

Comparative Analysis of Digital Image Watermarking Techniques in Frequency Domain using MATLAB SIMULINK

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ABSTRACT

Digital multimedia data is easily created, copied, processed, stored and distributed among unauthorized users using freely available software. So, digital watermarking technique provides solution to the problem. Watermarking is the process in which an informal data is incorporated in original data to protect the owner's copyright over that content. In this paper, comparative analysis of digital image watermarking techniques in frequency domain is presented. Behavioral MODEL of different image watermarking techniques is introduced in MATLAB SIMULINK using Simulink library blocks. In this paper, comparative analysis is performed based on robustness and computational complexity of different watermarking algorithms after attacks.

Keywords- Watermarking; discrete cosine transform (DCT); Matlab Simulink; Robust; Image.

1. INTRODUCTION

In the recent times, with the development of network technology, protection of multimedia data becomes increasingly prominent. Because of their digital nature, multimedia data can be duplicated, modified, transformed, and diffused very easily [1]. The growth of internet is so vast that any data can be easily transferred to the other person in just a single click. Due to its portability, the trend of piracy and duplicity rapidly approaches to Everest now days. The original producer of the file even doesn't know that the file created by him/her is available for free through internet and even if knows, nothing can be done[2]. It has been recognized for quite some time that current copyright laws are inadequate for dealing with digital data.

So, recent development of digital watermarking technology can solve this problem. Watermarking is the process to hide some data which is called watermark or label into the original data(image, audio or video) such that watermark can be extracted or detected later to make an assertion about the object. Watermarks of varying degree of visibility are added to presentation media as a guarantee of authenticity, quality, ownership and source.[1]

For insertion and extraction of watermark, there are two primary methods that are spatial domain and transform domain. The spatial domain method

involves an algorithm that directly operates on the pixel values of the host image. In transform domain method, the pixel values are transformed into another domain by applying appropriate transform technique like discrete cosine transform (DCT) and discrete wavelet transform (DWT). Generally, frequency domain watermarking is more robust than the spatial domain. In this paper, we will implement different digital image watermarking techniques in MATLAB SIMULINK for comparative analysis.

1.1 Matlab Simulink

Simulink is a graphical simulation tool for dynamic system modeling, simulation and comprehensive analysis. It can call MATLAB powerful function library, save a lot of duplicate codes writing work, and the user can immediately see the results of simulation results [3]. Initially for behavioral model, several in-built function are used for watermarking process and several blocks are created using Matlab function block.

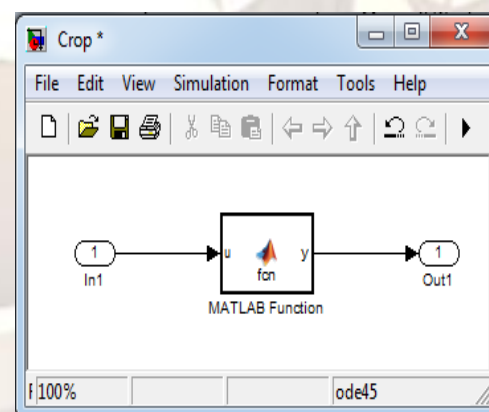


Figure 1.1: Block creating using Matlab function

In this block, we can write a function according to our desired dimensions for cropping the input image. This solves the problem of non-availability of in-built blocks. In the above Matlab function, image crop block is not available, so function for cropping image to desired size is written. Here u defines the input and y defines output of the block.

2. RELATED WORKS

There are many papers in which authors use DCT and DWT transforms in their algorithm for embedding watermark. Authors of [1] used DWT using fuzzy logic on FPGA for hardware for an adaptive encrypted watermarking method aims to achieve low power usage, real-time performance, reliability. They conclude the watermarking scheme is imperceptible and robust against geometric attacks. Importance of fuzzy logic to calculate the gain factor with respect to texture sensitivity of the image was also proved. Authors of [2] implement their algorithm on DWT transform. In this, first they apply Arnold transform to the watermark after which, Chaos transform is applied to the to the output of Arnold transform and then embedding is done to get the watermarked image and conclude that the watermark becomes more secure with Arnold and Chaos pseudo random sequence. Another encryption algorithm in [3] based on color image watermarking is proposed in SIMULINK. In this, they first separate color components into RGB and then embedded watermark on G components after DCT. Also a key is set for encryption of watermark. They conclude that their embedding and detection algorithm is fast and conveniently verify the correctness of the algorithm. In [4] the authors used DCT and DWT both for watermarking scheme. In their algorithm, the information of digital watermarking which has been Discrete Cosine Transformed, is put into the high frequency band of image which has been wavelet transformed. According to them, their simulation results show that their algorithm is invisible and has good robustness for some common image processing operations. Authors of [5] proposed hardware implementation using DCT/IDCT in Xilinx XC3S4000 FPGA which increases the speed close to 500% over the conventional methods. In [6], a dual image watermarking technique based on DWT is used. In this, watermarking technique incorporates two watermarks in a host image, a watermark in from of PN sequence is embedded in the wavelet domain of a primary watermark before being embedded in the host image and concludes that algorithm proves its robustness against several kinds of attacks.

