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Texture Image Fusion on Wavelet Scheme with Space Borne High Resolution Imagery: An Experimental Study

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Abstract : Wavelet transform and its inverse processing provide the effective framework for data fusion. The purpose of this study is to investigate applicability of wavelet transform using texture images for the urban remote sensing application. We tried several experiments regarding image fusion by wavelet transform and texture imaging using high resolution images such as IKONOS and KOMPSAT EOC. As for texture images, we used homogeneity and ASM (Angular Second Moment) images according that these two types of texture images reveal detailed information of complex features of urban environment well. To find out the useful combination scheme for further applications, we performed DWT(Discrete Wavelet Transform) and IDWT(Inverse Discrete Wavelet Transform) using texture images and original images, with adding edge information on the fused images to display texture-wavelet information within edge boundaries. The edge images were obtained by the LoG (Laplacian of Gaussian) processing of original image. As the qualitative result by the visual interpretation of these experiments, the resultant image by each fusion scheme will be utilized to extract unique details of surface characterization on urban features around edge boundaries.

Key Words : High-resolution imagery, Image Fusion, Texture, Wavelet Transformation.

1. Introduction

In recent, interests on data fusion issues are increasing owing to the general availability of multiple sensor/sources images and the practical necessity of target-based secondary information from them. Among several fusion methods, the wavelet scheme provides the effective framework. In remote sensing applications, data fusion based on the wavelet scheme has been mainly used to combine multi-resolution images obtained from different sensors in the same coverage area or compress large sized image (Carr, 2004; Pajares and Cruz, 2004). The previous works of wavelet based texture image processing were focused on classifying multi-level images followed by texture measures and segmentation of wavelet coefficients (Arivazhagan and Ganesan, 2003; Myint, 2003).

But there are few attempts the fusion of original image and texture image using the wavelet scheme. So, we proposed a new approach based on the wavelet

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scheme and the texture image processing to help for interpretation the urban environment, as one of the useful applications with high-resolution imagery.

In this study, the experiments related to fusion of the wavelet transformed texture images were performed with actual imageries of IKONOS and KOMPSAT. First, we produced homogeneity and ASM (Angular Second Moment) image, as texture image representing surface features of road pavement. The edge also was extracted from original image by well-known LoG operation. We decomposed space borne imagery and its texture image using Discrete Wavelet Transform (DWT), accomplished Inverse Discrete Wavelet Transform (IDWT) based on image fusion scheme and added edge to the resultant image of IDWT. The experiments in this study were carried out as following 4 cases, and the results were presented: (1) fusion of three H bands of an original image and LL band of texture image, (2) Texture image with edge image (3) fusion of LL band of original image and three H bands of texture image and adding edge image, and (4) fusion of original three H bands and texture LL band with edge image.

2. Overview of Applied Scheme

In this study, the wavelet scheme and the texture imaging process were applied. We also extracted an edge image from an original image to add the edge component on IDWT resultant image or fused image. In this section, the basic schemes, applied to implement new program, are overviewed: Wavelet scheme, Texture image by Gray Level Co-occurrence Matrix (GLCM) and Laplacian of Gaussian (LoG) operation.

1) The Wavelet Scheme

The discrete wavelet transform (DWT) is known to one of the most useful techniques for multi -resolution image analysis. Furthermore, the wavelet scheme composed of the wavelet transformation and its inverse transformation provides a powerful and flexible set of tools for handling problems in noise removal, signal or image compression, object detection, image enhancement and so on (Mallat, 1989).

Wavelets are functions satisfying a linear combination of different scaling and translation of a wave function (Fig. 1). As well, a wavelet is used as a basis function in representing and analyzing target functions given, like sinusoidal functions in Fourier analysis. The basic of the wavelet scheme is to represent an arbitrary signal or image as a superposition of wavelets. By this superposition process, it can be decomposed the given function into different quad-scale levels (Antonini *et al.*, 1992). One-dimensional signals are represented by translations and dilations of the wavelet, $\psi(\frac{x-b}{a})$,

$$f(a, b) = \frac{1}{|a|^{1/2}} \int \psi(\frac{x-b}{a}) f(x) dx \quad (1)$$

where a and b represent translation and scaling parameter, respectively.

