

# Merging SPOT XS and SAR Imagery Using the Wavelet Transform Method to Improve Classification Accuracy

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**Abstract** - SPOT XS imagery is often used to generate land use categories. Foresters, urban planners, environmental engineers, environmental scientists, and other researchers then use the resulting land use categories. State of the knowledge research in remote sensing attempts to improve the accuracy of classification techniques. This study examines the effectiveness of the Wavelet technique for the fusion of SAR (Synthetic Aperture Radar) and SPOT XS imagery before classification. The Wavelet technique least distorts the spectral characteristics of the SPOT XS imagery while combining with the SAR imagery. A maximum likelihood algorithm is then employed for the fused data and SPOT XS data alone. Comparison using the same accuracy assessment data reveals differences in classification. Complementary characteristics of the SPOT XS and SAR imagery improve the classification accuracy.

## INTRODUCTION

Wavelets are a mathematical tool for hierarchical decomposing functions. Although wavelets become more popular in recent years, their roots go back to Karl Weierstrass's work in 1873 [1]. After many successful applications in signal processing, physics, and approximation theory, wavelets have also been accepted as a powerful image processing technique among the remote sensing society. Wavelet theory has been applied to data compression, speckle removal in SAR imagery, analysis of remotely sensed images [2], automated geometrical registration of the images, and data fusion [3], [4].

The motivation behind *data fusion* is to generate an interpretation of the scene not obtainable with data from a single sensor, or to reduce the uncertainty associated with the data from individual sensor [5]. Data fusion is a procedure that is the combination of information of multiple sources as to the identity of an object [6]. Wald defined data fusion as a formal framework in which are expressed means and tools for the alliance of data originating from different sources [7]. Another definition of *data fusion* is given as "*data fusion is a process dealing with data and information from multiple sources to achieve refined/improved information for decision making*" [8].

Many terms have been used for the term '*data fusion*' in the literature such as merging, combination, and integration. The term '*Image Fusion*' has been used by Pohl and Genderen and their definition is given as "*Image fusion is the combination of two or more different images to form a new image by using a certain*

*algorithm*" [9]. David A. Yocky has used the term 'Image Merging'. His definition for *image merging* is given as "*Image merging refers to image processing techniques that combine image sets from two or more sensors, forming an enhanced final image*" [4].

For classification, reducing the classification error rate obtained by single source classification is the major goal of fusing data from different sensor [10]. It should be remembered that selection of data sets and fusion techniques is the key behind the success. This study was intended to improve classification accuracy using a wavelet fusion technique. The objectives include:

- to complement data sets for improved classification. Because of the complementary characteristics of the radar data, an improvement is expected in classification accuracy.
- to create a better fusion technique,
- to compare two fusion techniques in terms of classification accuracy; PCA method, and Wavelet method.

## DATA ACQUISITION AND STUDY AREA

The SAR and SPOT XS images were provided by SERTIT. The SPOT XS data were collected on July 22 1996 (©CNES '1996' -Processing SERTIT). SAR data (© ESA '1994' - Processing SERTIT) are the sum of two ERS-1 C-Band (frequency range: 3.9-6.2 GHz; wavelength range: 3.8-7.6 cm) images that were acquired on May 22, 1994 and October 17, 1994 respectively. The study area is in France.

## WAVELET TRANSFORMATIONS

The objective is to build a set of basis functions and transforms that will give a descriptive, effective, and beneficial description of a signal. Moreover, wavelets provide efficient localization in both time and frequency or scale when the signal represented as a function of time [11].

So, what is a wavelet transform? A signal can be stated a linear decomposition by

$$f(t) = \sum \alpha_l \psi_l(t) \quad (1)$$

where  $l$  is described as an integer index for the finite or infinite sum,  $\alpha_l$  are the real-valued expansion coefficients, and  $\psi_l(t)$  are the expansion set. If the expansion (1) is unique, the set is called a *basis* for the class of functions that can be so expressed. If there is orthogonality which can be expressed as

$$\psi_k(t), \psi_l(t) = \psi_k(t)\psi_l(t) dt=0 k \neq l, \quad (2)$$

then using the inner product, the coefficients can be calculated

$$\alpha_k = \int \psi_k(t) f(t) dt, \quad \psi_l(t) = f(t) \psi_l(t) dt. \quad (3)$$