3. WATERMARKING BASED ON DCT IN MATLAB SIMULINK

The DCT transform a signal from a spatial representation into a frequency representation. Lower frequencies are more obvious in an image than higher frequencies so if we transform an image into its frequency components and throw away a lot of higher frequency coefficients, we can reduce the amount of data needed to describe the image without sacrificing too much image quality. The discrete cosine transform (DCT) represent an image as a sum of sinusoids of varying magnitudes and frequencies. [4] The DCT has the property that, for a typical image,

most of the visually significant information about the image is concentrated in just a few coefficients of the DCT. For this reason, the DCT is often used in image compression applications.

In this algorithm, the original image is divided into several 8x8 blocks. Then those several blocks are discrete cosine transformed (DCT-2). The watermark is embedded by 8*8 piecemeal and then again passed through Inverse DCT-2.

The definition of the two-dimensional DCT for an input image A and output image B is

$$B_{pq} = \alpha_p \alpha_q \sum_{m=0}^{N-1} \sum_{n=0}^{N-1} A_{mn} \cos \frac{\pi(2m+1)p}{2M} \cos \frac{\pi(2m+1)q}{2N} \quad (1)$$

$$0 \leq p \leq N-1$$

$$0 \leq q \leq N-1$$

$$\alpha(p) = \begin{cases} \frac{1}{\sqrt{N}}, & p = 0 \\ \sqrt{2/N}, & 1 \leq p \leq N-1 \end{cases} \quad (2)$$

$$\alpha(q) = \begin{cases} \frac{1}{\sqrt{N}}, & q = 0 \\ \sqrt{2/N}, & 1 \leq q \leq N-1 \end{cases} \quad (3)$$

p and q varies from 0 to N-1, and M-1.

Two dimensional inverse DCT can be calculated as below

$$A_{mn} = \alpha_p \alpha_q \sum_{p=0}^{N-1} \sum_{q=0}^{N-1} B_{mn} \cos \frac{\pi(2m+1)p}{2M} \cos \frac{\pi(2m+1)q}{2N} \quad (4)$$

$$0 \leq m \leq N-1$$

$$0 \leq n \leq N-1$$

$$\alpha(p) = \begin{cases} \frac{1}{\sqrt{N}}, & p = 0 \\ \sqrt{2/N}, & 1 \leq p \leq N-1 \end{cases} \quad (5)$$

$$\alpha(q) = \begin{cases} \frac{1}{\sqrt{N}}, & q = 0 \\ \sqrt{2/N}, & 1 \leq q \leq N-1 \end{cases} \quad (6)$$

Where M and N are the row and column size of image A (Input data).

3.1 Watermark Embedding

The watermarking scheme consist of DCT transform of original image which will concentrate the main image information into the least low frequency coefficients, and cause smallest image blocking effect, thus achieves good compromise between centralized information and computational complexity. Moreover, 2D-DCT is real transformation. It has good energy compression ability, goes to the related ability envelope compatibility with the international compression standard. It is a good choice about using the 2D-DCT transform to implement the watermarking embedding and extraction. Figure 3.1 shows the embedding procedure of watermark.