This function can be extended to 2 D image processing.

In general, the wavelet decomposition can be implemented using two channel filter banks composed of a low-pass and a high-pass filter, and each filter bank is then sampled at a half rate of the frequency at the upper level (Fig. 2(a)). By repeating this procedure or

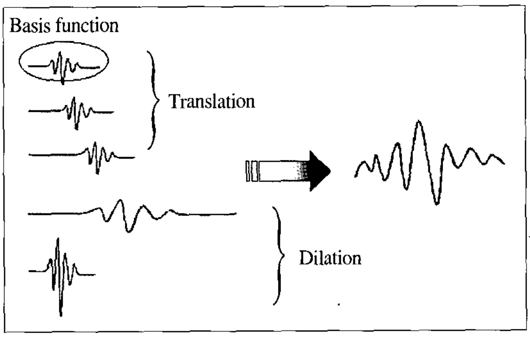


Fig. 1. The concept of 1-D wavelet transforms.

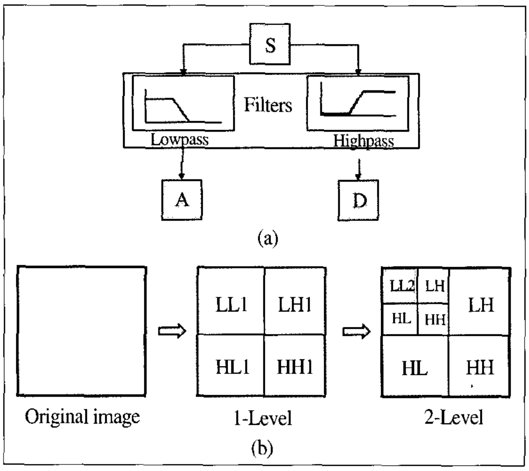


Fig. 2. (a) A two-band filter bank for one dimensional signal, (b) The wavelet decomposition according to down level.

down leveling, it is possible to perform the wavelet transformation of any level. As shown in Fig. 2(b), the down-sampling procedure preserves the scaling parameter constant (n = 1/2) throughout successive wavelet transformation so that it enables a relatively simple computation. The 2D image filtering can be performed along the line-direction filtering and column-direction filtering. As a consequence, an original image can be decomposed into four sub quad-images,

- *LL: Both horizontal and vertical directions have low-frequencies.*
- *LH: The horizontal direction has low-frequencies and the vertical one has high-frequencies.*
- *HL: The horizontal direction has high-frequencies and the vertical one has low-frequencies.*
- *HH: Both horizontal and vertical directions have high-frequencies.*

In this study, DAUB4, as the wavelet basis, was applied and it is known to one of basis functions for the wavelet processing (Huang and Dai, 2004).

2) GLCM-Based Texture

In remotely sensing image analysis and interpretation, texture terms the variability or uniformity of image tone or color (Avery and Berlin, 1992). It can be characterized by the spatial distribution of the gray levels in a neighborhood. Land covered features are composed of various materials so that this is regarded as a useful method for urban remote sensing.

Texture image processing based on second order statistics contains the initial step for grouping of neighborhood pixels. For this purpose, the GLCM (Gray Level Co-occurrence Matrix) uses a tabulation of how often different combinations of pixel brightness values occur in an image (Lee, Jeon, and Kwon, 2005).

GLCM texture imaging needs to consider the relationship between two neighboring pixels in one offset, as the second order texture. Second order measures consider the relationship between groups of two pixels in the original image, and it should be considered the relationship between pairs of pixels in the kernel after transformation to gray image. The kernel is moved through the data, and at each point the textural measure is evaluated. While, general GLCM texture measure depends on size of kernel mask, direction and type of parameters such as contrast, entropy, energy, dissimilarity, angular second moment (ASM) and homogeneity. Among texture measures, contrast and dissimilarity are effective for extracting edge. Meanwhile, Homogeneity and ASM are effective to search for delicate difference of pixel value, which is invisible in original image.

