Robust Watermarking of Greyscale Images in Frequency Domain by Optimizing Watermarking Sterngth Parameter

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Abstract— Unlimited number of replicas of the original content can be made from unprotected digital content. Billions of bits of data is created in every fraction of a second. Also, with the advent of internet, creation and delivery of digital data (images, video and audio files, digital repositories and libraries, web publishing) has grown many fold. Since copying a digital data is very easy and fast too so, issues like, protection of rights of the content and proving ownership, arises. Digital watermarking came as a technique and a tool to overcome shortcomings of current copyright laws for digital data. The specialty of watermark is that it remains intact to the cover work even if it is copied. So to prove ownership or copyrights of data watermark is extracted and tested. It is very difficult for counterfeiters to remove or alter watermark. As such the real owner can always have his data safe and secure. The focus of this dissertation is the watermarking of grayscale images. Different watermarking techniques exists, in spacial (pixel) and frequency (signal) domain, which are resistant to all types of attack, scalar or geometric. In this work, a method for watermarking of grayscale images in frequency domain is proposal. The standard method of Fast Fourier Transform based image watermarking is augmented with cost function based on watermark strength and similarity factor. Mathematical techniques are presented which embeds watermark in frequency domain, while at the same time, maintaining the robustness or watermark under various attacks. The simulation is done using MATLAB and results are compared with existing techniques of DFT based watermarking. Comparison of the results are presented which shows a considerable improvement in Peak Signal to Noise Ratio.

Key words: Watermarking, Grayscale Images, DFT, Blurring, PSNR

I. INTRODUCTION

Digital watermark [1] is a kind of technology that embeds copyright information into multimedia data. Unlike encryption, which is useful for transmission but does not provide a way to examine the original data in its protected form, the watermark remains in the content in its original form and does not prevent a user from listening to, viewing, examining, or manipulating the content. Digital watermarking technology opens a new door to authors, producers, publishers, and service providers for protecting their rights and interests in multimedia documents. An effective image watermarking scheme mainly includes watermark generation, watermark embedding, watermark identification, and watermark attack [2]. Watermark generation refers to what content and form of data a watermarking scheme adopts as watermark. The data may be original or encrypted from copyright information of number, letter, image, and so on. The copyright information to be used as watermark may be meaningful or meaningless. Meaningful information could be easily authenticated and usually needs to be encrypted in practice to strengthen watermarking security. Watermark embedding is the most important part in a watermarking scheme and must meet the two most fundamental requirements under the condition of fixed watermark size, imperceptibility and robustness [3]. The two requirements are in conflict with each other and need to reach a trade-off. Watermark embedding can be done in either spatial domain [4] or frequency domain [5]. The spatial domain watermark embedding manipulates host image pixels, especially on Least Significant Bits (LSB) [6] that have less perceptual effect on the image. Although the spatial domain watermark embedding is simple and easy to implement, it is less robust than frequency domain watermark embedding to various attacks and noise, which is made on the frequency coefficients of the host image. The existing frequency transformation methods for watermark embedding include Discrete Fourier Transform (DFT) [7], Discrete Cosine Transform (DCT) [8], and Discrete Wavelet Transform (DWT) [9]. Considering watermarking imperceptibility, one needs to select an appropriate embedding algorithm to embed the watermarking bits into certain frequency coefficients so that the quality of watermarked image will not be degraded compared by original host image. Many traditional embedding algorithms in the literature do not optimize the embedding process by experiential method. In recent years, watermarking techniques have been improved using optimization algorithms such as Genetic Algorithm (GA) [10] which is a popular evolutionary optimization technique invented by Holland [11]. In the field of watermarking, GA is mainly used in the embedding procedure to search for locations to embed the watermark. The act of watermark detection can be named as watermark verification in which a watermarking receiver must do a yes or no judgment whether a watermark does exist in the received image. In general, the Normalized Cross-Correlation (NCC) value between the original and extracted watermark is used in watermark detection. Defined a threshold T, a yes judgment can be given if NC $\geq$T, or a contrary result will be given. After getting a yes judgment in watermark detection, especially to the meaningful watermark, people may do more things to judge the owner of extracted watermark because of possibility of spurious watermark. Based on the watermark detection, watermark identification is to further judge as to what degree extracted watermark is similar to original watermark and whose extracted watermark belongs to. Although Bit Correct Rate (BCR), NCC and human eyes can be used in watermark identification, they all depend upon experimental results and human experiences. For distinguishing extracted watermark more clearly, meaningful watermark may be recovered partly or entirely from watermarked image by Neural Networks [12]. The introduction of neural networks helps to pave the way for the further development of watermark identification techniques. The goal of watermark attack is to test the robustness of a watermarking system. To simulate the communication conditions and deliberate or unintentional processing, some attacks, including adding noise, filtering, compression and geometrical distortion, need to be used in the watermarked image. For copyright protection, we use robust watermark in the condition that the watermark can partially be recognized and the copyright can be preserved after attacked by some means. But based on the applied purpose of robust watermark, a watermarking scheme need not withstand all kinds of attack. This paper presents a novel DWT domain gray image watermarking scheme. The watermarking data comes from a meaningful binary image encrypted by two-dimensional chaotic stream encryption. In the procedure of watermark embedding, GA [10] is used to select the most fit wavelet coefficients to embed watermarking bits into the host gray image. After some kinds of attack, the extracted watermark can be identified expediently through the synergetic neural networks(SNN). The experimental results have shown that this scheme has preferable performance of security, imperceptibility and robustness.

