A comparison of wavelet and Fourier analysis for image change Detection

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Abstract: Wavelet and Fourier analyses are widely used in various fields of image processing. They can be utilized in land use remote sensing dynamic monitoring to detect change information automatically. The procedures are as followed: firstly do wavelet transform or Fourier transform to each band or principal component of the multi-spectrum images of two different periods, the coefficients after transform are subtracted, then do inverse transform. The result images display land using changing areas with high brightness. In this paper, we do experiments using the two transforms, and find the result of wavelet transform is better.
Keywords: change detection; remote sensing image; wavelet transform; Fourier transform

1. Introduction

Remote sensing change detection can find regions of change in remote sensing images of the same scene taken in different time. It is now widely used in land cover change detection. There are two methods of change detection, one is comparison after classification, the other is analyzing to the pixels, the former method classify the images, then compare the result after classification, get the change information, the latter method analyze the corresponding pixels of images. Normally, the latter method has the higher precision, but can't get the change of land use type. Both the methods have their own excellence.

Wavelet transform and Fourier transform are widely used in image processing, such as image enhancement, image rebuilding and image compression. In this paper, we use them in change detection of remote sensing images. We do transforms to the wave bands or principle components, and then get the difference of the transform coefficient, do inverse transform to the difference, get the change detection result images. Using the same image, we compare two result images, and analyze the result according to their property.

2. The Property of Wavelet Transform and Fourier Transform

Wavelet is a function whose integration (average) is 0, assume that $f(t) \in L^2(R)$ is an finite energy signal whose energy is $E = \int_R |f(t)|^2$. The method of wavelet transform is expressing the square function or finite energy signal $L^2(R)$ to the addition of wavelet coefficient by Multi-resolution Analysis. Fourier transform can express any period function to the sine and/or cosine of different frequency. Aperiodic function (finite curve) can be expressed to sine and/or cosine multiplies the integration of weighting function.

Wavelet function is attenuation fast enough in time (space) and frequency field. It has obvious double windows characteristic. Simultaneity, it can create a series of wavelet function cluster by zoom and move:

$$\psi_{a,b}(t) = \frac{1}{\sqrt{|a|}}\psi(\frac{t-b}{a}) \quad a,b \in R, a \neq 0$$

We can select the width and the center frequency position of wavelet function time (space)—frequency window conveniently from selecting scale coefficient a and move coefficient b. when |a| is less, the window is narrower; when checking low frequency character, the window is broaden. The lack of Fourier transform in this aspect is conquered by window Fourier transform. Compared to Fourier transform, wavelet transform maintains the excellence of window Fourier transform, furthermore conquers the lack of which time—frequency window's shape can't change. When processing aperiodic function (like remote sensing images), the efficiency of wavelet transform is higher than Fourier transform. The reason is that wavelet transform has gradually localized character, it can get signal's form near some point; solve the conflict between time field and frequency field skillfully. Wavelet transform has the local character in both time and frequency field, but the trigonometric function in Fourier transform has the global character. This is an important property of wavelet transform—focus changing.

The other basic property of wavelet transform is information maintenance. It's an information maintenance linearity operation, has an accurate inverse transform, and satisfies the conversation of energy equation. It can analyze signal to different scale subsections, and the information after analyse is maintenance completely in wavelet coefficient, it's an energy newly distribution, no loss of information. In this regard, Fourier transform has the same property, it can rebuild by inverse Fourier transform, no loss of any information.

Another advantage of wavelet transform to Fourier transform is the select agility of wavelet bases. In wavelet transform, the character of wavelet child space depends on selection of base wavelet $\psi(t)$, we can select $\psi(t)$ base on f in practice use. So it's more agile and pertinent than Fourier transform. Popularly, we can consider wavelet transform as a Band-Pass Filter which has the function high and low pass. As a result, using Multi-resolution Analysis, wavelet transform can analyze original dispersed signal C_J to multilayer low frequency subsection C_{J+1} and high frequency subsection D_{J+1},convenient for the measurement to special information. And inverse wavelet transform can rebuild the original signal C_J.

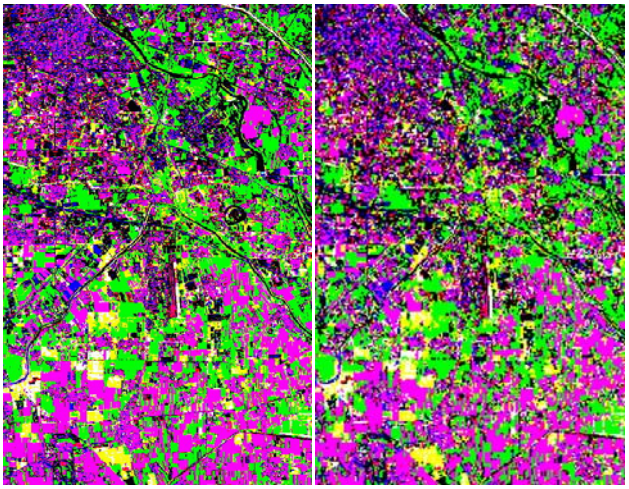
Thus, compared to Fourier transform, wavelet transform has Multi-resolution Analysis function and gradually localize character. Wavelet transform is a bound alterable window method, it can get more accurate low frequency information using longer interval, and get high frequency information using shorter interval, it provide the ability for local analyse and thinning. Wavelet transform analyzes image to different displacement and bulgy wavelets, and analyzes image to approach image and detail image, do several scale thinning step by step, get any detail of the image, but Fourier transform analyze image to different frequency sine wave. Fourier transform choose trigonometric function as basis function, compared to wavelet transform, the "scale change" correspond to "sin (ω), cos (ω), sin (2ω), cos (2ω)……" in dispersed Fourier transform, correspond to draught and compress of wavelet function.