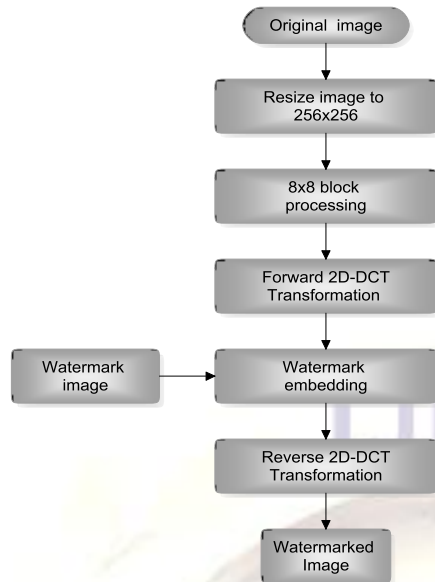


Figure 3.1 Watermark embedding algorithm

The watermark Embedding processes consists of following steps:

1. The original image is first resized into 256x256 pixels.
2. The watermark is resized into 32x32 pixels.
3. Then original resized image is block-processed into 8x8 blocks so as to completely embed the 32x32 watermark on 256x256 image.
4. After this, 2D- Discrete Cosine Transform is applied on these 8x8 sub-blocks individually to convert it from time domain to frequency domain.
5. The watermark image is embedded on the 8x8 blocks in the middle frequency band.
6. For embedding watermark, the value of frequency coefficient is changed in accordance to watermark data.
7. Reversed 2D-DCT is performed afterward on the watermark embedded image to convert from frequency domain to time domain.
8. The final image is the watermarked image.

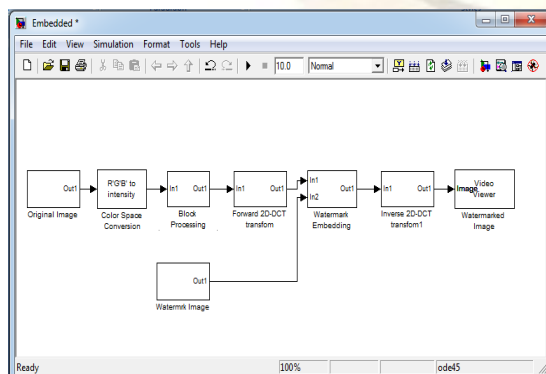


Figure 3.2 Watermark embedding model in Simulink

3.2 Watermark Extraction

Similarly the watermark can be extracted using the same transform but here the difference is, that only comparison is done according to the embedding scheme.

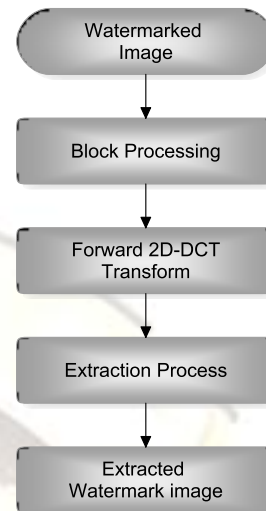


Figure 3.3 Watermark extraction algorithm

The watermark Extraction process consists of following steps:

1. Firstly the watermarked image is resized into 256x256 pixels if needed.
2. Then watermarked image is again block processed into 8x8 pixels.
3. Then Forward 2D-DCT is applied on the block processed image to have frequency separation.
4. After this, Extraction process is done in the same way as embedding was done in embedding process.
5. Depending upon the comparison done with particular pixels on which watermark data was embedded, decision is made which is stored in again 32x32 empty array.
6. Then this matrix is the extracted image which was original watermark image.

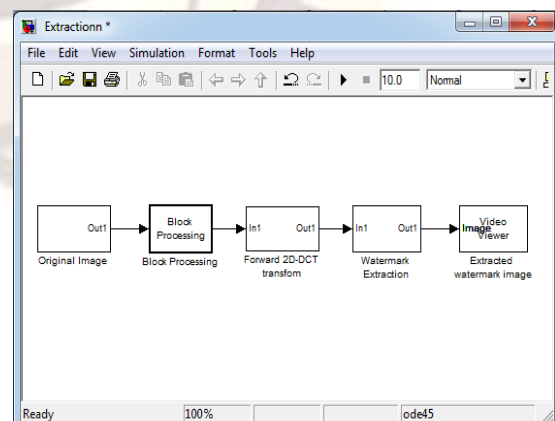


Figure 3.4 Watermark extraction model in Simulink

4. WATERMARKING BASED ON DWT

In this algorithm, the original image is first resized to 512x512. Then this is decomposed through 1-level Discrete Wavelet transform.

Discrete wavelets transform is frequency domain analysis method which can localize frequency domain [4]. The basic idea of discrete wavelet transform (DWT) in image processing is to multi-differentiated decompose the image into 4 frequency districts which is one low frequency district(LL) and three high frequency districts (LH,HL,HH). L and H represent Low-pass and High-pass filter. . A two level DWT decomposed image is shown in fig. 4.1.

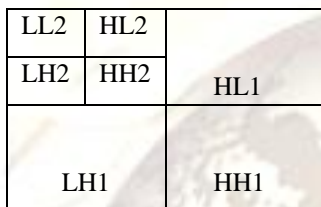


Figure 4.1: 2-level DWT decomposition

The information of low frequency district image is very close to the original image. The frequency district of LH, HL, and HH respectively represents the level detail, the upright detail and the diagonal detail. The human eye is sensitive to the change of smooth district of image, but not at the edges and peaks. So, it is not safe to putting watermark in coefficients of high frequency band of DWT image because it can be easily noticed. The brightness masking on human visual model shows that the larger the background brightness, the more the just noticeable difference of embeddable signal, which means low frequency approximate image can be embedded by more watermarking capacity is lower than JND, as human eyes cannot suspect the existence of signal. Some common attacking to low frequency coefficients, the host image is also destroyed. So it is good to embed watermark in medium and low frequency.

1.1 Watermark Embedding Model in Matlab Simulink

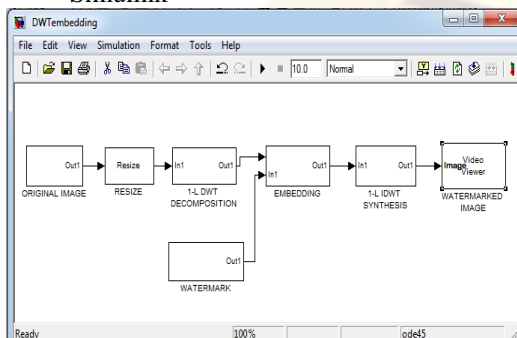


Figure 4.1: watermark embedding model in Simulink

The Watermark embedding process consists of the following steps:

1. The original image is first resized into 512x512 pixels because after DWT decomposition, we will get only with 256x256 pixel size image.
2. As, the size of our watermark is 32x32, 256x256 is the exact dimension to embedded 32x32 pixels on 8x8 sub-blocks in complete image.
3. Then this is decomposed through 1-level Discrete Wavelet Transform which leads the image into four parts [1] as explained above.
4. After this, watermark is embedded into the Low-high frequency components.
5. Then again, 1-level IDWT is applied to this image to synthesize it to complete image.
6. The final image is watermarked image.

1.2 Watermark Extraction Model in Matlab Simulink

The watermarking process is same but in the reverse order.

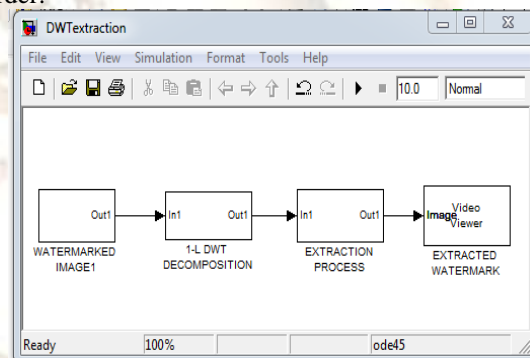


Figure 4.2: watermark extraction model

Watermark extraction process consists of following steps:

1. The watermarked image is resized into 512x512 pixels if needed.
2. The watermarked image is decomposed into 1-level DWT transform.
3. Then according to the embedding process, the comparison is done for extraction.
4. The generated image by comparison is the extracted watermark image.

5. WATERMARKING BASED ON DCT & DWT IN SIMULINK

In this algorithm, we use DCT and DWT both the transforms for embedding and extraction of watermark.