A. Desirable Characteristics of Watermark

An effective watermarking scheme should have the following desirable features:

(1) To be able to determine whether an image has been altered or not.
(2) To be able to locate any alteration made on the image.
(3) To be able to integrate authentication data with host image rather than as a separate data file.
(4) The embedded authentication data be invisible under normal viewing conditions.

To allow the watermarked image be stored in loss compression format [13].

B. Motivation

The sudden increase in watermarking interest is most likely due to the increase in concern over copyright protection of content. The Internet had become user friendly with the introduction of Marc Andreessen's Mosaic web browser in November 1993 [14], and it quickly became clear that people wanted to download pictures, music, and videos. The Internet, however, is one of the most excellent distribution systems for digital media because it is inexpensive, eliminates warehousing and stock, and delivery is almost instantaneous. However, content owners (especially large Hollywood studios and music labels) also see a high risk of piracy. This risk of piracy is exacerbated by the proliferation of high capacity digital recording devices.

When the only way the average customer who wants to keep a sound track could record a song or a movie was on analog tape, pirated copies were usually of a lower quality than the originals, and the quality of second-generation pirated copies (i.e., copies of a copy) was generally very poor. However, with digital recording devices, songs and movies can be recorded with little, if any, degradation in quality. Using these recording devices and using the Internet for distribution, would-be pirates can easily record and distribute copyright protected material without appropriate compensation being paid to the actual copyright owners. Thus, content owners are eagerly seeking technologies that promise to protect their rights. The first technology content owners turn to is cryptography. Cryptography [15] is probably the most common method of protecting digital content. It is certainly one of the best developed as a science. The content is encrypted prior to the delivery to the host or customer, and a decryption key is provided only to those who have purchased legitimate copies of the content. The encrypted file can then be made available via the Internet, but would be useless to a pirate without an appropriate key. Unfortunately, encryption cannot help the seller monitor how a legitimate customer handles the content after decryption. A pirate can actually purchase the product, use the decryption key to obtain an unprotected copy of the content, and then proceed to distribute illegal copies. In other words, cryptography can protect content in transit, but once decrypted, the content has no further protection. Thus, there is a strong need for an alternative or complement to cryptography: a technology that can protect content even after it is decrypted. Watermarking has the potential to fulfill this need because it places information within the content where it is never removed during normal usage. Decryption, re-encryption, compression, digital-to-analog conversion, and file format changes a watermark can be designed to survive all of these processes. Watermarking has been considered for many copy prevention and copyright protection applications. In copy prevention, the watermark maybe used to inform software or hardware devices that copying should be restricted. In copyright protection applications, the watermark may be used to identify the copyright holder and ensure proper payment of royalties. Although copy prevention and copyright protection have been major driving forces behind research in the watermarking field, there is a number of other applications for which watermarking has been used or suggested. These include broadcast monitoring, transaction tracking, authentication, copy control, and device control.

