An Overview of Digital Watermarking with a Performance Analysis of Wavelet Families for Image Compression

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Abstract

Objectives: This paper incorporates an outline of digital watermarking and further deals with the performance analysis of wavelet families. Methods: Discrete wavelet transform is an effective technique used in an extensive range of applications in signal manipulation such as de-noising, image compression, spectral clipping, dynamic filtering and so on etc., HAAR, DAUBECHIES, SYMLET and BIORTHOGONAL are some of the wavelet families discussed in this paper. Performance of these families are scrutinized based on the parameters namely MSE, PSNR, BPP and compression ratio. MATLAB R2012 is used to examine the performance using an image of size (126 x 226). Findings: Evaluating the results of the four wavelet families, biorthogonal gives a better result with the compression ratio of 1.65 and MSE with 26.83 which gives a better compressed image than other wavelets. Applications/Improvement: Comparison of the four wavelet families has been analyzed and the better one has to be chosen to compress a watermarked image, since compression is the first step in watermarking and also each wavelet family is best under different criteria.

Keywords: BPP, Compression Ratio, DWT, MSE, PSNR, Wavelet Families

1. Introduction

Digital watermarking is a technique used to embed information into a digital data which cannot be easily retrieved by the third party. It is a tool that provides user data security, authentication, and copyright ownership to the digital media1. This paper deals with an overview of digital watermarking and performance analysis of four wavelet families namely HAAR, DAUBECHIES, SYMLET and BIORTHOGONAL for image compression. An experimental result has been produced for the above comparison.

1.1 Digital Watermarking Characteristics

The following are the four important characteristics of digital watermarking. They are,

- Robustness: Watermarked data cannot be detached by any unauthorized users. It should remain secure even after some signal processing such as cropping, transformation, compression, etc.
- Imperceptibility: Watermark and the cover image should be perceptually identical that is, the observer cannot see any information embedded in the contents. Once the content is watermarked it should not affect the quality of the cover image. In case of any dispute over the digital media data, embedded watermark can be extracted and it can be used to identify the owner.
- Security: Watermarked data has been highly secured. Illegal access is denied. No one can detect, retrieve or modify the embedded watermark.
- Capacity: Capacity defines the number of bits a watermark encodes within a unit of time or work. This factor describes how much data should be embedded as a watermark for detection and extraction.

1.2 Digital Watermarking Classifications

The following are the classifications of digital watermarking.

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Visible Watermarking: Visible watermarking is that the text or image on the digital data such as video and image can be visualized by the user. Visible watermarks are text or logos. For example, in TV broadcasting, the logo of the channel is visible on the right end of the monitor. Invisible Watermark: The text or image embeds onto the digital data such as video and image cannot be visualized by the user. It is invisible but can be sensed by a different means.

Fragile: A digital watermark is said to be fragile if it is smashed under slight changes. This type of watermarking can be used for tampering detection. A fragile watermarking system should be able to identify the changes made in the original image.

Semi-Fragile: Semi-Fragile watermarking is a method in which watermark remains protected only under minor change but fails under malignant transformations. This type of watermarking can fight only under mild transformations. It can be used for detecting malignant transformation. Semi-Fragile is a combination of Fragile and Robust watermark.

Robust: Robust watermarking is a technique in which watermark remains as the original even after any modifications. This type of watermarking can be used in copyright protection application.

Blind: Blind watermark is that, it doesn’t need the original or any information about the original image.

Non Blind: This type of watermarking must need the original image for processing. The watermarked image should be compared with the original to confirm the quality of the watermarked image.

1.3 Digital Watermarking Applications
The important applications of digital watermarking are.

Copyright Protection: Watermarking is used to guard redeployment of copyrighted material through net.

Illegal replication is also prohibited through embedding technique.

Authentication: Authentication is all about the rights to access. It is the process of confirming an individual identity. Watermarking is also used for identity proof. For example a logo embed onto the paper, ensures the authenticity of the document and also the text or an image watermarked on ID-cards, credit cards and ATM cards identifies the appropriate bank and the card holder.

Security: Digital data such as text, image, audio and video are highly sheltered through some special watermarking method. Watermarked content is not easily fiddled by any unofficial person. It has been extremely secured.

Broadcast Monitoring: Broadcast Monitoring is a technique of cross-verifying whether the content that was supposed to be broadcasted on TV or Radio has really been broadcasted or not. Watermarking is also a part of broadcast monitoring to ensure whether this particular advertisement or program has been sponsored only by the concern channel in the stipulated time and duration.

Tamper Detection: A Fragile watermark technique has been used for tamper detection. If the fragile watermark is scratched, it indicates the presence of tampering and hence the digital content is ruined. Tamper detection is significant for some applications that involve highly delicate data like satellite imagery or medical imagery.

2. Different Techniques of Digital Watermarking
Digital watermarking techniques are broadly classified into two. They are spatial domain and frequency domain. The Frequency technique includes Discrete Cosine Transformation (DCT), Discrete Fourier Transformation (DFT) and Discrete Wavelet Transformation (DWT).

2.1 Discrete Fourier Transformation (DFT)
The Discrete Fourier transform is a most popular technique for signal analysis. It can be used to make over the signal from time domain to frequency domain or from frequency domain to time domain.
2.2 Discrete Cosine Transformation (DCT)
DCT is a Fourier related transform that uses real numbers\(^3\). The DCT is a very widespread transform function used in signal processing. It transforms a signal from spatial domain to frequency domain. It has been used in JPEG standard for image compression. DCT has been useful in many fields such as data compression, pattern recognition, and image processing, and so on. The DCT manipulate the original image into the smallest frequency coefficient and also it can represent the image blocking effect which can realize the high-quality business between the information centralizing and the computing complications.

DCT-based watermarking is based on two essentials\(^3\). The first is that most of the signal energy lies at low-frequencies sub band which contains the most imperative visual parts of the image. The second is that high frequency components of the image are usually detached through compression and noise attacks. The watermark is therefore implanted by changing the coefficients of the middle frequency sub band so that the visibility of the image will not be exaggerated and the watermark will not be isolated.

2.3 The Discrete Wavelet Transform (DWT)
DWT refers to wavelet transform in which the wavelets are discretely sampled\(^3\). It is especially suitable for images having higher resolution. The Discrete wavelet transform is a mathematical tool used effectively in the field of image processing. It is a contemporary technique currently used in an extensive range of applications in signal manipulation, such as audio and video compression, inference of noise in audio, and the replication of wireless antenna distribution. Since most of the real life signal is time varying in nature, the transform is based on the wavelet matrix, which can be worked out fastly than the Fourier matrix. The transform function localizes both space and scale. Unlike DCT, discrete wavelet transform fulfills the multi-resolution analysis. DWT represents image on different resolution level\(^3\). DWT Converts an input image coefficients series \(X_0, X_1, \ldots\) into high-pass wavelet coefficients series and one low-pass wavelet coefficient series.

\[
H = \sum_{m=0}^{k-1} x_{2r-m} s_m(z) \\
L = \sum_{m=0}^{k-1} x_{2r-m} t_m(z)
\]

Where \(s_m(z)\) and \(t_m(z)\) are called wavelet filters and \(K\) is the length of the filter. The above equations 1 and 2 are applied recursively on the low pass coefficients till the desired output is reached. It splits the signal into two bands namely high frequency band and low frequency band. The high frequency contains the edge components and the low frequency band is again split into high and low frequency sub bands. DWT is manipulated in the vertical, followed in horizontal direction. A recursive filtering is done on both the direction, thus splitting the image into four sub bands namely LL, HL, LH & HH (Approximation, Horizontal, Vertical and Diagonal). After the first level of
decomposition, there are four sub bands. To manipulate the next level of decompositions, the LL sub band of the previous levels is used as the input. Finally this results in 10 sub bands per component and contains the highest frequency part of the image. Figure 3 shows three level decomposition and Figure 4 shows sample input has been decomposed up to three levels.

### 3. Discrete Wavelet Families

The most basic types of wavelets are:

- **HAAR Wavelet transform.**
- **DAUBECHIES wavelet transform.**
- **SYMLET wavelet transform.**
- **BIORTHOGONAL wavelet transform.**

#### 3.1 HAAR Wavelet

HAAR wavelet transform is the simplest wavelet family for image compression. It is not continuous and resembles like a step function. This wavelet is more computationally efficient. It calculates the sum and the difference of every image of the every column of the resulting matrix. The wavelet repeats the process until 16x16. It involves in averaging, differencing, storing, eliminating data.

#### 3.2 DAUBECHIES Wavelet

DAUBECHIES are used to model compactly supported orthogonal wavelets with reassigned smoothness. The scaling and the wavelet functions are calculated by taking the inner product of the coefficients and four data values. In each iteration wavelet calculates the scaling function value and a wavelet function value. It is the biggest star of the wavelet family.

#### 3.3 SYMLET Wavelet

SYMLET wavelets are the modifications of DAUBECHIES wavelet. It has been modified to improve the symmetry.

#### 3.4 BIORTHOGONAL Wavelet

BIORTHOGONAL Wavelet gives the property of linear phase needed for image and signal reconstruction. It has two wavelets, one for decomposition and other for reconstruction. Decomposition and reconstruction specifies the analysis and synthesis of the signal. BIORTHOGONAL filter banks are 1.1, 1.3, 1.5, 2.2, 2.4, 2.6, 2.8, 3.1, 3.3, and 3.5 and so on. The first number indicates the order of the synthesis filter and the second number indicates the order of the analysis filter. The default one is 1.1.

### 4. Results and Discussions

In this study, four wavelet families namely HAAR, DAUBECHIES, SYMLET and BIORTHOGONAL wavelets are examined. The experiment is done with a color image of size (126x226) and evaluated in MATLAB R2012. Results are measured in terms of Mean Square Error (MSE), Peak Signal Noise Ratio (PSNR), Bits per Pixel Ratio (BPP) and Compression Ratio after compression.

Figure 5 is the sample input image. Table 1 gives the experimental results of the four different wavelet families. The compression ratio for bi orthogonal wavelet is least (1.65) when compared to others. HAAR wavelet gives a least mean square error (10.85), but produces a higher compression ratio. Each wavelet has its own features and its best suited for different applications. Since this paper deals with image compression, BIORTHOGONAL wavelet produces a better result than others and therefore best.
suited for image compression. Figure 6 gives the comparison graph for the four wavelet families. Each family and its parameters are differentiated by various colors.

5. Conclusion

The paper incorporates an overview of digital watermarking and their techniques. It further examines the comparative study of four wavelets namely HAAR, DAUBECHIES, SYMLET and BIORTHOGONAL. Results are measured in terms of MSE, PSNR, BPP, and compression ratio. From the experimental outputs, BIORTHOGONAL wavelet gives a least compression ratio of 1.62. Even HAAR wavelet produces a least MSE of 10.85, but its compression ratio is much higher. Hence BIORTHOGONAL wavelet is better when compare to other wavelets. This paper might be useful for the upcoming researchers who are going to bring out their work in Digital watermarking and image compression using DWT. In future, this BIORTHOGONAL wavelet has to be compared with other wavelet families like Coiflets, Mexican Hat, Morlet and Meyer, to identify the best wavelet for image compression.

6. References

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