges at the high-frequency subbands.

2. RELATED WORK

A Robust Image Fusion Method Based on Local Spectral and Spatial Correlation [1]has a solution of spectral and spatial correlation (SSC)-based synthetic variable ratio (SSCSVR) to remove the spectral distortion of fused image while preserving the spatial characteristic of the PAN image. First, the regression model of the SVR is improved with a spatial correlated component. Second, they adopted a modified localized adaptive processing strategy to better preserve the spectral information.Implementation of Hybrid Image

Fusion Technique Using Wavelet Based Fusion Rules [2] adopted a novel approach to decompose the original images into high and low frequencyParts to the smallest pixel and then fuse both the parts separately using same fusion rules to get an accurate, high resolution image with preserved spectral characteristics. It is focused on Multi resolution Image Fusion techniques based on pixel level fusion methods. Multi Resolution fusion uses pyramid or wavelet transform at multi scale for the representation of the source images.

An Optimized Approach for Pansharpening Very High Resolution Multispectral Images [3] was described to avoid explicitly modeling the detail injection process. The fusion performances severely rely on the accuracy of the modeling and the estimation of model parameters. The solution employs the gradient field of the Pan image for spatial enhancement. The low-pass (LP) version of the fused bands is constrained to be the most similar to the original MS bands to preserve the spectral characteristics. Here the local correlation coefficients between the MS band and the LP version of the Pan image is used to adjust the two sources based on a simple observation.

Problems in the fusion of commercial high resolution satellite images as well as Landsat 7 images and initial solutions [4] explained about currently available image fusion techniques are not efficient for fusing the new satellite images such as IKONOS and Landsat 7. Significant color distortion is one of the major problems. Reasons for this distortion are analyzed in this paper. A new initial automatic solution for fusing the new images is introduced. The new solution has reached an optimum fusion result with minimized color distortion and maximized spatial detail.The initial fusion technique has been tested with many IKONOS and Landsat 7 data sets covering different areas. The sizes of some data sets were more than 10,000 by 10,000 pixels.

3. IMAGE FUSION USING WAVELET TRANSFORM

The block diagram of a generic wavelet-based image fusion scheme is shown in the following figure 1. Wavelet transform is first performed on each source images, and then a fusion levels will have smaller size. The fused wavelet coefficient map can be constructed from the wavelet coefficients of the source images according decision map is generated based on a set of fusion rules. The frequency bands in higher decomposition to the fusion decision map. Finally the fused image is obtained by performing the inverse wavelet transform.

A. FUSION RULES

When constructing each wavelet coefficient for the fused image its necessary to determine which source image describes this coefficient better. This information will be kept in the fusion decision map. The fusion decision map has the same size as the original image. Each value is the index of the source image which may be more informative on the corresponding wavelet coefficient. Thus, decision will be made on each coefficient.

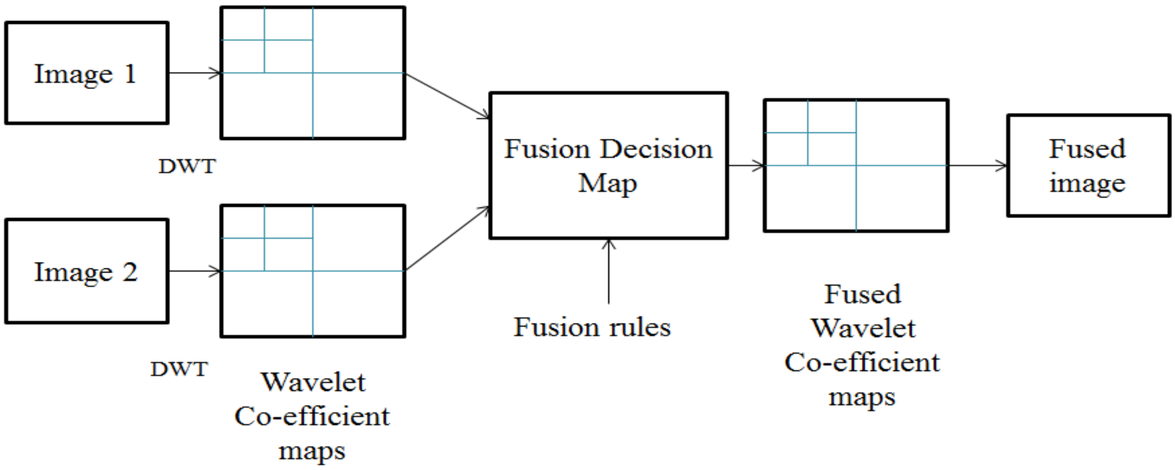

Fig 1: Block diagram of a generic wavelet-based image fusion approach

There are two frequently used methods in the previous research. In order to make the decision on one of the coefficients of the fused image, one way is to consider the corresponding coefficients in the source images as illustrated by the red pixels. This is called pixel-based fusion rule. The other way is to consider not only the corresponding coefficients, but also their close neighbors, say a 3x3 or 5x5 windows, as illustrated by the blue and shadowing pixels in figure 2. This is called window-based fusion rules. This method considered the fact thatthere usually has high correlation among neighboring pixels.

The basic fusion rule is shown in figure 2. The source images are converted to frequency domain using wavelet transform. The obtained wavelet coefficients from this transform technique are subject to fusion process. There are two types of fusion rules are applicable. They are pixel based fusion rules and window based fusion rules. In the prior one each and every pixel are treated individually. In the later one block of pixels are considered.

Objects carry the information of interest, each pixel or small neighboring pixels are just one part of an object. Thus region-based fusion scheme is proposed. When make the decision on each coefficient, not only the corresponding coefficients and their closing neighborhood, but also the regions the coefficients are considered. The regions represent the objects of interest.

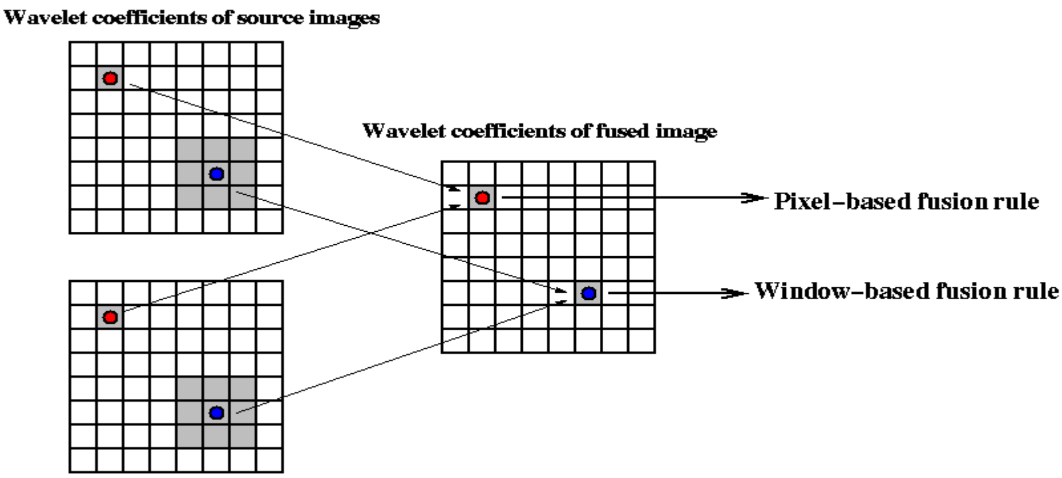

Fig 2: Basic Fusion Rule

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B. COEFFICIENT COMBINING METHODS

Selection and averaging are probably the most popular coefficient combining methods. Selection method can collect the largest DWT coefficients between two images. Therefore, it is suitable for collecting the edges or corners, i.e. detailed information. Averaging method is employed while the DWT coefficients between two images are both important. Therefore, averaging method is suitable for combing the low-frequency bands because the approximation images of the images to be fused usually look similar.

The first step is selection. The simplest selection method is choose-max (CM), in the high-frequency bands (H11, H12, H13, H21…), the larger DWT coefficients correspond to sharper brightness changes and thus to the salient features in the image such as edges, lines, and region boundaries. Therefore, the CM method is useful in the collection of the detailed information. In multifocus image fusion, the input images PANand MShave diffident regions out of focus. It is obvious the detailed DWT coefficients of the out-of-focus region in PANwould be smaller than those of the corresponding region in MS. Thus, the CM scheme is very suitable for merging the detail information of PANand MS.

The second step is General weighted average. For each pixel, the composite is obtain by the weighting factors wX(pan) and wY(ms) can be deterministic or dependent on the activity levels of both images, are obtained by WA-WBA method, and as the normalized cross-correlation between PANand MSover a neighborhood of pixel is defined. If the cross-correlation is too small, it implies that the regions neighboring pixel in PAN and MSare quite different, and thus CM method is used. If is larger, the average of the DWT coefficients with weights dependent on the cross-correlation is considered. The WA method is useful for merging the LL bands of PAN and MSbecause the approximation images usually looks similar, i.e. have high cross-correlation. However, since the DWT coefficients in high-frequency bands would have negative values, the WA may introduce the pattern cancellation problem if employed in high-frequency bands.

The third step is Adaptive weighted average (AWA). The AWA scheme is a special WA scheme that the weight is not deterministic or dependent on the cross-correlation but only relevant to the neighborhood around pixel. Simply speaking, the weight represents the degree of interest of pixel. For example, the warmer and cooler pixels in the thermal image will be assigned larger weights. Thus, the AWA scheme is useful to distinguish objects having special characteristics compared to their neighborhoods.

Among the various image fusion methods region based image fusion is adopted. Since satellite images are very big in size and comprised of several regions. In order to process such large size image region based method is used. Satellite images are preprocessed before it undergone wavelet transform. This Preprocessing includes edge detection and region based segmentation. PAN images are bigger than MS image. One pixel in MS image corresponds to four pixels in PAN image if the MS to PAN ratio is 1:4.

C. REGION-BASED IMAGE FUSION

Here are some key points of region-based image fusion approach:

- Consider each pixel as part of object or region of interest
- Use image features, such as edges and regions to guide the fusion
- Retrieve both spatial and frequency information from the wavelet coefficients.

First apply canny edge detection on the LL band of the wavelet coefficient maps of the source images.

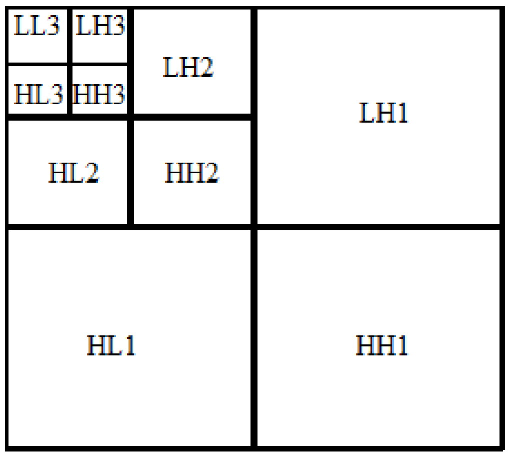

Fig 3: Two Level Wavelet Decomposition

The results are the edge images which provide the location and intensity of edges in the source images. Next, perform region segmentation using the edge information. The output is region images, in which different values represent different regions. Then, the activity levels of each region are obtained by averaging the high-frequency wavelet coefficients, which may be more informative. Thus, generate the region activity tables. The larger activity value mean more informative of the region. Based on the edge and region image and the region activity table, we apply the following fusion rules to compute the fusion decision map.

- High activity level preferred over low activity level
- Edge points preferred over non-edge points
- Small regions preferred over large regions
- Make decision on non-edge point first and consider their neighbors when making the decision on edge points
- Avoid isolated points in decision map

Based on this fusion decision map, we can construct the fused wavelet coefficient map, and then obtain the fusion image by inverse wavelet transform.

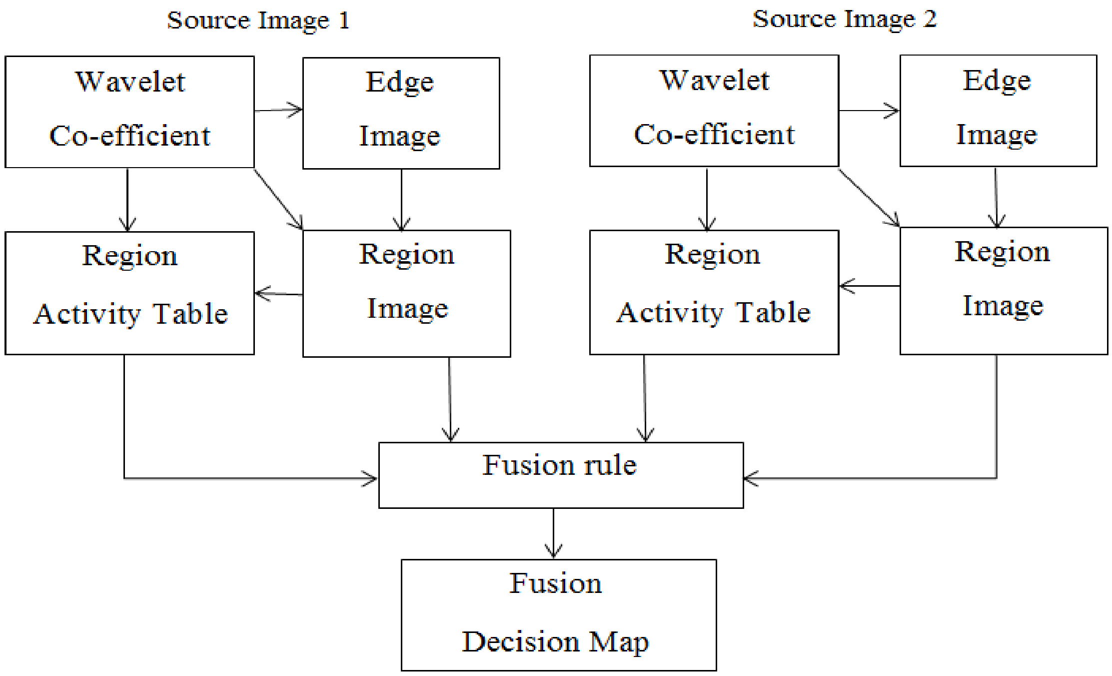

Fig 4: Illustration for creating the decision map

4. CONCLUSION

In this paper Discrete Wavelet Transform based image fusion method is proposed. The architecture and fusion rules adopted in this method shows that this fusion methodology performs spatially as well as spectrally well. Each pixel of MS and PAN images are treated individually to get the accurate fusion results.

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