C. Problem Statement

DFT based image watermarking on Grayscale images using a binary watermark is presented. The watermark embedding is further improved with a cost function which gives optimal values of the strength factor against various regions of cover image. Also, the PSNR values are calculated against various levels of blurring operations of the binary watermark. The proposed method uses a non-bind technique for watermark detection in which the original image is required at the detector. It is however, more desirable have a blind watermarking technique in which the detector can detect the watermark without the need of the original copy at the reciever.

II. RESEARCH APPROACH

The original image is converted in frequency domain using two dimensional Fourier Transform. This original image is grayscale in which the pixel values range from 0 to 255 (total 256 values, ranging from 0; black to 255; white). The watermark is a binary image which can be of same or smaller size. This watermark comprised of only two levels, 0 (black) and 1 (white). The Fourier coefficients of the watermark are multiplied by a strength factor and added to the Fourier coefficients of the cover image. Inverse Fourier Transform of the resultant Fourier Coefficients are computed, thus providing the watermarked image. The value of the strength factor is computed based on watermark embedding segment of the image and the optimal value of the similarity factor.

III. PROPOSED WORK

A. *Watermarking using Fast Fourier Transform*

The Fourier Transform is a tool that breaks a waveform (a function or signal) into an alternate representation, characterized by sine and cosines. The Fourier Transform shows that any waveform can be re-written as the sum of sinusoidal functions. The Continuous Fourier Transform (CFT) of a function f(x) is defined as:

$$F(s) = \int_{-\infty}^{\infty} f(t)\, e^{-ist} \mathrm{dt} \qquad eq.\ 3.1$$

The inverse Fourier Transform is defined as:

$$f(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(s)\, e^{ist} \mathrm{ds} \qquad eq.\ 3.2$$

If the signal f(t) is periodic, band limited and sampled at Nyquist Frequency or higher, the Fast Fourier Transform (FFT) represents the CFT exactly.

$$X(s) = \frac{1}{\sqrt{\mathrm{N}}} \sum_{n=0}^{N-1} x(n) e^{-i2\pi sn/N} \qquad eq.\ 3.3$$

and

$$x(n) = \frac{1}{\sqrt{\mathrm{N}}} \sum_{s=0}^{N-1} X(s) e^{i2\pi sn/N} \qquad eq.\ 3.4$$

2D Fourier transforms simply involve a number of one dimensional Fourier transforms. More precisely, a 2D transform is achieved by first transforming each row, i.e. replacing each row with its 1D Fourier transform. This first step yields an intermediary 'picture' in which the horizontal axis is frequency f and the vertical axis is space y. The second step is to apply 1D Fourier transform individually to the vertical line of the intermediate image. This new image will be the 2D Fourier transformation of the initial image.

A schematic representation how the 2D Fourier transform is performed is presented in figure 9.1. From the figure it is obvious that a 2D Fourier transform from an image with n*n pixels consists of 2n one dimensional transforms. The formulas used for 2D Fourier transform follow directly from the definition of the Fourier transform of a continuous variable or the discrete Fourier transform of a discrete system.

In the most general situation a 2D Fourier transform takes a complex array. But, the most common application is for image processing where each value in the array represents one pixel, therefore the real value is the pixel value and the imaginary value is 0.

$$F(u,v) = \frac{1}{\mathrm{M} * \mathrm{N}} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} f(x,y) e^{-i2\pi(\frac{ux}{\mathrm{M}} + \frac{vy}{\mathrm{N}})} \qquad eq.\ 3.5$$

and the corresponding inverse Fourier Transform is

$$f(x,y) = \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} F(u,v) e^{i2\pi(\frac{ux}{\mathrm{M}} + \frac{vy}{\mathrm{N}})} \qquad eq.\ 3.6$$

Consider the color image of lena of dimension 225 by 225, shown in figure 3.1 below

Fig. 3.1: Color Image of Lena

The corresponding grayscale image can be obtained by 8 bit color map, by averaging the values of Red, Green and Blue planes, as shown in figure 3.2.

Fig. 3.2: Grayscale Image of Lena

The two dimensional Fourier Transform of the grayscale image of figure 3.2 can be obtained through MATLAB simulation and is shown in the figure 3.3 below.

