Study of Wavelet Functions of Discrete Wavelet Transformation in Image Watermarking

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Abstract. The aim of this paper is to examine a set of wavelet functions (wavelets) used in image watermarking system. Several wavelet functions are used to transform the component detail of the image in frequency domain. Discrete wavelet transform (DWT), discrete Fourier transform (DFT) and discrete cosine transform (DCT) are some commonly used transform domain functions out of which discrete wavelet transform is widely used due to its inherent properties. In this paper, discrete wavelet transform is studied and the salient features of discrete wavelet transform are discussed. Discrete wavelet transform has several wavelet functions associated with it. The properties of various wavelet functions of discrete wavelet transform are discussed and the graphical plots of the wavelet functions are plotted using MATLAB, and a comparative analysis is carried out.

Keywords: Digital image watermarking, discrete wavelet transform, Haar, Daubechies, Symlet, Coiflet wavelet.

1. Introduction

In the modern vast era of digital media, there is dramatically increase in the volume of digital data transmission. This digital data may be text, audio, images, and video. Various signal processing techniques are used to transmit this raw data in terms of electronic media. These signal processing techniques are used to secure the data transmission and make real time transmission possible. Security of the data being transmitted against fraudulent activities is the main concern, and a lot of research in this area is carried out by researchers since past decade. One way to secure the digital data is to add watermark or signature within the content of digital media and extract this watermark or signature at the receiver end to validate the authenticity of the data, this process is called as digital watermarking.

Digital watermarking is a method whereby information can be invisibly embedded into digital media. Later the watermark can be extracted and used for authentication and verification of ownership. This embedded information should ideally be robust against common signal manipulations such as the addition of random noise, digital-to-analog conversion, and intentional attacks to remove the embedded watermark.

Digital watermarking plays an important role in protecting copyrights in digital media (images, audio and video). Copyright infringement or copyright violations can be detected or checked using watermarking [1]-[3]. The main aim of this paper is to examine various available wavelet techniques used in the field of image watermarking. Image watermarking can be defined as the process of embedding the watermark or signature image into the original image (cover image).

Image watermarking is broadly classified into two categories: Spatial domain watermarking and transform-domain watermarking [4]. Watermark can be embedded in the spatial domain of an image by changing the pixel values. In spatial domain the pixel values of the cover image are varied to embed the watermark into the cover image. As the variations in the pixel values causes degradation in the cover image. So, the spatial domain watermarking is used only in rare cases in which the image quality is not of forth importance. The transform domain schemes which are based on the mathematical transformations embed the watermark by modulating the frequency coefficients in a transformed domain.

The various transform domains commonly used are discrete cosine transform (DCT), discrete Fourier transforms (DFT), discrete wavelet transformation (DWT) [5]-[7]. Transformed domain watermarking schemes produce better results than spatial domain watermarking scheme [8].

In the next sections of paper, Discrete wavelet transform, wavelets are discussed which are used in transform domain watermarking systems.

2. Discrete Wavelet Transform

Discrete Wavelet transform (DWT) is a mathematical tool for hierarchically decomposing an image [7]. This transform is based on wavelets which are of varying frequency. The transform of a signal is just another way of representing the signal; it does not change the information content present in the signal. The Discrete wavelet transform provides a time-frequency representation of the signal. DWT is the popular technique which is used for image watermarking and image compression applications with excellent visual quality of the processed image. The basic idea of discrete wavelet transform in image processing is to decompose the image into sub-image of different spatial domain and independent frequency sub-bands. After the cover image has been DWT transformed, it is decomposed into four frequency parts (LL, LH, HL, and HH) as shown in Fig. 1. LL is the low frequency sub-band which contains the approximation of the original image. HL represents the high frequency sub-band which contains the horizontal details of the image. LH represents the high frequency sub-band which contains the vertical details of the image. HH represents the high frequency sub band of the diagonal image.

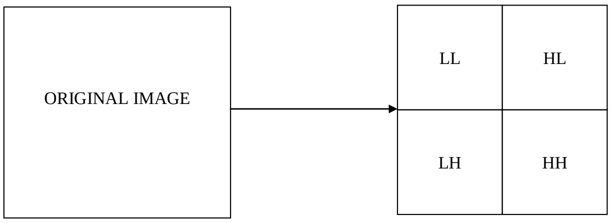

Fig. 1. 1-Level Decomposition of an Image

DWT can be decomposed up to N levels. In the 2nd level decomposition the sub-band LL will be decomposed into four sub-bands and so on.