3) Laplacian of Gaussian (LoG) Operation

Laplacian filters are derivative filters used to find areas of rapid change (edge) in images. Since derivative filters are very sensitive to noise, it is common to smooth the image (e.g., using a Gaussian filter) before applying the Laplacian. This two-step process is calling the Laplacian of Gaussian (LoG) operation. To include a smoothing Gaussian filter, combine the Laplacian and Gaussian functions to obtain a single equation:

$$\mathrm{LoG}(x, y) = -\frac{1}{\pi\sigma^4}\left[1 - \frac{x^2+y^2}{2\sigma^3}\right]e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{2}$$

In this approach, random noises are reduced by convoluting the image with a Gaussian filter and isolated noise points and small structures are also filtered out. With smoothing; however; edges are spread. Those pixels, that have locally maximum gradient, can be extracted as edges by the edge detector in which zero crossings of the second derivative are used. To avoid detection of insignificant edges, only the zero crossings, whose corresponding first derivative is above some thresholds, are selected as edge point. The edge direction is obtained using the direction in which zero crossing occurs. If the original image is filtered by Laplacian operator, the resulting output is rather noisy. On the other hand, using a larger σ for the Gaussian will affect to reduction of the noise with less sharpening effect. By the way, LoG operation can be applied both for sharpening edges and for decreasing noise.

3. Experiments and Discussion

Three types of different spatial resolution images were used at the experiments in this study: IKONOS 1 m GeoTiFF 8bit PAN, standard geometrically corrected, acquired from ISPRS sample image sets (Fig 3 (a)), IKONOS image (Fig. 3 (b)) and KOMPSAT 6.6 m panchromatic imagery (Fig. 3(c)). IKONOS and KOMPSAT image are covered with regions around Gwangju-city and Namyangju-city bordered with Seoul, Geounggi-do, respectively.

In this study, the computer program was newly developed to test the wavelet transformations of original image and texture image (Fig. 4), This program contains the functions of the wavelet transformation of DWT, edge detection (LoG operation), edge addition and fusion by IDWT.

1) Preparing Image

Especially, ASM and homogeneity among several

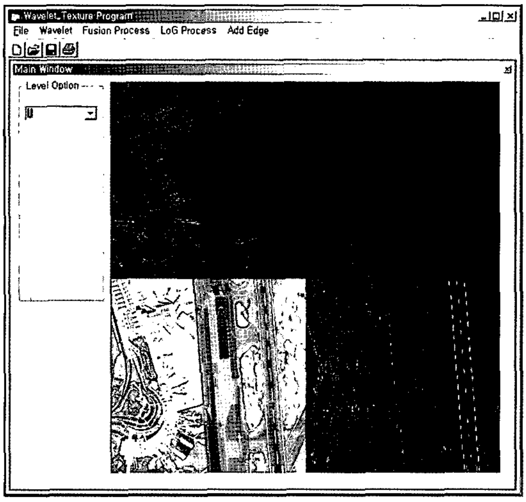
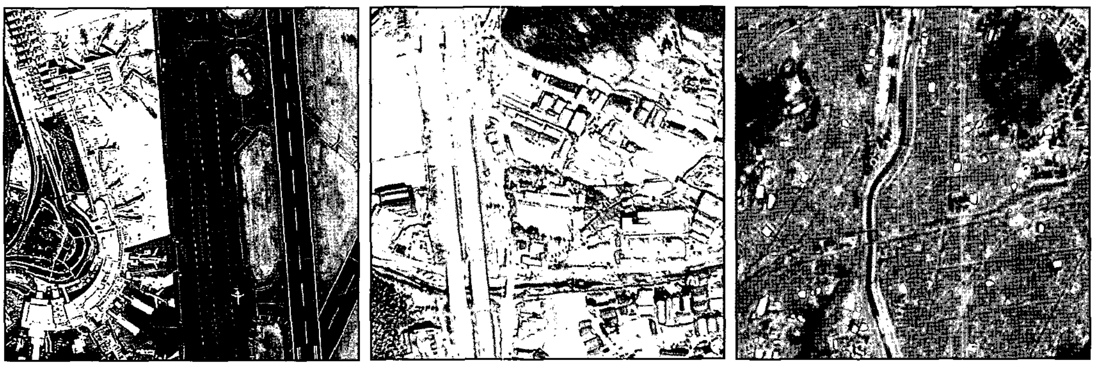


Fig. 4. The main frame of the implemented program.



