Wavelet compression for remotely sensed images

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Abstract

Image compression is very important in reducing the costs of data storage transmission in relatively slow channels. Wavelet transform has received significant attention because their multiresolution decomposition that allows efficient image analysis. This paper attempts to give an understanding of the wavelet transform using two more popular examples for wavelet transform, Haar and Daubechies techniques, and make compression between their effects on the image compression.

Key words

Image compression, wavelet transform, Daubechies techniques.

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ضغط الصور الفضائية باستخدام تقنية التحويل الموجي

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الخلاصة

ان عملية ضغط بيانات الصورمهم جدا وذلك لتقليل كلفة نقل هذه البيانات ولهذا فان هناك طلب جدي للبيانات المشفرة بطرق كفؤة. إن استخدام التحويل الموجي لضغط الصورة يكون اقل تعقيدا من استخدام التحويلات الأخرى. يحاول هذا البحث إن يعطي شرح للتحويل الموجي ولقد تم تطبيق اثنين من التقنيات الموجية الشائعة لضغط بيانات الصور، تقنية Haar وتقنية Daubechies. أجريت في هذا المقال مقارنة بين تأثير هاتين التقنيتين في عملية الضغط. من المقاييس الكمية Objective Test التي تم استخدامها في هذا المقال هو مقياس مستوى نسبة الإشارة إلى الضوضاء (PSNR). أن الطرق التي تم استخدامها قد أدت الي نتائج جيدة عند تطبيقها، حيث تم الحصول على نسب ضغط جيدة مع جودة للصور والتي تم توضيحها في نتائج هذا البحث.

Introduction

The wavelet means small wave, so for a function to be a wavelet it must be small, and it must be a wave. Therefore, the function must be decreased in amplitude as a function of the distance from its center and has some periodicity representing a wave[1]. The wavelet transform is really a family of transforms that satisfy specific conditions. The wavelet transform can be described as a transform that has basis functions that are shifted and expanded version of them. Because of this, the wavelet transform contains not just frequency information but spatial information as well. The wavelet transform breaks an image down into four subsampled. They are subsampled by keeping every other pixel. The results consist of one image that has been highpass filtered in both the horizontal and vertical direction, one that has been highpass filtered in the vertical and lowpass filtered in the horizontal, one that has been lowpassed in the vertical and highpassed in the horizontal, and one that has been lowpass filtered in both direction [2].

Wavelet Coding

Wavelet coding also called sub-bands coding [3] .The basis idea is split up the two dimensional frequency band image into sub-sampling channels which are encoded using techniques accurately matched to individual signal statistics and possibly to the properties of the human visual system in the individual sub-bands. One-dimensional filter is used in order to separate the frequency bands both horizontally and vertically, the reason is that separable filter implementation of non-separable two-dimensional filters. On other hand, the gain in coding efficiency obtain by applications of non-separable filter is usually small or negligible [4]. The main purpose behind using the sub-band coding technique for video and digital image applications is the acquisition of a set of sub sampled frequency bands where each band contains various structural features of the original image. The base-band of the image presents a smaller replica of the original consisting of all the low frequency components that are of major perceptual importance. The neighboring picture elements of the base are highly correlated and this spatial redundancy needs to be exploited by an appropriate coding scheme [5]. Sub-band filtering provides asset of disjoint upper bands that are structurally different from the base band and do not display strong pixel to pixel intra-band correlation [6]. The original image can be transformed into four sub-images, as shown in Fig. 1.

Low/Low	Low/High
High/Low	High/high

Fig.1: The four sub-images result from the transformation

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

Daubechies and Haar basis vectors are more popular example for wavelet transform. These are separable, so they can used to implement a wavelet transform by first convolving them with the rows and then the columns [7].

Image Comprssion System

Fig. 2 shows the compression system, which is used in this paper. This compression system consists of two distinct structural blocks: an encoder and a decoder. An input image f(x,y) is fed into the encoder, which creates a set of symbols from the input data and reconstructs a compressed image, while encoded representation is fed to the decoder, where a reconstructed output image f(x,y) is generated[8].