2.1. Decomposition Process

In the decomposition stage of the image, the image is high and low-pass filtered along the rows and the results of each filter are down-sampled by two. Fig. 2 shows one decomposition step of the two dimensional gray scale image using DWT.

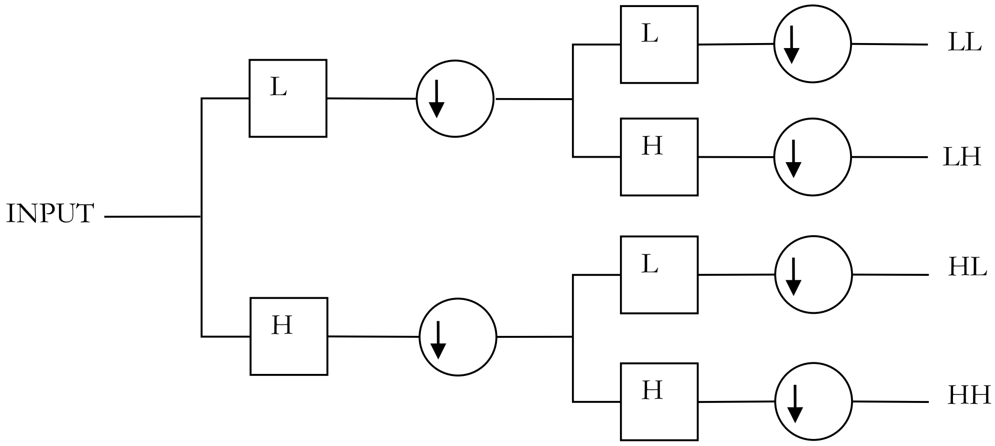

Fig. 2. One Decomposition step of the two dimensional image using DWT

The two sub-signals correspond to the high and low frequency components along the rows and each of size N by N/2. Each of the sub-signals is then again high and low-pass filtered, but this time along the column data. The results are again down-sampled by two. In this way the original data is split into four sub-images each of size N/2 by N/2 containing information from different frequency components

2.2. Reconstruction Process

The reconstruction process using IDWT is shown in Fig. 3. Reconstruction means obtaining same image from the four sub-frequency bands. In this the information from four sub-bands is up-sampled and then filtered with the corresponding inverse filters using the columns. The two results are added and then again up-sampled and filtered with the corresponding inverse filters. The results from each step are added to form the original image.

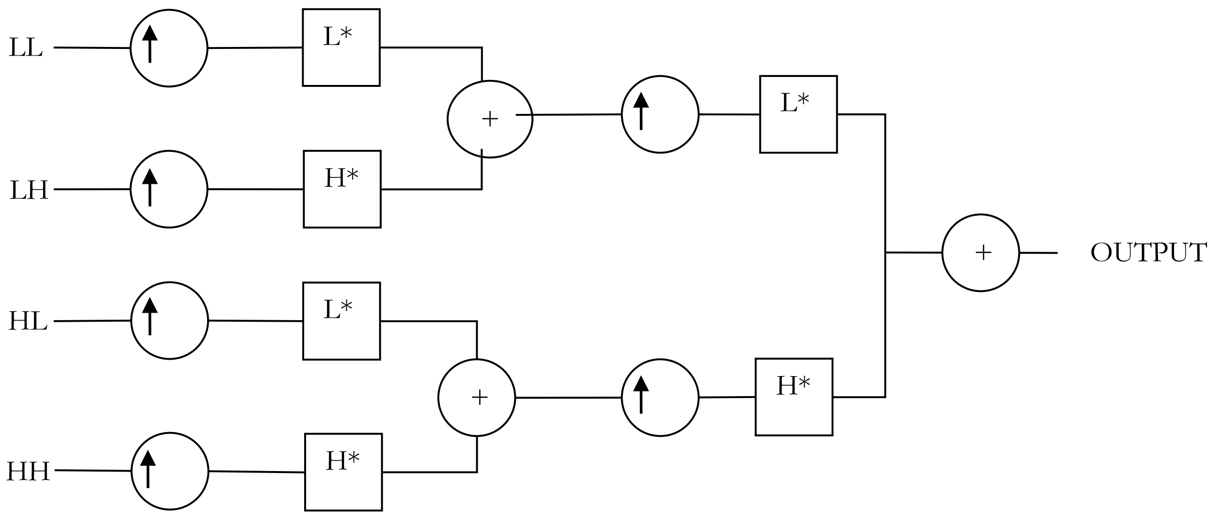

Fig. 3. Reconstruction step of the four sub-bands using IDWT

Several types of wavelets used to decompose the image are; Haar, Daubechies, symlet, Coiflet which are discussed in the following sections.