1.3 Watermark Embedding Model in Matlab Simulink

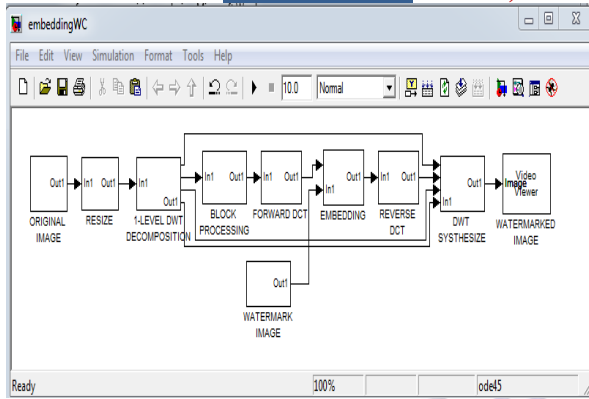


Figure5.1: watermark embedding model

Embedding process consists of following steps:

1. The original image is first resized into 512x512 pixels.
 2. Then it is decomposed through 1-level Discrete Wavelet transform (DWT) which results the image into four parts.
 3. Then the high-low frequency sector is block processed into 8*8 blocks to let 32x32 watermark image embed completely into host image correspond to a single pixel in every 8x8 block.
 4. After this, forward DCT-2 is applied on each 8x8 sub-blocks for better frequency band separation.
 5. Then watermark image is embedded into the processed image in the middle frequency band of sub-blocks.
 6. Again inverse IDCT-2 is applied after embedding the watermark.
 7. After this, to get the original image, IDWT is applied to synthesize the complete image.
 8. The final image is the watermarked image.
- 1.4 Watermark Extraction Model in Matlab Simulink

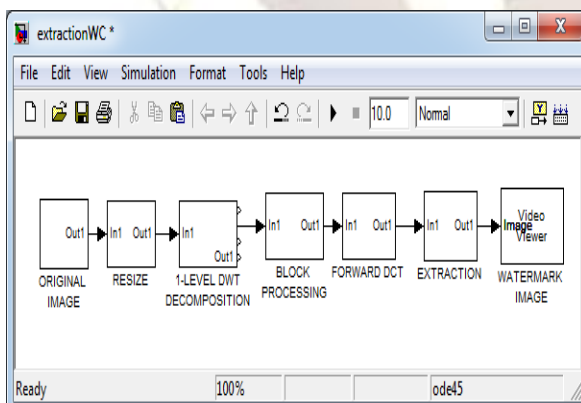


Figure5.2: watermark extraction model

The extraction process consists of the following steps:

1. The watermark image is decomposed through 1-level DWT transform to again have four different frequency sectors.[1]

2. Then the low-high frequency sector is block-processed into 8x8 blocks.
3. These 8x8 sub-blocks are passed through Discrete Cosine Transform (DCT-2).
4. Then, according to the embedding scheme on individual pixel, comparison decision as done whose result is stored in an empty array of 32x32 same as above.
5. Finally this empty array will contain the complete decision information and this array will be the extracted watermark image.

6. COMPARATIVE ANALYSIS OF DIFFERENT ALGORITHM

The 32x32 is taken as watermark image information in fig. 6.1 and 256x256 is taken as the source image shown in fig. 6.2



Figure 6.1



Figure 6.2

TABLE I. RESULTS AFTER ATTACKS (PSNR in dB)

CATAGORY	DCT	DWT	DCT& DWT
WATERMARKED IMAGE	34.45	36.38	41.40
SALT & PEPPER(0.02)	20.02	21.33	22.05
ROTATION (2 degree)	14.91	15.57	17.61
ENHANCEMENT (contrast limit-0.6-0.9)	30.41	32.65	37.41
GAUSSIAN NOISE(mean-0.01,var-0.01)	16.23	17.11	21.34
SPECKLE (0.06)	15.85	16.21	18.83

TABLE II. RESULTS AFTER ATTACKS (NC in dB)

CATAGORY	DCT	DWT	DCT& DWT
WATERMARKED IMAGE	1	1	1

SALT & PEPPER(0.02)	0.991	0.996	0.998
ROTATION (2 degree)	0.952	0.963	0.982
ENHANCEMENT (contrast limit-0.6-0.9)	0.983	1	1
GAUSSIAN NOISE(mean-0.01,var-0.01)	0.964	0.972	0.985
SPECKLE (0.06)	0.965	0.972	0.988

7. CONCLUSION

In this paper, we implemented different watermarking algorithms using MATLAB SIMULINK based on DCT, DWT and combination of DCT&DWT transform. Simulation results show that DWT is somewhat better than DCT but, combination of these two gives much better results than individual one. The capability of watermarking algorithm is robust to salt & pepper, enhancement and speckle, but somewhat weaker to rotate and Gaussian noise. Moreover, we can implement robust watermarking using combined DCT&DWT transforms with advanced modification in the algorithm for much better results in Simulink and hardware implementation can be done in the next step.

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