Due to the infinitude ductibility in time field of sine function, it is unnecessary to change the phase by adjusting position. Due to the local undulation of wavelet function, we can approach in full time field by changing position. So, wavelet transform has the character of band-pass filter. When checking high frequency component, wavelet function is narrower, time resolution is higher, frequency window is wider, and frequency resolution is lower. When checking low frequency signal, time window is wider, sampling time is longer, and frequency resolution is higher. If we want to know the signal in special time, we can move the position of time window, put the signal into analyzed.

3. Data Processing

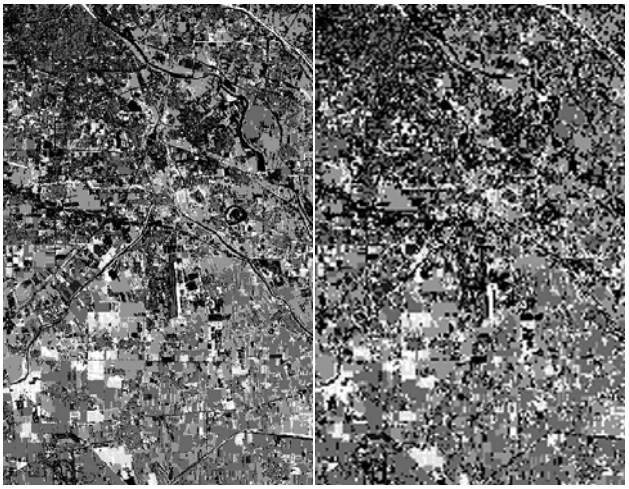
The two times remote sensing images used in the paper are May 19, 2004 and July 6, 2004 TM image in a region in Beijing. Transforms can be done to each band or each principle component, but we find that the difference is little, and doing transforms to the band can preserve more information of the images, so we do transforms to each band. After transforming, we get each band's wavelet coefficient or Fourier coefficient, then get the difference of the coefficient, do inverse transform, get the result image of each band, then combine them, get the change detection pseudo color result image. We compare the use of wavelet basis like Haar, Bior, coif, db, and select Bior3.7 as wavelet basis, scale is 2. The pseudo color result images of wavelet and Fourier transforms are given in figure1.

In the result images, when the pixel's brightness is higher, this pixel in the two original images is more difference. In figure 1, yellow part changes acutely, next is green part, red part has less change. We can transform them to gray style to see more patent in figure 2.



(a) WAVELET TRANSFORM (b) FOURIER TRANSFORM

Figure 1. pseudo color result images



(a) WAVELET TRANSFORM (b) FOURIER TRANSFORM

Figure 2. gray style result images

In figure 2, a few white blocks are areas changing acutely between two time remote sensing images. To zoom in the detail of the images, we can find the result of wavelet transform is much better than Fourier transform. The changing areas are clearer, the boundary is clearer. It's favor to find the change.

Statistics of the result images suggests that wavelet transform gray image's standard deviation is 64.488, Fourier transform gray image's standard deviation is 60.2142. The standard deviation of wavelet transform is larger, means the pixels in the image are more different, the information of change detection in wavelet transform image is more than in Fourier transform image. When we do the same smoothing to two result images, Statistics to the change of wheat ripe to harvesting, the accuracy of wavelet transform is higher than Fourier transform.

4. Result Analyse and Discussion

The reason of wavelet transform performs better than Fourier transform is related to their property. Wavelet transform uses wavelets to approach the signal, it has non-equality distribution resolution: uses high frequency resolution and low time resolution in low frequency channel, uses low frequency and high time resolution in high frequency channel. Thus, it is suitable for sudden change signal. So it is better to use wavelet transform than Fourier transform in remote sensing image change detection. Wavelet transform can describe the local character of the image; get more and clearer change information.

The other result acquired from this experiment is the effect of wavelet transform using in image classification and getting certain class earth. From the Histogram of the result gray image of wavelet transform in figure 3, we find that the

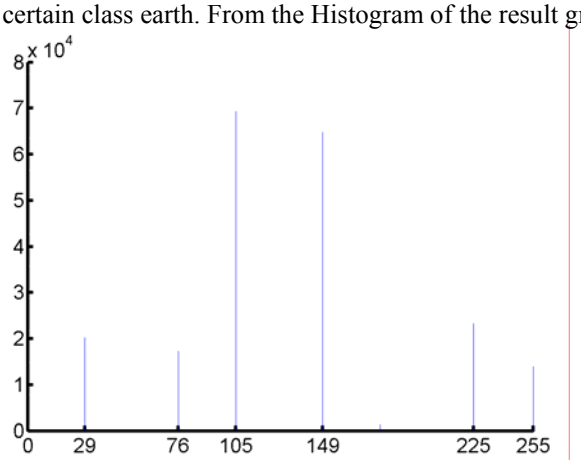


Figure 3. histogram

gray values are all distributing in several values: 0, 29, 76, 105, 149, 225, and 255. It shows that wavelet transform classifies the image to 7 classes; each class corresponds to one pixel value. But this classification is not directly done to the original images; it's after comparison of transformation to the images. It brings convenience to get the certain class earth from the several time remote sensing images. The pixel of 105 value in the image mostly integrate to blocks, these areas are wheat land, it's in autumn in May, and is in harvest time in July. We can select proper filter to remove the pixels scattered. This method has a high definition in getting wheat land from two time remote sensing images.

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