(a) (b) (c)

Fig. 3. The test dataset: (a) IKONOS PAN 1 M, ISPRS sample image, (b) IKONOS 4M Color image, and (c) KOMPSAT PAN image.

available texture parameters qualitatively reveal the detailed surface characteristics of urban features such as road pavement condition or material types. As the target data image prior to executing the wavelet transformation and data fusion, it is considered these two texture images as the complimentary urban image. Besides, the edge image using the LoG processing is generated from the original image.

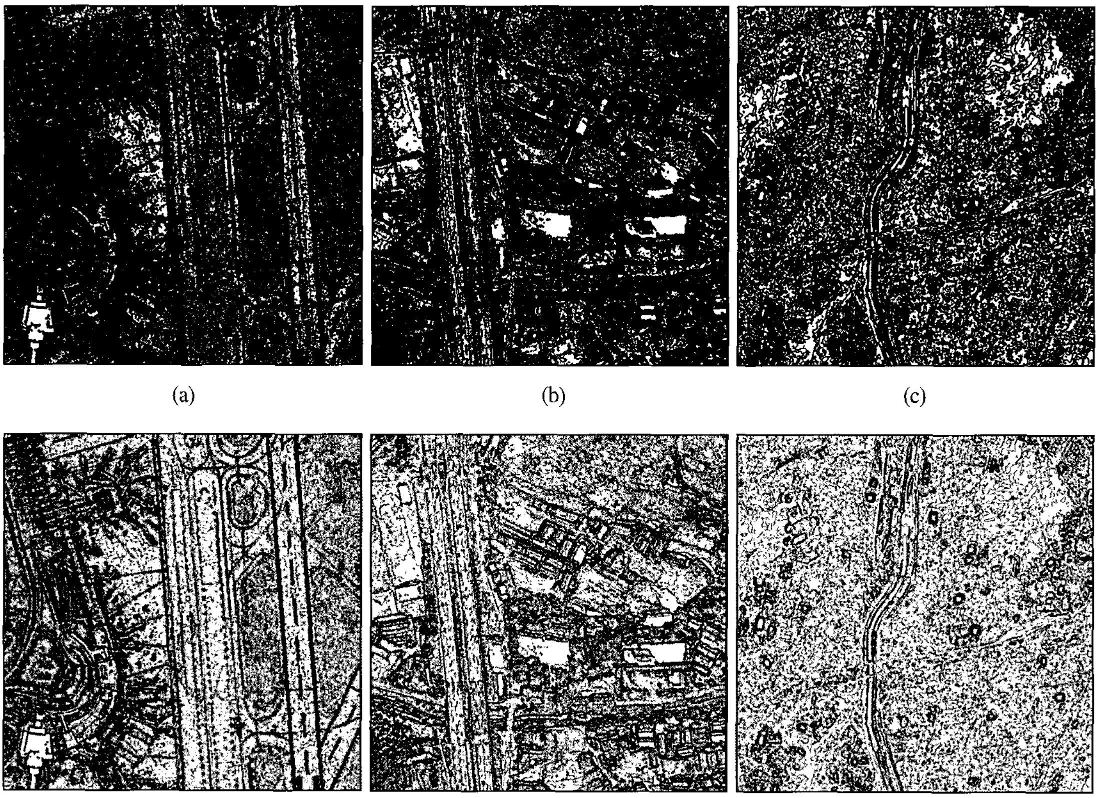
For the generation of ASM and homogeneity texture images from the various space-borne imageries, kernel size and shift direction are 3×3 and circular direction for GLCM, respectively. The resultant texture images are shown in Fig. 5. In general, homogeneity images are brighter than ASM and the dark parts mean rough roads on the occasion of ASM and homogeneity.

Abrupt change shown in the texture image at the forest area on the KOMPSAT image is noticeable point, compared with the original image showing almost similar tone.

For the further processing, we extracted edge information from original image using LoG operation (Fig. 6).

2) Fusion Process with Original, Texture and Edge Images

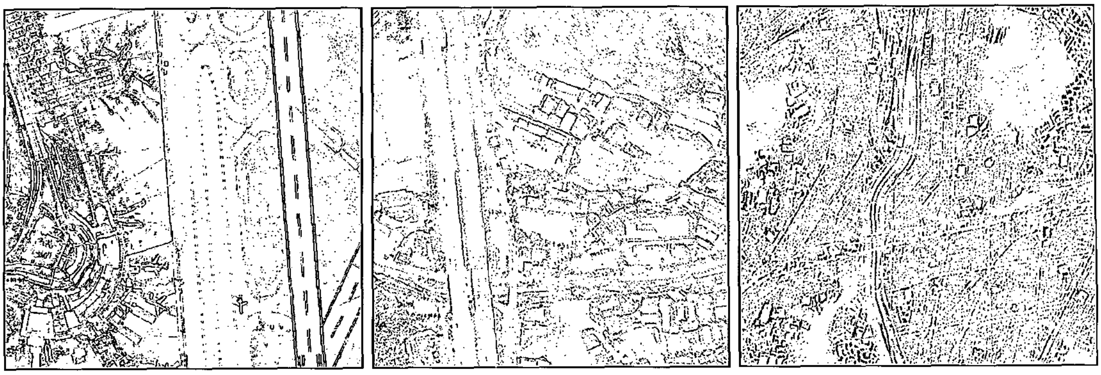
First of all, we tried to fuse H bands of original image and LL band of texture image on the assumption that we can obtain edge information from H bands of original image (Fig. 7 (a)). H bands and LL band corresponds directional detailed information of features and high-



(a) (b) (c)

(d) (e) (f)

Fig. 5. The texture images: (a) ASM (Fig. 3(a)), (b) ASM (Fig. 3(b)), (c) ASM (Fig. 3(c)), (d) homogeneity (Fig. 3(a)), (e) homogeneity (Fig. 3(b)) and (f) homogeneity (Fig. 3(c)).



(a) (b) (c)

Fig. 6. The edge images by LoG operation with respect to Fig. 3(a), (b), and (c).

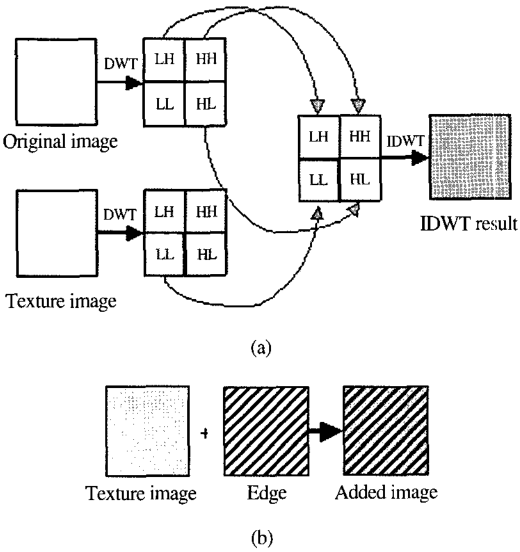


Fig. 7. (a) The wavelet scheme applied for Fig 8 (a) and (b).
(b) The simple adding processing for Fig 8 (c) and (d).

pass filtered road pavement information, respectively. We attempted to obtain pavement and edge information from these results at the same time. Fig. 8(a) and (b) show the fused image using LL band of the texture image and LH, HL and HH band of the original image.

However, H bands contain both edge information and detailed changes of features. We attempted to extract edge from original image separately and to add edge information to the previous results (Fig. 7 (b)). For this purpose, we adopted LoG operation to detect edges. Preferentially, we simply overlaid detected edge on texture image. Fig. 7(c) and (d) show these results.