3. Wavelets

Wavelets are the functions that satisfy certain mathematical requirements and are used in representing data or other functions [9]. DWT uses different types of functions that are used as the mother wavelet for wavelet transformation. Wavelets families are divided into two categories, orthogonal and Bi-orthogonal. The various wavelets associated with DWT are:

- Haar,
- Daubechies,
- Symlet,
- Coiflet.

3.1. Haar Wavelet

Haar wavelet is the one of the oldest and simplest wavelet. Haar wavelet is discontinuous, and resembles a step function. Haar wavelet is called as the mother of all wavelets as it produces all wavelet functions used in transformation through translation and scaling functions. Fig. 4 shows plot of Haar wavelet in MATLAB.

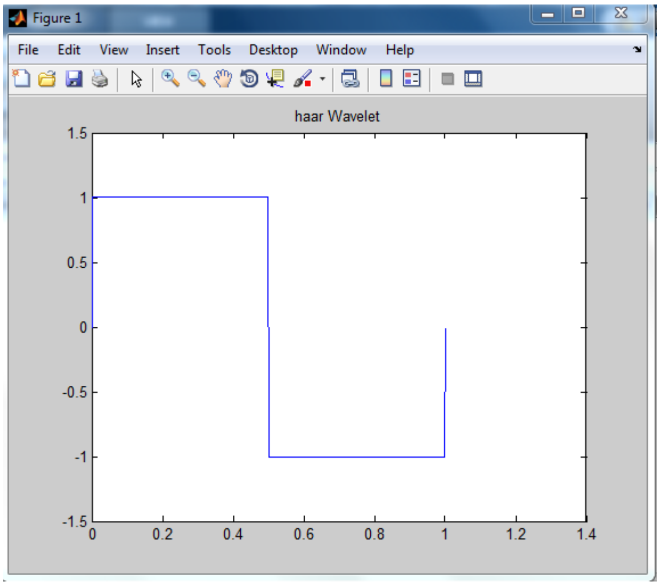

Fig. 4. Wavelet function for decomposition of Haar wavelet

3.2. Daubechies Wavelet

Daubechies wavelet was invented by Ingrid Daubechies [10]. The names of Daubechies family wavelets are written as dbN, where N is the order, and db is the surname of the wavelet. Daubechies wavelets are orthogonal wavelets which makes discrete wavelet analysis practically possible. The main characteristics of dbN family are compactly supported wavelets with external –phase and highest number of vanishing moments for a given support width. Db1 is same as Haar wavelet, generally these are considered as same wavelet. The graphical plot of the Daubechies wavelet function is shown in Fig. 5.

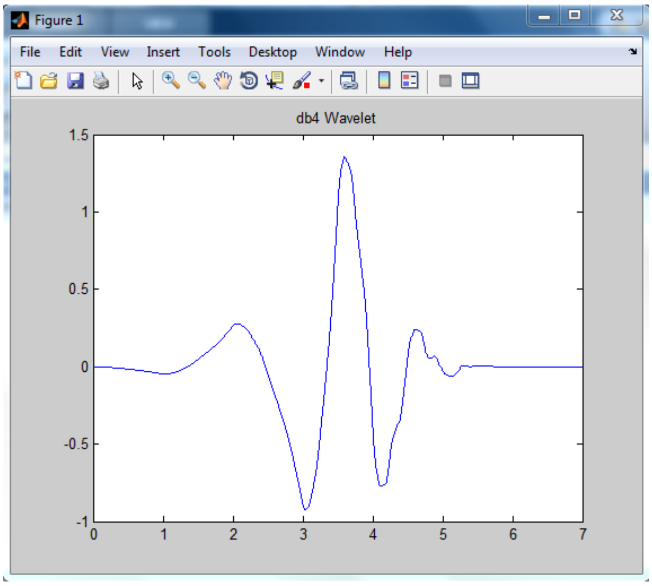

Fig. 5. Wavelet function for decomposition of Daubechies (fourth order) wavelet

3.3. Symlet Wavelet

Symlet wavelets are formed by modification of symmetry of Daubechies wavelets and the properties of symlet wavelets are almost same as that of Daubechies wavelets. These are the symmetrical wavelets so named as symlet wavelet. Symlet wavelets are written as SymN where N is the order. The graphical plot of the Daubechies wavelet function is shown in Fig. 6.