MATLAB code:

```
I=fft2('lena_grayscale.jpg');
 imshow(log(abs(fftshift(I))+1),[ ] );
```

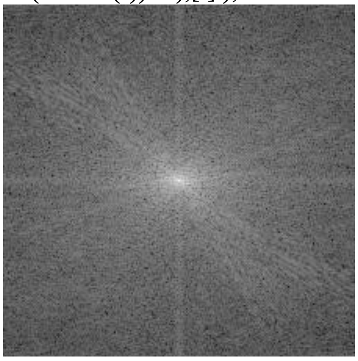


Fig. 3.3: DFT Plot for Grayscale Lena

The watermark as a binary image of the same dimension is shown in the figure 3.4.

Fig. 3.4: Copyright Logo as Watermark (Binary Image)

The two dimensional Fourier Transform of the binary image of figure 3.4 can be obtained through MATLAB simulation and is illustrated in Figure 3.5 below.

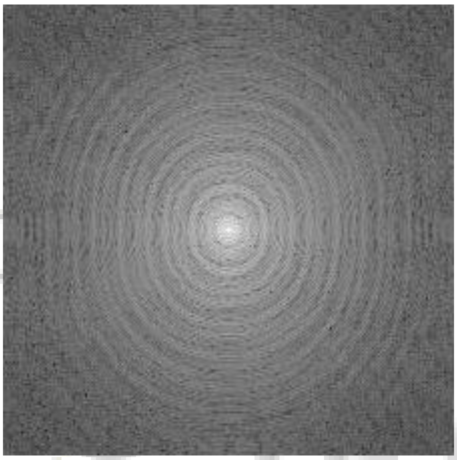


Fig. 3.5: DFT of copyright logo

The addition of these two DFT values can be done as per the equation given below:

$DFT_W = DFT_I + \alpha * DFT_C$

where DFT_I and DFT_C are the DFT values of image and watermark respectively. The watermarked image can be obtained as:

$IMAGE_W = Inverse\_DFT(DFT_W)$

The watermarked image for various values of α is illustrated in table 3.1:

	
α = 1	α = 10
	
α = 20	α = 30
	
α = 40	α = 50
	
α = 60	α = 70
	
α = 80	α = 90
	
A = 100	A = 110

Table 3.1: Fft Based Watermarking For Varying Values Of Strength Factor

The extracted watermark can be obtained using the following code:

$DFTw = IMAGE_W$ // Fourier Transform of Watermarked Image

$DFTo = IMAGEo$ // Fourier Transform of Original Image

$DFT_{WM} = DFTw - DFTo$ // Fourier Transform of Original Image

$WATERMARK = Inverse\_DFT(DFT_{WM})$

The extracted watermark is shown in the figure 3.7 below

Fig. 3.6: Extracted Watermark (under no-noise addition)

The mean square error metric corresponding to α values are shown in the table 3.2. However, as illustrated above, as the strength of watermark is increased, the visibility of the watermark becomes more and more prominent.

Alpha	MSE	PSNR
1	31378	3.164551
10	31467	3.15225
20	32456	3.017854
30	34567	2.744187
40	35667	2.608138
50	38765	2.246406
60	39876	2.123688
70	40012	2.108901
80	41302	1.971093
90	45092	1.589809
100	47005	1.409363
110	48012	1.317306

Table 3.2: Psnr Values Of Varying Values Of Strength Factor

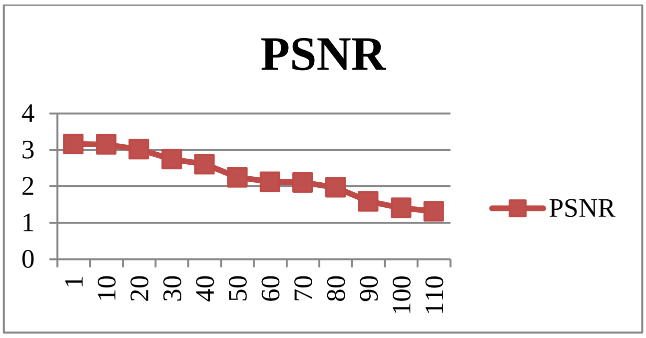


Fig. 3.7: Plot for PSNR values against strength Parameters.