These results contain both pavement and boundary information; however, the detailed change of features is not included. Therefore, we added edge to fused images after integration LL band of original image and LH, HL, HH band of texture image (Fig. 9 and Fig. 10). But, texture image property is rarely reflected because most of energy concentrated on LL band among DWT sub-band.

As the last case, we decomposed original image and texture image individually, and performed inverse processing with original H bands and texture LL band. And then, edge image extracted from original image is added on the fused image (Fig. 11). As for the applied results, the tone of the wide road at the left side of Fig. 12 (a) and (b) seems changeless in original image. But the condition of road pavement is distinguished by texture image, as shown Fig. 12 (c) and (d). Meanwhile, road appears nearly line feature on the occasion of KOMPSAT (Fig. 12 (e) and (f)), because the spatial resolution is too coarse. So, we cannot recognize pavement information in details. It can be inferred that these results as the fused image represent the road pavement condition within road boundary, unrevealed in the original images, when spatial resolution is sufficiently high.

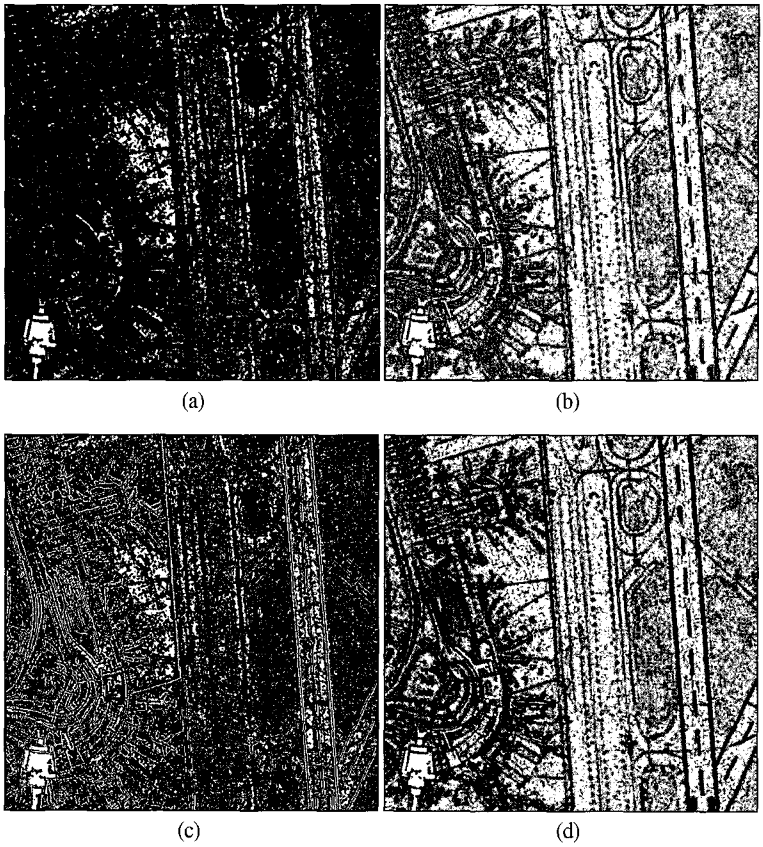


Fig. 8. The fused images of texture LL band and original LH, HL, HH band: (a) ASM and (b) Homogeneity. The output of adding edge on texture image: (c) ASM and (d) Homogeneity.

