Digital image Watermarking using Two Dimensional Discrete Wavelet Transform, Discrete Cosine Transform and Fast Fourier Transform

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Abstract—In digital watermarking, a watermark is embedded into a cover text in such a way that the resulting watermarked signal is robust to certain distortion caused by either standard data processing in a friendly environment or malicious attacks in an unfriendly environment. This paper presents a digital image watermarking based on two dimensional discrete cosine transform (DCT2), two dimensional discrete wavelet transform (DWT2) and two dimensional fast Fourier transform (FFT2). Signal to noise ratio (SNR), peak signal to noise ratio (PSNR) and weighted peak signal to noise ratio (WPSNR) are computed to measure image quality for each transform. We present traces of original and watermarked images. From traces we observe that we get good SNR, PSNR and WPSNR with DCT2.

Index Terms—DCT2, DWT2, FFT2, SNR, PSNR, WPSNR

I. INTRODUCTION

The earliest forms of information hiding can actually be considered to be highly crude forms of private-key cryptography; the “key” in this case being the knowledge of the method being employed (security through obscurity). Steganography books are filled with examples of such methods used throughout history [2]. This becomes particularly important as the technological disparity between individuals and organizations grows. Governments and businesses typically have access to more powerful systems and better encryption algorithms then individuals. Another advantage hinted at by A. Tewfik [1] is that information hiding can fundamentally change the way that we think about information security. In this paper different transforms (two dimensional Discrete Wavelet Transform, Discrete Cosine Transform and Fast Fourier Transform) are presents for digital watermarking.

II. TRANSFORMS

A. Discrete Wavelet Transform

The DWT (Discrete Wavelet Transform) separates an image into a lower resolution approximation image (LL) as well as horizontal (HL), vertical (LH) and diagonal (HH) detail components. The process can then be repeated to compute multiple “scale” wavelet decomposition, as in the 2 scale wavelet transforms shown in figure 1.

![Figure 1. 2 Scale 2-Dimensional Discrete Wavelet Transform](Image)

One of the many advantages over the wavelet transform is that it is believed to more accurately model aspects of the HVS as compared to the FFT or DCT. This allows us to use higher energy watermarks in regions that the HVS is known to be less sensitive to, such as the high resolution detail bands (LL, HL, HH) [3].

B. The Two-Dimensional DCT

The objective of this document is to study the efficacy of DCT [6] on images. The 2-D DCT is a direct extension of the 1-D case and is given by

\[ C(u,v) = \alpha(u)\alpha(v) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x,y) \cos \left( \frac{\pi(2x+1)u}{2N} \right) \cos \left( \frac{\pi(2y+1)v}{2N} \right) \]

for \( u,v = 0,1,2,\ldots,N-1 \) and \( \alpha(u) \) and \( \alpha(v) \) are defined in (2.3). The inverse transform is defined as

\[ f(x,y) = \sum_{u=0}^{N-1} \sum_{v=0}^{N-1} C(u,v) \alpha(u)\alpha(v) \cos \left( \frac{\pi(2x+1)u}{2N} \right) \cos \left( \frac{\pi(2y+1)v}{2N} \right) \]

for \( x,y = 0,1,2,\ldots,N-1 \). The 2-D basis functions can be generated by multiplying the horizontally oriented 1-D basis functions with vertically oriented set of the same functions. DCT formula is called the analysis formula or the forward transform, while inverse discrete cosine transform is the synthesis formula or inverse transform.
C. Two-Dimensional FFT

2-dimensional Fourier transforms [7] simply involve a number of 1-dimensional fourier transforms. 2D transform of a 1K by 1K image requires 2K 1D transforms. This follows directly from the definition of the Fourier transform of a continuous variable or the discrete Fourier transform of a discrete system.

\[
F(u, v) = \frac{1}{MN} \sum_{x=0}^{M} \sum_{y=0}^{N} f(x, y) e^{-j2\pi(ux/M + vy/N)}
\]

The inverse transform is defined as

\[
f(x, y) = \sum_{u=0}^{M} \sum_{v=0}^{N} F(u, v) e^{j2\pi(ux/M + vy/N)}
\]

D. Image Matrices

This section discusses some parameters used to measure image quality. From the error data mean square error (MSE), root mean square error (RMSE), signal to noise ratio (SNR), and peak signal to noise ratio (PSNR) were calculated [4].

\[
MSE = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} [f(x, y) - f^*(x, y)]^2
\]