B. Cost Function for the evaluation of optimal α and SF.

The cost function can be computed as shown below:

$$C.F. = \frac{A}{SF} + B * \alpha \qquad eq.\ 3.7$$

As described in the equation above, it is the weighted sum of reciprocal of Similarity Factor (SF) and the Strength Factor (α). The aim is to minimize the value of the cost function. This is for the following reasons:

(1) A large value of α means a more visible watermark. Thereby, reducing the perpetual quality of the image. Thus, this value should be as low as possible.

(2) A large value of similarity factor is certainly required as it is a measure of similarity between the original image and the watermarked image. A large value of SF is a guarantee of high PSNR value of the watermarked image.

The original cover image can be partitioned into blocks of suitable size for watermark embedding as shown in the figure 3.8 below:

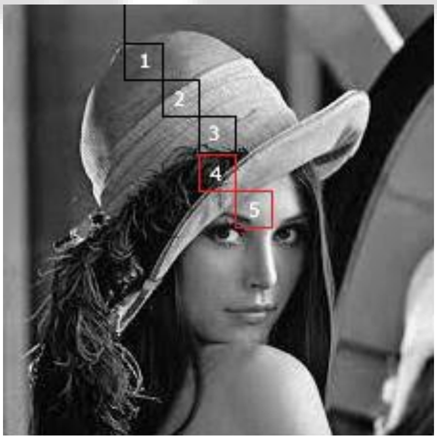


Fig. 3.8: Identification of Embedding Regions

The 20*20 sample of Lena image is shown in the figure given below (block 1):

201	227	227	193	3	37	156	69	154	246
82	255	3	185	110	2	200	64	146	49
128	15	58	168	83	31	40	268	22	160
161	88	194	126	120	172	186	237	74	163
146	120	67	135	193	253	199	85	216	211
185	248	50	141	27	181	202	215	89	216
82	44	233	141	20	113	56	57	41	66
131	40	223	82	5	22	106	33	184	236
64	159	92	98	69	7	214	119	120	28
62	170	200	38	62	169	88	251	175	222
169	244	13	156	141	169	48	102	72	28
206	14	89	1	87	66	93	225	240	49
180	152	0	69	161	159	232	4	240	245
189	241	24	124	196	196	33	188	158	155
242	68	68	5	210	254	163	171	247	128
190	240	78	240	36	105	183	252	159	10
164	55	51	47	151	45	142	84	199	11
61	3	15	24	33	167	81	9	90	208
37	146	34	201	143	185	251	156	82	140
141	154	249	59	49	241	183	59	89	170

Table 3.3: Pixel Matrix Of Block 1 Of The Image Of Lena (Figure 3.8)

The 20*20 Binary Copyright Image is shown in the figure given below:

Fig. 3.9: Copyright Image (Magnified 800 percent)

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1
1	1	1	1	1	0	1	0	0	1	0	0	1	0	0	1	0	1	0	1
1	1	1	1	0	0	1	1	1	0	0	0	0	1	1	1	0	1	1	1
1	1	1	1	1	0	0	0	1	0	1	0	0	1	0	1	1	0	0	1
1	1	1	1	0	0	1	1	1	0	1	1	0	1	1	0	0	1	1	1
1	1	1	1	1	0	1	1	1	1	1	0	1	1	0	0	0	1	1	1
1	0	0	0	0	0	1	0	1	1	1	0	0	1	1	1	0	1	0	1
1	0	0	0	1	1	1	1	1	0	0	1	0	0	0	0	1	1	1	1
1	1	1	0	0	1	0	1	1	0	0	1	1	0	0	0	0	1	0	1
1	0	1	0	1	1	0	1	0	1	0	1	1	1	1	1	1	1	1	1
1	0	1	0	0	1	0	0	0	1	0	1	0	1	0	1	0	1	1	1
1	1	0	0	1	1	1	1	1	1	0	1	0	1	1	0	0	1	1	1
1	1	1	1	1	0	1	1	0	0	1	0	0	1	0	1	0	0	0	1
1	0	1	1	1	1	0	0	0	1	0	0	1	1	1	0	0	1	0	1
1	1	0	1	1	0	1	2	1	0	0	1	0	1	0	0	1	0	1	1
1	0	0	1	0	0	0	1	1	0	1	1	0	0	0	1	0	0	1	1
1	0	0	1	0	0	1	1	0	1	0	0	1	0	1	1	1	1	0	1
1	1	0	1	0	0	1	1	1	1	0	0	0	1	0	0	1	1	0	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Table 3.4: Pixel Matrix Of 20*20 Image Matrix