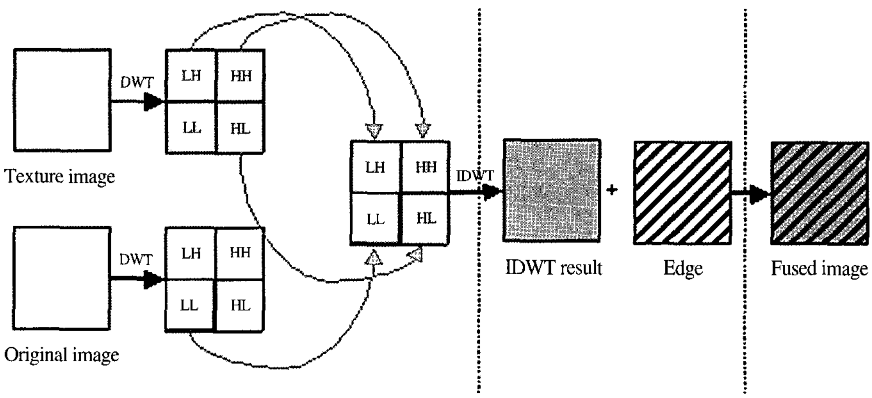
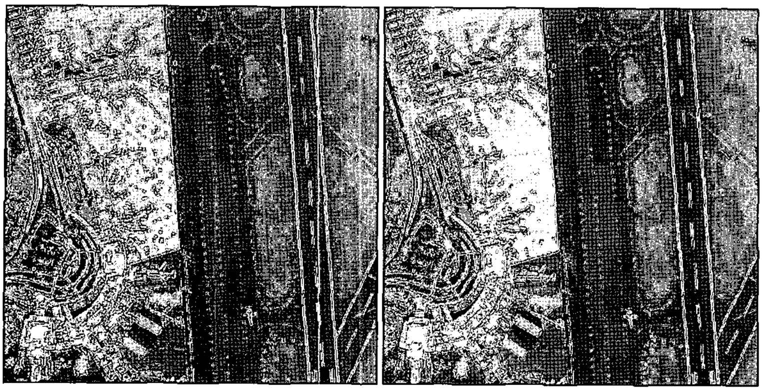


Fig. 9. The wavelet scheme applied for Fig. 10.



(a) (b)

Fig. 10. The fused images with original of LL band, texture LH, HL, HH band and edge: (a) ASM, (b) Homogeneity.

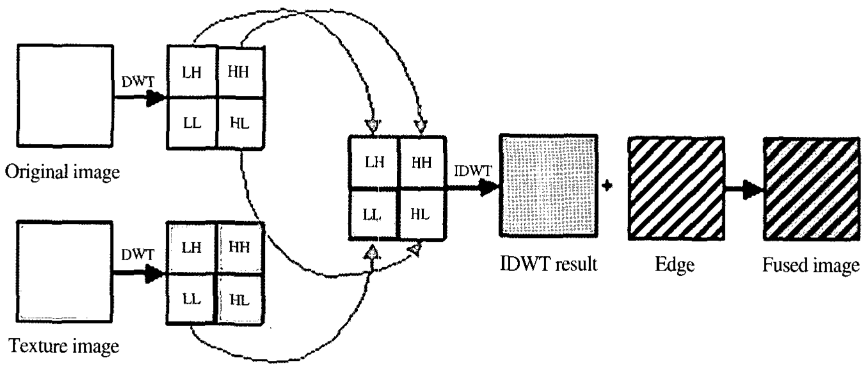


Fig. 11. The wavelet scheme applied for Fig. 12.

4. Concluding Remarks

In this study, we tried the several experiments using wavelet transform and texture analysis. Wavelet transformation and its inverse processing provide the effective framework for data fusion. We tried to apply high resolution images for this study: IKONOS image and KOMPSAT imagery. To overcome the problems of methods, we finally proposed the process that is to decompose original image and texture image respectively, perform inverse processing with original H bands and texture LL band and add edge on the fused image. This result shows the condition of pavement, details of feature changes and edge effectively.