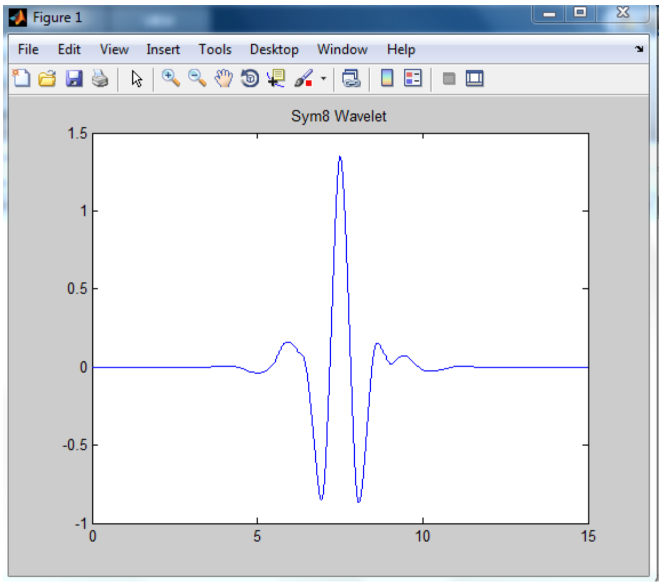

Fig. 6. Wavelet function for decomposition of Symlet (eight order) wavelet

3.4. Coiflet Wavelet

Coiflet wavelets are compactly supported wavelets with highest number of vanishing moments for a given support width. In CoifN, N is the order. In some literature it is written as 2N. Coiflet wavelets are more symmetric than that of dbN's. The graphical plot of the 5th order Coiflet wavelet function is shown in Fig. 7. Coif5 refers to the 5th order.

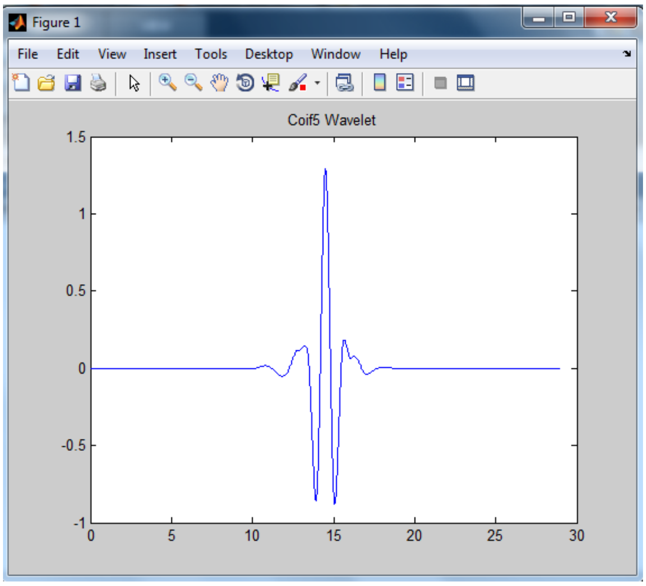

Fig. 7. Wavelet function for decomposition of Coiflet wavelet

In the next section of paper, properties of wavelet functions have been listed in Table I. The optimal choice of the wavelet to be used depends on our application requirement. Generally the Haar wavelet is used most frequently [11].

Table 1. Comparative Analysis of Wavelets

Wavelet description				
Family	**Haar**	**Daubechies**	**Coiflets**	**Symlets**
Short name	Haar	Db	Coif	Sym
Examples	Haar is same as db	Db1 or Haar, db4	Coif 2, Coif 5	Sym2, Sym8
Ortogonal	Yes	Yes	Yes	Yes
Biorthogonal	Yes	Yes	Yes	Yes

Compact support	Yes	Yes	Yes	Yes
DWT	Possible	Possible	Possible	Possible
CWT	Possible	Possible	Possible	Possible
Support width	1	2N-1	6N-1	2N-1
Filters length	2	2N	6N	2N
Symmetry	Yes	Far from	Near from	Near form
Number of vanishing moments for psi	1	N	2N	N

4. Conclusions

In this paper, different wavelet functions have been discussed. Haar is the mother wavelet of all other wavelets, as all other wavelets are derived from Haar wavelet by translation and scaling functions. Db1 is similar to Haar wavelet. Properties of these wavelets are compared in Table I. The wavelets are chosen based on their shape and their ability to analyze the signal in a particular application. The final choice of optimal wavelet in image watermarking application depends on image quality and computational complexity.

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