For an initial value of A = B = 1, and α = 1, the values of cost function for following cover images is shown in the table 3.5 below:

A=1		
B=1		
Strength Factor (α) = 1		
Block	**Similarity Factor (SF)**	**CF**
1	1.23	1.813008
2	2.34	1.42735
3	2.44	1.409836
4	3.11	1.321543
5	3.01	1.332226

Table 3.5: Plot Of Similarity Factor For Various Image Regions

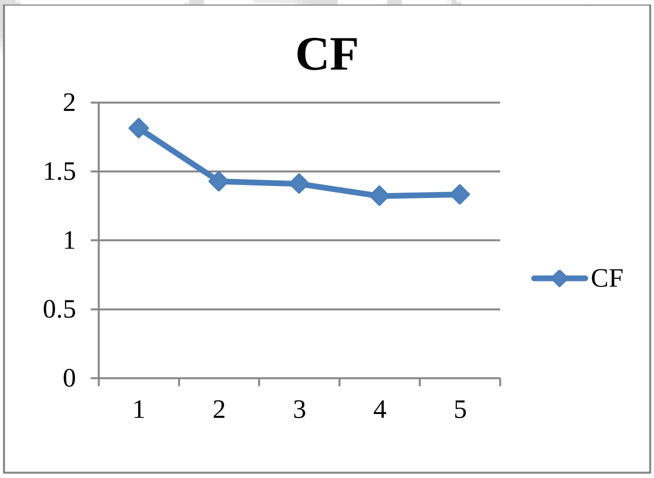


Fig. 3.10: Dependency of Cost Function on the Blocks as illustrated in Original Image of Lena.

C. Dependency of Cost Function with Gaussian Blurring of the watermark

Images are often corrupted by random variations in intensity, illumination, or have poor contrast and can't be used directly. One can use following operations on images for enhancement/suppression of certain characteristics.

1. (1) Filtering: Transform pixel intensity values to reveal certain image characteristics.
2. (2) Enhancement: Improves contrast
3. (3) Smoothing: Remove noises
4. (4) Template matching: detects known patterns

The Gaussian Blurring of image can be obtained through a low pass filtering of the Fourier Transform of the image as shown in the table 3.6 given below.

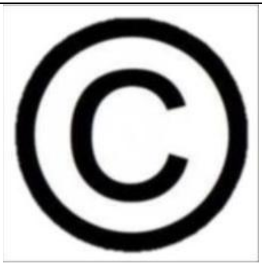
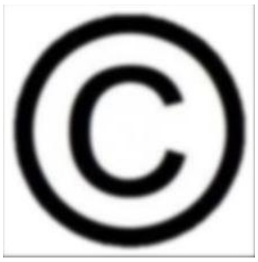
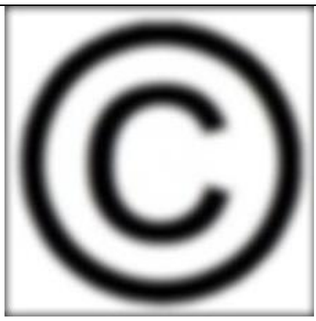
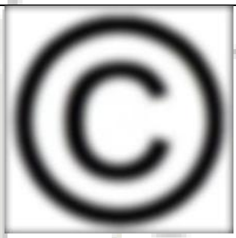
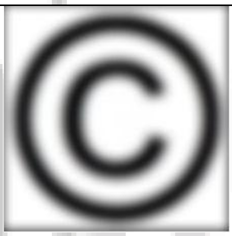
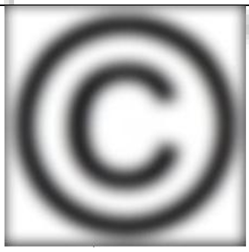
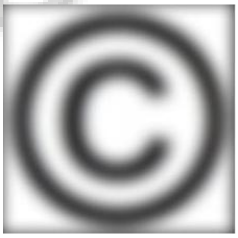
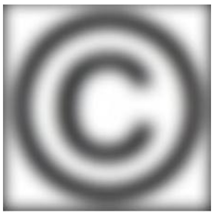
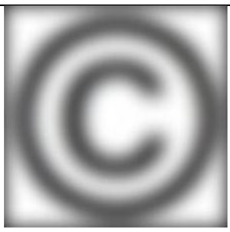
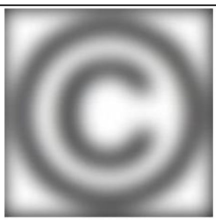
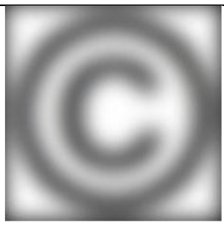
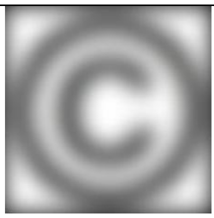
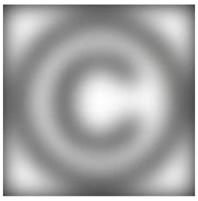
	