Aftermath single  $\alpha_k$  coefficient can be calculated by substituting (1) in to (3) and using (2). A dual basis set  $\tilde{\psi}_k(t)$  exists where the basis is not orthogonal, if so using (3) with the dual basis gives the desired coefficients. For the *wavelet expansion*, creation of a two-parameter system (using (1)) gives

$$f(t) = \sum_j \sum_k \alpha_{j,k} \psi_{j,k}(t) \quad (4)$$

where both  $j$  and  $k$  are integer indices and the  $\psi_{j,k}(t)$  are the wavelet expansion functions that usually form an orthogonal basis. The set of expansion coefficients  $\alpha_{j,k}$  are called the *discrete wavelet transform* of  $f(t)$  and equation (4) is the inverse transform. [11]

## METHOD

### A. Data Preprocessing

Usually radar data comes with speckle noise. The effect of speckle in SAR images is a result of interaction of the coherent electromagnetic wave with a surface [12]. Several filter options (Mean, Median, Lee-Sigma, Local Region, Lee, Frost, and Gamma-MAP) exist in ERDAS IMAGINE software to suppress speckle effect. Lee-Sigma filter was chosen to perform speckle suppression in this project. Despite the data used for this experiment have already been geo-corrected, the digital images (SAR and SPOT XS) were geometrically registered to each other. This step with resampling were done in ERDAS IMAGINE to minimize positional error. SAR imagery was further resampled to 10-meter pixel size with using the Cubic Convolution method.

Final step for the data preparation before the fusion in ERDAS IMAGINE was creation of three radar images whose histograms were matched to the histogram of each SPOT XS band to assure data compatibility.

### B. Two-Dimensional Wavelet Transform and Data Fusion

To implement the transform, rather than using complex formulas directly,  $h$  and  $g$  (low and high-pass) filters are used. To illustrate this procedure, let us begin showing how filtering works (Fig. 1):

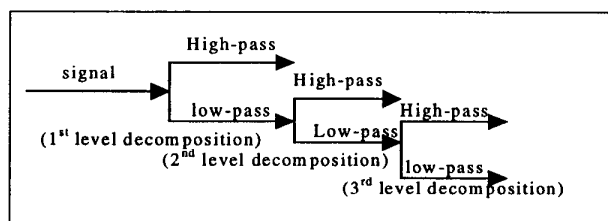


Fig. 1 Upper branches are high-pass ( $g$ ) filtering, and lower branches are low-pass ( $h$ ).

At every scale, the low-pass residue is placed at the top-left corner of the corresponding sub-image, the horizontal high frequency band at the top-right, the vertical high frequency band at the bottom-left and the diagonal high frequency band at the

bottom-right (Fig. 2). Every successive wavelet sub-image substitutes the residue of the previous scale.

First scale wavelet transformation were then performed to all three radar images, whose histograms were matched to SPOT XS bands, in order to get horizontal, vertical, and diagonal details

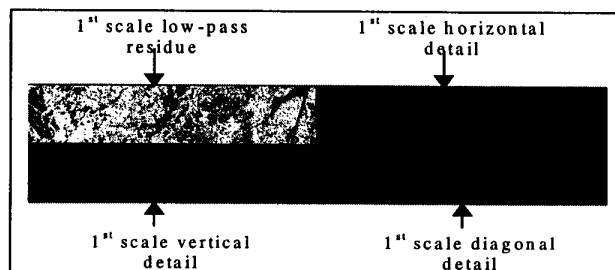


Fig. 2 First scale decomposition of SAR imagery using wavelets.