The Haar- Basis Transforms

The Haar wavelet transform was first described in the early years of this century and described in almost every text on the wavelet transform. The Haar transform uses square pulses to approximate the original function. The basis function for Haar wavelets at some level look like a unit pulse, shifted along the x-axis [4]. Scales are the name of the basis function in the wavelet terminology, and are usually denoted as function Φ (t), where t denotes time.

$$\Phi(t) = \begin{cases} 1 & -t\leq 0 \text{ and } t-1<0 \\ 0 & \text{Otherwisw} \end{cases}$$

The Haar scales are all of the unit pulses. The function Φ (t-1) is the shifted pulses, shifted by "s" units to the right. The Haar basis vectors are simple:

$$\text{LowPass}= \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & 1 \end{pmatrix}$$

$$\text{HighPass}= \frac{1}{\sqrt{2}} \begin{pmatrix} 1 & -1 \end{pmatrix}$$

To use the basis vectors to implement the wavelet transform, they must be zero-padded to be the same size as the image (or subimage). Also note that the origin of the basis vectors is in the center, corresponding to the value to the right of the middle of the vector. The inverse of M is [2]:

$$\begin{pmatrix} 1 & -1 \\ 1 & 1 \end{pmatrix}$$

The Daubechies - Basis Transform

Wavelet is the set found by Daubechies, the simplest of which has four coefficients:

$h0= (1+ 3^{1/2})/4$ $h1= (3+ 3^{1/2})/4$

$h2= (3- 3^{1/2})/4$ $h3= (1- 3^{1/2})/4$

The coefficient can be substituted into Ψ (t)= Φ (2t)-Φ (2t-1). An example of Daubechies basis vector:

$$\text{LowPass: } \frac{1}{4\sqrt{2}} [1+\sqrt{3}, 3+\sqrt{3}, 3-\sqrt{3}, 1-\sqrt{3}$$

$$\text{HighPass: } \frac{1}{4\sqrt{2}} [1-\sqrt{3}, \sqrt{3}-3, 3+\sqrt{3}, -1-\sqrt{3}$$

To use the basis vector to implement the wavelet, they must be zero-padded to be the same size as the image. Also the ordinal of the basis vectors in the center, corresponding to the right of the middle of the vector. After the basis vectors have been zero-padded, doing the following steps performs the wavelet transform.

1. Convolute the low pass filter with rows and save the results.
2. Convolute the low pass filter with columns and sub-sample this result by taking all other value; this gives the low pass, low pass version of the image.
3. Convolute the result from step1, the low pass filtered with the high pass filter on the columns. Sub-sample is taking the other values to produce the low pass-high pass image.

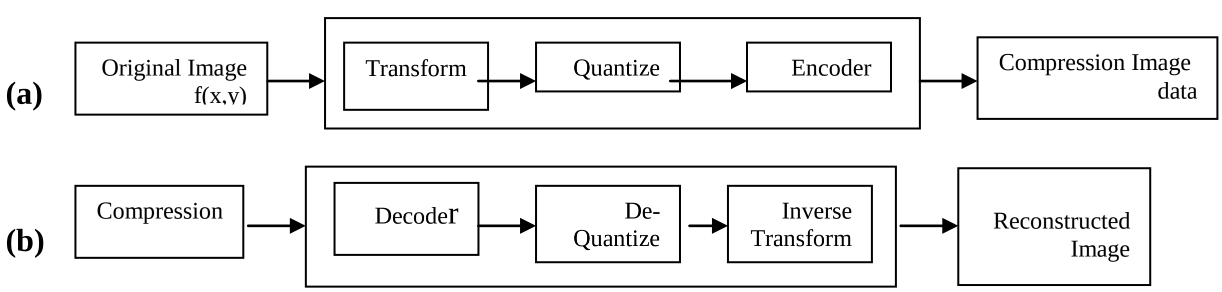


Fig. 2: Image compression system (a) encoder. (b) decoder

4. Convolute the original image with the high pass filter on the rows and save the result.
5. Convolute the result from step4 with the low pass filter on the columns; Sub sample to yield the high pass-low pass version of the image.
6. Convolute the columns of the result from step4 with the high pass filter to obtain the high pass- high pass version.

In Practice the convolution sum of the other pixel is not performed since the resulting values are not used [2,8].

Image Fidelity Measured

The loss in information associated with compressed images. Fidelity measures are often used to measure the amount of information losses produced by performing certain coding algorithm. Among the most commonly used fidelity criteria is the Peak Signal-to-Noise Ratio (PSNR) which is defined as:

$$PSNR=[\text{Peak to Peak of } f(x,y)]^2/MSE \quad (1)$$

where MSE is defined as:

$$MSE=1/N*M \quad (2)$$

where f(x,y),f'(x,y) represented the original and the reconstructed image samples, respectively Each of size M*N pixels. The PSNR can be represented in (dB) unit as [7،8]:

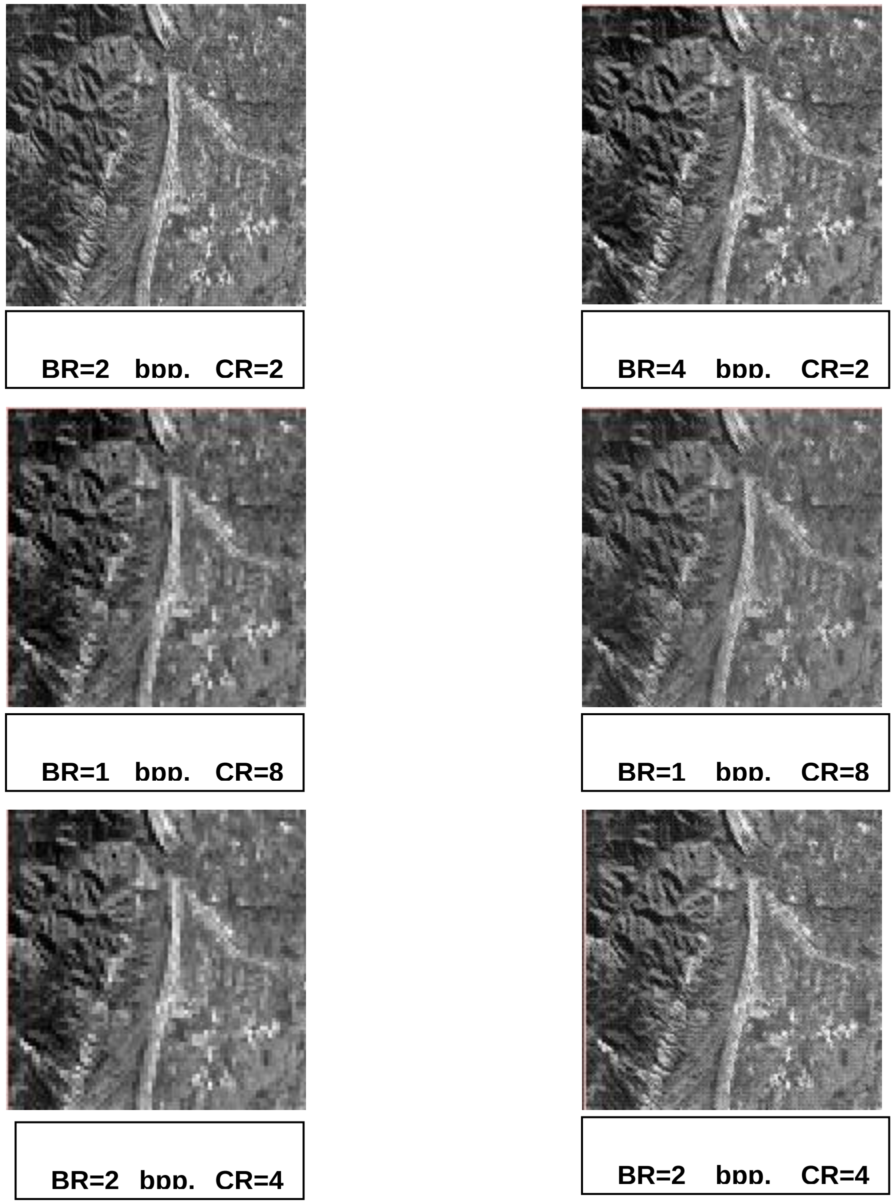
$$PSNR=10 \log_{10} [\text{gray scale of image}/MSE]^2 \quad (3)$$

Experimental Results

The results obtained by this paper can be demonstrated through the values of bit-rate (BR), the Peak-Signal to Noise Ratio (PSNR) and compression Ratio (CR). Image that is used to demonstrate the coding results is shown in Fig. 3. The adopted image is satellite image that covered a part of Iraqi country. The compressing image with the Haar transform and Daubechies transform was implemented on the above sample image for different values of the parameters.

Results and Conclusions

Haar and Daubechies filters have been used to implement the wavelet transformation; it can be seen that both of them have power and weakness in some sides, as follows: Haar and Daubechies give the same results (i.e. wavelet transformation) but Haar method is faster than Daubechies method because the basis vector of haar filter is 2x2 block while the basis vector of Daubechies is 4x4 block. This mean that Daubechies filter has more calculation than Haar filter. At the same time, the resulted image for Daubechies filter is better Haar filter where it has a good PSNR, but the speed of Haar basis method is higher than the Daubechies method.



(a) (b)

Fig. 3: (a) decoded images reconstructed by selecting 4 sub-band using the Haar wavelet compression over satellite image. (b) decoded images reconstructed by selecting 4 sub-band using the Daubechies wavelet compression over satellite image.

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