Masksize = 2, Sigma = 0.5	Masksize = 5, Sigma = 1
	
Masksize = 9, Sigma = 2	Masksize = 15, Sigma = 4
	
Masksize = 20, Sigma = 5	Masksize = 25, Sigma = 6
	
Masksize = 30, Sigma = 7	Masksize = 35, Sigma = 8
	
Masksize = 40, Sigma = 9	Masksize = 45, Sigma = 10
	
Masksize = 50, Sigma = 11	Masksize = 55, Sigma = 12
	
Masksize = 60, Sigma = 13	Masksize = 65, Sigma = 14

Table 3.6: Gaussian Blurring For Watermark Against Varing Values Of Standard Deviation And Mask Windows

SIGMA	PSNR
0.5	35.45
1	35.96
2	36.11
4	39.21
5	39.57
6	39.88
7	40.12
8	41.23
9	41.87
10	41.92
11	42.02
12	43.15
13	43.67
14	43.91

Table 3.7: Psnr Values For Varying Values Of Standard Deviation For Block #1 Of The Cover Image Lena

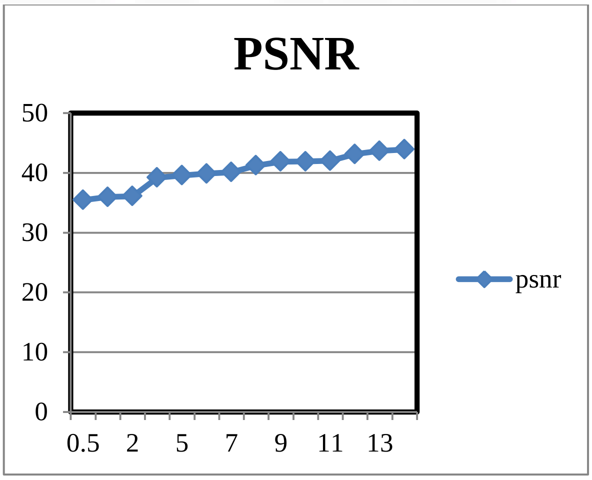


Fig. 3.11: Plot for various values of PSNR against standard deviation

It is clearly evident that the PSNR value increases as the watermark image becomes more and more blurred. This is in accordance with the assertion that as the blurring increases, the magnitude of the frequency spectrum scatters across the boundaries and gives a homogenous aggregation.

IV. CONCLUSION

The Fourier Transform is an important image processing tool which is used to decompose an image into its sine and cosine components. The output of the transformation represents the image in the *Fourier* or frequency domain, while the input image is the spatial domain equivalent. In the Fourier domain image, each point represents a particular frequency contained in the spatial domain image. The Fourier Transform is used in a wide range of applications, such as image analysis, image filtering, image reconstruction, image compression and image watermarking. FFT based watermarking is robust against various types of attacks.The PSNR values also depends upon the selection of the embedding block of the cover image and better results can be obtained in the blocks with comparable pixel intensities.

One obvious result can be derived from figure 3.12 in context of PSNR is this that it achieves a good value as the watermark symbol gets blurred. This is because as the blurring increases, the neighborhood of a specific pixel contains the intensity in the same range only, thus yielding smaller values for Mean Square Error and correspondingly, better PSNR..

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