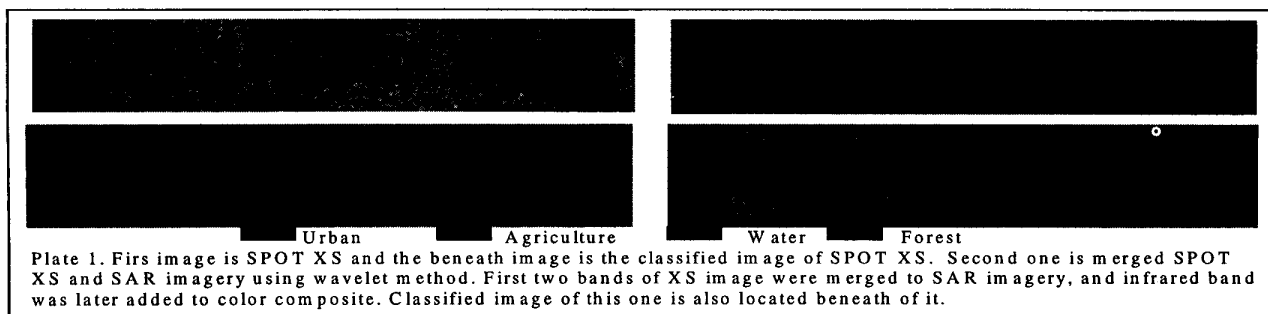
present between 10 meter and 20 meter spatial resolutions. After extracting those details, the final step was the injection of those details into each SPOT XS band. In another word, low-pass residues of the SAR images were replaced by each SPOT XS band. Then, inverse wavelet transform was performed with synthesis filters.

Consequently, two new SPOT XS images were produced at 10-meter spatial resolution with this method. The spectral characteristics of the XS were conserved because only the details between 10-meter and 20-meter resolution from SAR imagery have been added. Second image was created using only two bands of the XS. Blue and green bands were fused with the radar data leaving out red band. Red band was later undersampled to 10-meter resolution and added to color composite (Plate 1, Image 2). Red band was left out because it introduced some noise to the first image. Third image was produced using Principal Component Analysis (PCA) fusing technique. The PCA was (usually) performed in three steps; derivation of the variance-covariance matrix, computation of the eigenvectors, and linear transformation of the data set. In this method, the image channels of different sensors were combined into one file and PCA was calculated from all the channels.

SPOT XS image and fused images were classified into four land-use/land-cover classes using supervised classification technique with maximum likelihood classifier. Those classes were forested area, water bodies, agricultural land, and urban (or developed) area.

## RESULT AND DISCUSSION

First visual evaluation of the fused images gave the impression that PCA method was better than the wavelet technique. Especially, noise introduced by SAR imagery to SPOT XS imagery through wavelet transformation method made this impression strong. Those noises distinctively were focussed over forested areas, water bodies and hillsides. We injected the details from radar image to SPOT XS image, thus introduction of the noises where over the strong backscattering occurring areas were



unavoidable. Majority of the noise occurrence was on the infrared (IR) band. Because of this phenomenon, another fusion process was carried on, but this time only first two XS band were fused with SAR and IR band was later added to color composite. The image produced in this way had a lot less noises than the first image, but still had some noise and undefined pixel on it.

Initial classification accuracy results showed that overall accuracy for the image fused with PCA method was 84 percent. It was 87 percent for the first image fused with wavelet (all xs bands were fused), but was almost equal, around 94 percent for the xs alone and the second image fused with wavelet (IR band was not merged with radar data). This was partly due to strong classifier characteristics of the infrared band.

SAR systems use side-looking geometry, for that reason on the mountainous terrain, hills have both strong DN (Digital Number) value and weak (hill shadows) DN values. Usually these areas cause misclassification (mostly with water). Because of this negative effect of radar data, there has been some misclassification over forest cover with water class on the left side of the fused images (Plate 1, Image 4).

### CONCLUSION

Wavelet transformation technique is rather a new method compare to the others, but it has a big advantage over the other techniques is that it less distorts spectral characteristics of the images. It is especially good fusion technique to fuse multispectral /high-resolution data since the technique is based on the introduction of details present between spatial resolution difference of the data pairs (i.e., as in SPOT PAN/ XS fusion example, details of the PAN image present between 10 and 20 meters were injected to XS image [3]). Wavelet technique did good performance in terms of the classification accuracy in our experiment, although introduction of the noise to the final image was undeniable because of the characteristics of the radar data and the technique itself. Off course, selection of the fusion method always depends on the study objective and data type for the earth resource management applications.

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