This method gives more valuable results when high-resolution imagery such as IKONOS imagery is applied. The reason is that it can be obtained the fused image with the pavement condition on road boundary when the spatial resolution is sufficiently high. Meanwhile, we cannot recognize detailed road pavement information on the occasion of KOMPSAT imagery, but qualitative characterization of urban features is partly possible. As the qualitative result for the visual interpretation of these experiments, the resultant image by each fusion scheme will be utilized to extract unique details of surface characterization on urban features around edge boundaries. The approach and experiment in this study can be regarded as one of fundamental issues for urban

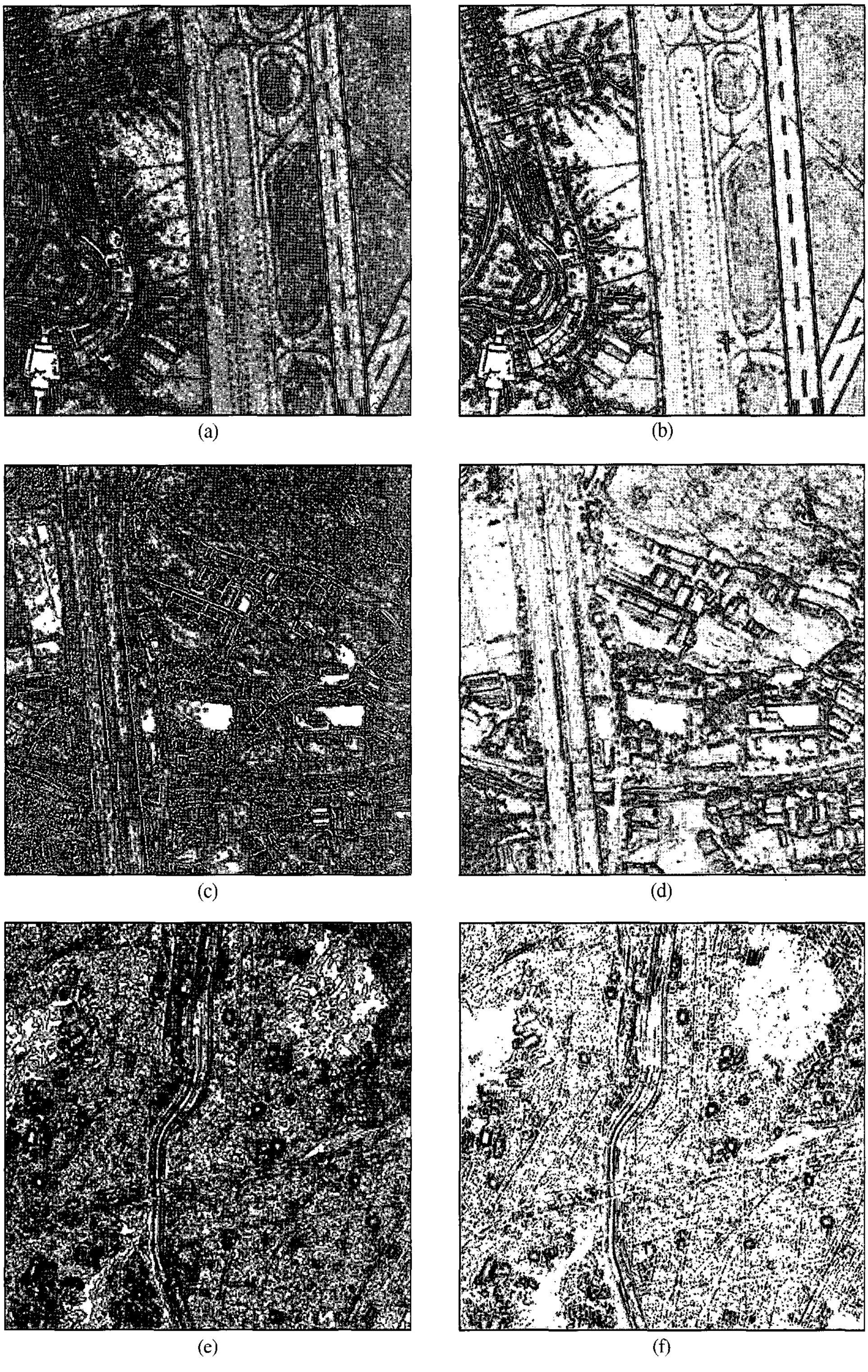


Fig. 12. The fused results of texture LL band, original image H bands and edge: (a)-(c)-(e): ASM as texture LL band, (b)-(d)-(f): Homogeneity as texture LL band.

remote sensing researches dealing with the complex types of surface features.

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