Where \(f(x, y)\) is the original image data and \(f^*(x, y)\) is the watermarked image value. The formulas for calculated image matrices are:

\[
RMSE = \sqrt{MSE}
\]

\[
SNR = 10 \log_{10} \left( \frac{\sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x, y)^2}{\sum_{x=0}^{M-1} \sum_{y=0}^{N-1} [f(x, y) - f^*(x, y)]^2} \right)
\]

\[
PSNR = 20 \log_{10} \left( \frac{255}{\sqrt{MSE}} \right)
\]

E. Weighted Peak Signal to Noise Ratio (WPSNR)

The WPSNR is a different quality measurement suggested in [5]. The WPSNR uses an additional parameter called the Noise Visibility Function (NVF) which is a texture masking function. The WPSNR uses the value of NVF as a penalization factor.

\[
WPSNR = 10 \log_{10} \left( \frac{L_{\text{max}}^2}{MSE \cdot \text{NVF}^2} \right)
\]

For flat regions, the NVF is close to 1. And for edge or textured regions NVF is more close to 0. This indicates that for smooth image, WPSNR approximately equals to PSNR. But for textured image, WPSNR is a little bit higher than PSNR. The form of NVF is given as

\[
NVF(i, j) = \frac{1}{1 + \theta \sigma_i^2(i, j)}
\]

Where \(\sigma_i^2(i, j)\) denotes the local variance of the image in a window centered on the pixel with coordinates \((i, j)\) and \(\theta\) is a tuning parameter corresponding to the particular image. Local variance is given as

\[
\sigma_i^2(i, j) = \frac{1}{(2L+1)^2} \sum_{k=-L}^{L} \sum_{l=-L}^{L} (x(i+k, j+l) - \bar{x}(i, j))^2
\]

where a window of size \((2L+1) \times (2L+1)\) is considered. The image-depend tuning parameter is given as

\[
\theta = \frac{D}{\sigma_{\text{max}}^2}
\]

Where \(\sigma_{\text{max}}^2\) is the maximum local variance for a given image and D is an experimental value, range from 50 to 100.

III. RESULTS AND DISCUSSION

This paper applies the different transforms (two dimensional Discrete Wavelet Transform, Discrete Cosine Transform and Fast Fourier Transform) for digital watermarking. Table I shows the comparison of different transform on the bases of SNR, PSNR and WPSNR. Table I concludes that as we increase the threshold value, the SNR value also increases. Out of these transforms DCT2 gives the best picture quality than FFT2 and DWT2.

Figure 3, 5, 7 shows the original image and the marked images hid by applying all three transforms with different threshold values. It also shows that original and watermarked images are similar at different threshold values. Figure 4, 6, 8 shows the difference between the original image and the watermarked images with these transforms.

<table>
<thead>
<tr>
<th>Threshold</th>
<th>Transform</th>
<th>SNR</th>
<th>PSNR</th>
<th>WPSNR</th>
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<tr>
<td>50</td>
<td>DWT2</td>
<td>38.7396 ± 43.32</td>
<td>-37.2403</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DCT2</td>
<td>50.0031 ± 43.33</td>
<td>-37.1960</td>
<td></td>
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<tr>
<td></td>
<td>FFT2</td>
<td>40.1098 ± 43.30</td>
<td>-36.4787</td>
<td></td>
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<td>39.0323 ± 43.32</td>
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<td>-37.2843</td>
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<tr>
<td></td>
<td>FFT2</td>
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<tr>
<td>150</td>
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<td></td>
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<tr>
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<tr>
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<tr>
<td></td>
<td>FFT2</td>
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</tr>
</tbody>
</table>
Figure 2. Marked image that is to be hided

Figure 3. Comparison of DWT2, DCT2 and FFT2 at threshold 50.

Figure 4. Watermark of DWT2, DCT2 and FFT2 at threshold 50.

Figure 5. Comparison of DWT2, DCT2 and FFT2 at threshold 150.

Figure 6. Watermark of DWT2, DCT2 and FFT2 at threshold 150.

Figure 7. Comparison of DWT2, DCT2 and FFT2 at threshold 250.

Figure 8. Watermark of DWT2, DCT2 and FFT2 at threshold 250.

IV. CONCLUSION

This study has presented a different transforms for the watermarking of digital images, as well as touching on the limitations and possibilities of each. In this paper digital watermarking has been done using three transforms and between them two dimensional discrete cosine transform give the better results than other transforms.

V. REFERENCE: