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Reversible watermarking Based on Bi-orthogonal wavelet Transform

Dr.Arvind.H.S, Neha Shankar
ECE Dept, RITM, Bangalore, Karnataka, India

ABSTRACT: *As the popularity of Digital Medias is growing faster the intellectual property needs copyright protection. For the prevention of illegal verification and copying of content integrity. Therefore new data hiding techniques has to be developed that satisfy the requirements of Robustness ,Imperceptibility, Capacity or data hiding rate and the security of the hidden data. Watermarking has been utilized widely by researchers to provide security to the digital documents. In this project I have proposed a method which is an efficient technique for protecting the copyrights of digital images with the aid of "Watermarking". I have implemented watermarking algorithm in the frequency domain which is based on the Bi-orthogonal Wavelet Transform. Watermark is embedded by modifying the coefficients of the middle frequency sub band within region of non interest by which the visibility of the image and diagnosis capability will not be affected. Therefore the attacks on the image will not be able to remove the watermark.I have selected the blue channel of the cover image for embedding the watermark because it is more resistant to changes when compared to red and green channels Blue channel is decomposed into n-level by using bi-orthogonal wavelet transform because bi-orthogonal wavelet transform is an invertible transform and it has the property of exact reconstruction and smoothness. The horizontal and vertical sub bands are selected for the embedding watermark. This proposed method is shown to be robust against many geometric attacks and signal processing operations.*

INDEXTERMS: *Digital Image Watermarking, Biorthogonal Wavelets Transform, Robust Watermarking, Copyright Protection, Attacks*.

I. INTRODUCTION

In 13th century watermarks were used to paper brand and the mill that produced it in Italy and in 18th century watermarks were used as the anti-counterfeiting measures on money and other documents. In 1995 the field of watermarking started to bloom, from past five years intense research has been carried out in this field, which has led to the discovery of various algorithms. Currently there are many techniques for embedding digital watermarks. The desired information is directly written onto images or audio data digitally, in such a manner that the audio data or images are not damaged. In the process of embedding a watermark should not result in a significant reduction or increase in the original data.

1.1 Principle of watermarking:

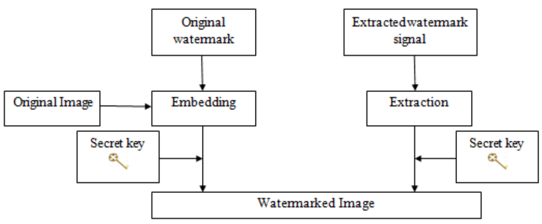

Fig 1.1: Watermarking block diagram

A watermarking system is divided into two distinct steps. They are embedding and detection. In embedding process the proposed algorithm accepts the host and the data to be embedded, and a watermarked signal is produced. The watermarked signal is then transmitted or stored. The obtained watermarked image is passed through a decoder in which a reverse algorithm is applied to retrieve the watermark. The different techniques uses different ways of embedding watermark onto the cover object. During embedding and extraction process a secret key to prevent illegal access to watermark. For a practical and useful watermarking scheme it has to meet the following requirements:Robustness: Robustness means a digital watermarking scheme should be able to resist the watermark attacks or modifications like resizing, file compression, rotation etc made to the original file. On the other hand, several intentional or unintentional attacks may be incurred to remove the embedded watermark. Thus, the watermarked image has to survive the legitimate usage such as resamples, conversions, lossy compressions and other malicious operations. A robust watermarking scheme should recognize the retrieved watermark and the image quality should not be seriously harmed. Imperceptibility:A visible or invisible watermark can be embedded into an image, the visible watermark is perceptible and it is just like noise. Using a noise removal process we can remove the visible watermark. In order to reduce this risk of cracking, most of the proposed watermarking techniques use invisible watermarks. On the other hand, the quality of the watermarked image is also very important. If in the process of embedding watermark, the quality of the watermarked image is affected, then the watermarked image will lose its value or even draw the attention of the attackers. Imperceptibility is a very important requirement therefore the quality between the original image and the watermarked image should not be seriously degraded.Readily embedding and retrieving: The watermark should be securely and easily embedded and retrieved by the owner of the original image.Data load or capacity**:** Data load or capacity means the maximum amount of data that can be embedded into the image to ensure proper retrieval of the watermark during extraction. Blind: Some of the conventional watermarking schemes require the help of the original image in order to retrieve the embedded watermark. But the reversible watermarking schemes has the ability to recover the original image from the watermarked image directly. As the retrieval process doesn’t need the original image, we reversible watermarking as blind.Transparency: This refers to the perceptual similarity between the watermarked image and the original image. The inserted watermark should be imperceptible. The watermark may lead to the degradation in the quality of the digital content, but in some applications a small amount of degradation may be accepted to get higher robustness.

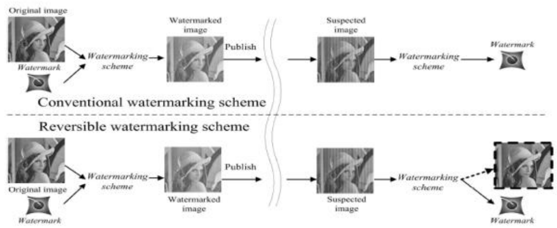

Fig 1.2: Conventional and reversible watermarking schemes

In the figure 1.2 the procedure of conventional and reversible watermarking schemes is illustrated. The steps of conventional watermarking and reversible watermarking are similar but there is an additional function to recover the original image from the suspected image. Therefore, the reversible watermarking is very much suitable for the applications that require high quality images such as medical and military images.

II. METHODOLOGY

Wavelets are the mathematical functions that differentiate data into different frequency components, and each component is studied with the resolution matched to its scale. They are more advantageous compared to Fourier methods in analyzing physical situations, in which the signal contains sharp spikes and discontinuities. Wavelets were developed independently in the fields of quantum physics, mathematics, seismic geology and electrical engineering. Image compression, image denoising, watermarking, human vision, turbulence earthquake prediction and radar are the applications of wavelet that have emerged during last ten years by the interchanges between the above mentioned fields. A wave is an oscillating function of space or time that is periodic. It is an infinite length continuous function in space or time. In contrast, wavelets are localized waves. A wavelet is a waveform of a limited duration that has an average value of zero. A function can be called a wavelet if it poses some of the properties such as, the function is either oscillatory or has a wavy appearance, it should have good space localization or in other words it should be confined to a finite interval and it should have sufficient decay in frequency.

Wavelet transform has achieved more attention in the field of image processing due to its ability in adapting to visual characteristics and its flexibility in representing non-stationary image signals. Wavelet transforms are most widely used and the most powerful tool in the field of image processing. A wavelet transform divides a signal into many segments corresponding to different frequency bands.Fourier transform is a powerful tool that has been used by the signal analysts for many years. It gives information regarding frequency component of the signal. The main problem of using Fourier transform is that frequency analysis cannot offer both time resolution and good frequency at the same time. A Fourier transform will not give any information about the time at which the particular frequency has occurred in the signal. Hence Fourier transform is not that effective tool to analyze the non-stationary signal. Therefore, to overcome this problem, short time Fourier transforms or windowed Fourier transform was introduced. Even though a windowed Fourier transform has the ability to give time information, multi resolution is not possible. So wavelets were introduced as the answer for this problem. A wavelet has a unique property of not having a fixed width sampling window. The wavelet transform can be classified into discrete wavelet transform and continuous wavelet transform. As the continuous wavelet transforms needs to integrate over all times of long signals, it can be bit time consuming. To overcome this problem discrete wavelet transform was introduced. Using sub band coding discrete wavelet transform can be implemented. The discrete wavelet transform is very much useful in image processing because it can simultaneously localize signals in scale and time. But Discrete Fourier transform and discrete cosine transform can localize signals only in frequency domain. The discrete wavelet transform can be obtained by performing filtering operation on the signal by using a series of digital filters at different scales. The scaling operating can be performed by changing the resolution of the signal by using the process of sub sampling. The discrete wavelet transform can be computed using convolution based or lifting based procedures. The input sequences are decomposed into high pass and low pass sub bands in both the methods. Each consist of the half the number of samples in the original sequence.

2.1 2D wavelet transform:

A 2D wavelet transform is equivalent to two 1D wavelet transform in series. A 2D discrete wavelet transform is computed by using high pass and low pass filtering of the image pixels. In the figure 3.1 shown below, the low pass filters are denoted by H(z) and the high pass filters are denoted by G(n). This figure clearly depicts the two level of 3D discrete wavelet transform decomposition. At each level, the low pass filter generates the coarse approximation of the input image and the high pass filter produces the detailed pixel information of the image.The DWT of a signal 'X' is calculated by using a mathematical equation 1 given below. First the samples will be passed through a low pass filter which has an impulse response 'g' and it is also decomposed simultaneously using a high pass filter denoted by 'h'. The filter outputs are sub sampled by 2.

$$y(n) = (x * g)(n) = \sum_{k=-\infty}^{\infty} x(k)g(n-k)$$

$$y\ low(n) = (x * g)(n) = \sum_{k=-\infty}^{\infty} x(k)g(2n-k)$$

$$y\ high(n) = (x * g)(n) = \sum_{k=-\infty}^{\infty} x(k)h(2n-k)$$

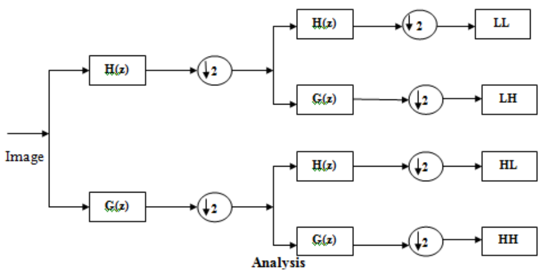

Fig 2.1: One level filter bank for the computation of 2D DWT

At the end of each high pass and low pass filter, the outputs are down sampled by 2. For computing 2D discrete wavelet transform, 1D discrete wavelet transform should be applied twice in both vertical and horizontal dimension. Or we can also say that a 2D discrete wavelet transform can be performed by first performing 1D DWT on each row of the image followed by 1D DWT on each column. Performing 1D DWT on row is called as horizontal filtering and on columns is called as vertical filtering.

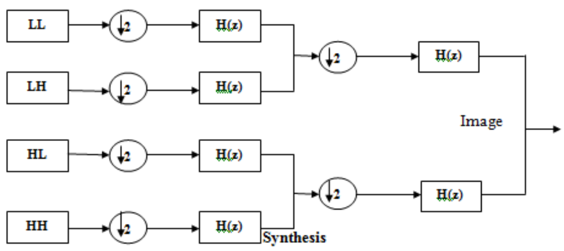

Fig 2.2: one level filter bank for computation of 2D IDWT

The figure 2.2 shows the one level filter banks for the inverse discrete wavelet transform. In the discrete wavelet transform, the taken image signal can be analyzed by passing the image through an analysis filter bank which is followed by decimation operation. When the signal is passed through the filters, it is split into two bands. A two dimensional DWT is accomplished by performing one dimensional transform two times. And by using synthesis filter the image is reconstructed back.

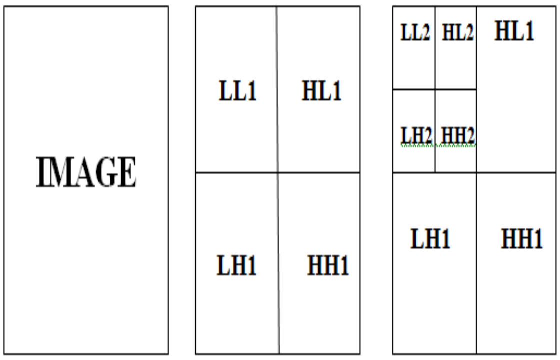

Fig 2.3: Two level 2D decomposition

The above figure 2.3 shows the structure of two level 2D discrete wavelet transform decomposition. For multiple levels of decomposition LL1 band will be iteratively decomposed. LL band contains approximation co-efficients. HL sub band contains horizontal details. LH sub band consists of vertical details and HH sub band consists of diagonal details. LL sub band not only contains coarse approximation of the image but it also contains most of the image's energy co-efficients.Usually wavelets can be either orthogonal (orthonormal) or bi-orthogonal. Earlier most of the watermarking schemes used orthogonal wavelets. The bi-orthogonal wavelets transform is an invertible transform. The property of symmetric wavelet functions and perfect reconstruction is satisfied by bi-orthogonal wavelets, because they have two sets of high pass filters for decomposition and two sets of low pass filters for reconstruction. One set is dual of the other. But in orthogonal wavelets it has only one set. In bi-orthogonal wavelets the reconstruction and decomposition are obtained from two scaling functions associated with two multi resolution analyses in duality. Bi-orthogonal wavelets have higher embedding capacity if they are used to decompose image in to different channels. This is another advantage of bi-orthogonal wavelets over orthogonal wavelets. In 1998 Hatzinakos and Kundur suggested a watermarking technique based on bi-orthogonal wavelet transform which embeds a watermark in the detailed wavelet co-efficients of the host image. The results they got was robust against many signal distortions.

2.3 Proposed method:

The objective of the proposed method is to present a imperceptible and robust watermarking scheme which is based on bi-orthogonal wavelet transform. After performing 2d DWT the image will be decomposed as we have discussed before. Among all the sub bands, the higher level sub bands are more significant when compared to the lower level sub bands. The reason is, the higher level sub bands contain most of the energy co-efficients, and therefore embedding the watermark in the higher level sub band will provide more robustness. As the lower level sub bands have minor energy co-efficients, watermark embedded in these bands are easily prone to attacks.The higher level approximation sub band i.e. LL2 sub band is not best for embedding a watermark as it contains important information of the image. And it is also a low frequency band and can be easily distorted. On the second level, considering diagonal sub band i.e. HH2 is not good of embedding watermark as it can be easily be eliminated. If we do lossy compression of the image this sub band can be eliminated as it has minor energy co-efficients. Therefore the middle frequency sub bands both vertical and horizontal are best for embedding a watermark. The LH2 sub band contains more significant co-efficients compared to HL2 sub band. For this reason, it's better to embed the watermark in the middle frequency band LH2 instead of embedding the watermark in HL2.In the embedding process, the R, G and B channels of the color host image has to be separated. Blue channel in particular is selected for embedding watermark because this channel is more resistant to the changes done when compared to the other two channels red and green. And other advantage is the human eye is less sensitive to the blue channel. An invisible watermark in the blue channel can contain more energy than embedded in the luminance channel of the color host image.Blue channel is decomposed into n-level by using bi-orthogonal wavelet transform. The property of symmetric wavelet function and reconstruction exist in bi-orthogonal wavelet transform. Let us select us select bitmap image as watermark image, which is of size 64*64. Then convert this watermark image into 1-D vector. Two PN sequences are selected for embedding purpose i.e. 0 and 1 in the mid frequency sub bands of the higher level decomposition of the blue channel. Now using a additive watermarking technique for constructing the image as follows

LH2' = LH2 + alpha * PN(0)

HL2' = HL2 + alpha * PN(1)

Where HL2' and LH'2 are the watermarked sub bands and alpha is the embedding strength. The flow chart for the embedding process of the watermark is as show below.

2.3 Performance evaluation:

Performance evaluation is very important in any project because it decides whether the project is successful, efficient or not. For evaluating the performance I have calculated peak signal to noise ratio and normalized cross correlation.Peak signal to noise ratio: Peak signal to noise ratio can be defined as the ratio between the maximum possible power of the signal and the power of the noise that affects the signal's fidelity of representation. It can be easily defined by mean squared error i.e. MSE. Let's take two m*n images 'I' and 'K' where one of them is considered as the noisy approximation of the other image. Then the equations for MSE and Peak signal to noise ratio are as given below.

$$\text{MSE} = \frac{1}{m*n} \sum\sum ||I(i,j) - K(i,j)||2$$

$$\text{PSNR (db)} = 10 \log 10 * 255^2 / MSE$$

Normalized cross correlation: Normalized cross correlation usually denoted as NCCR is defined as the correlation between the watermark image 'W' and the extracted watermark 'W''. After calculation if the value of NC is nearer to 1 then W and W' are more similar to each other. Normalized correlation can be calculated using the equation given below.

$$\textbf{NC=} \frac{\sum i \sum j \ W(i,j)*W'(i,j)}{\sum i \sum j [W(i,j)]^{\wedge}2}$$

The peak signal to noise ratio and MSE values will be obtained using the original cover image with two different watermarks i.e. text watermark and a logo watermark at different embedding strength alpha. I have tested the performance of the proposed method by performing image processing operations such as adding Gaussian noise and salt & pepper noise on the watermarked image. And I have tested it for various geometric operations such as scaling, rotation as well as cropping.

III. RESULTS

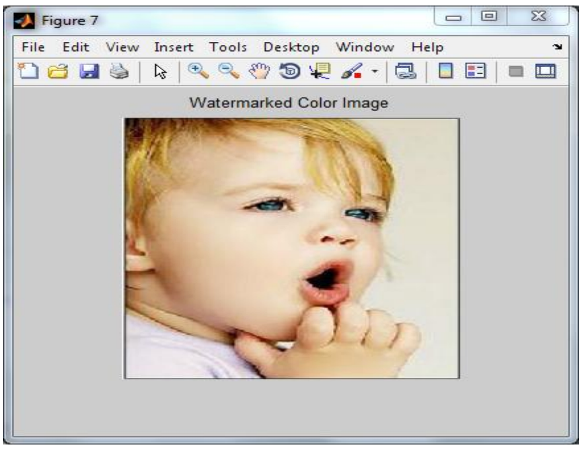

Fig 3.1. Watermarked colored image

After getting the blue plane, we'll concatenate all red, green and blue planes to get back the color image with the watermark embedded. The above showed figure is the watermarked color image.Peak signal to noise ratio is the ratio between the maximum possible power of a signal and the power of corrupting noise the affects the fidelity of its representation. After the watermark embedding process, we'll calculate the PSNR value is displayed as show in the above figure.

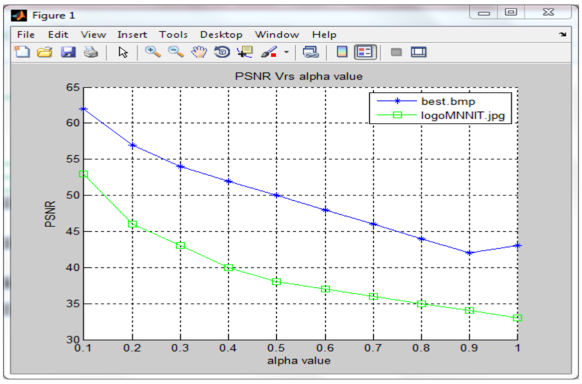

Fig 3.2 Graph of PSNR value v/s Alpha

The above figure is the graph showing PSNR value v/s the embedding factor alpha for both the text and logo watermarks.

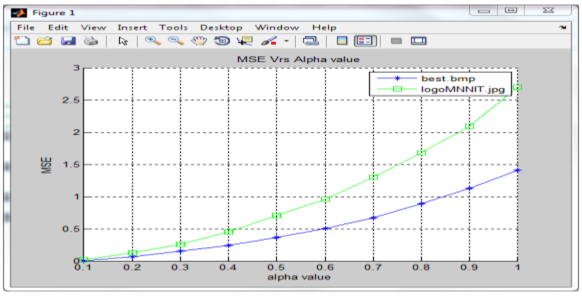

Fig 3.3 Graph of MSE v/s Alpha

The above figure is the graph showing MSE(Means square error) value v/s the embedding factor alpha for both the text and logo watermarks

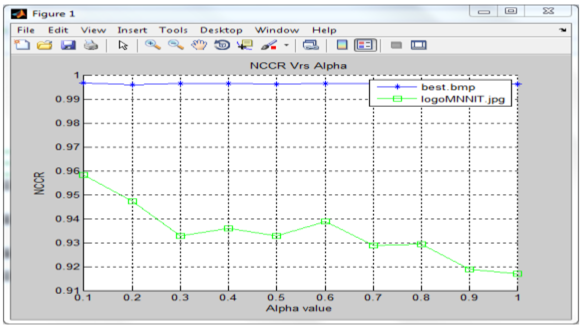

Fig 3.4 Graph of NCCR v/s alpha

The above figure is the graph showing NCCR (Normalized cross correlation) value v/s the embedding factor alpha for both the text and logo watermarks.

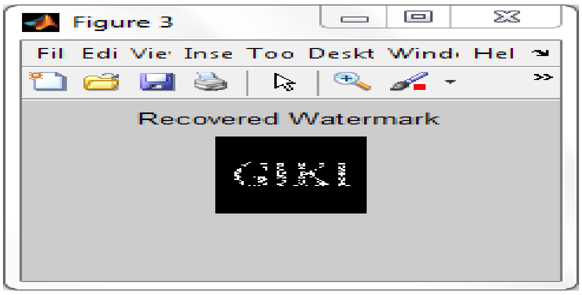

Fig 3.5 Recovered text watermark

The above figure is the decrypted text watermark which was embedded into the cover image

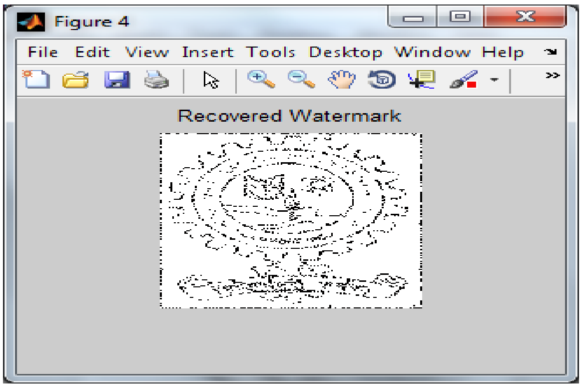

Fig 3.6 Recovered logo watermark

The above figure is the decrypted logo watermark which was embedded into the cover image. To check the performance of the implemented method I have tried image processing operations on the watermarked image such as adding salt & pepper as well as Gaussian noise to it. First we'll take the watermarked image either watermarked by text or logo watermark, then salt and pepper noise will be added to that. The embedding factor alpha should be fixed value 0.6 for both salt and pepper and Gaussian noise added.

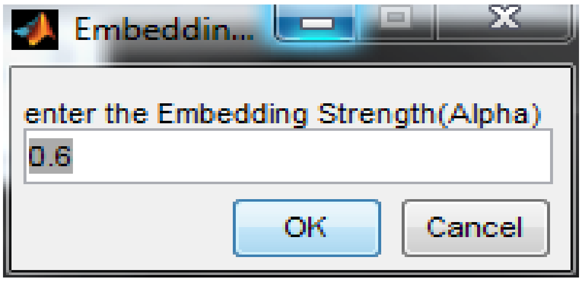

Fig 3.7 Fixed embedding factor 0.6

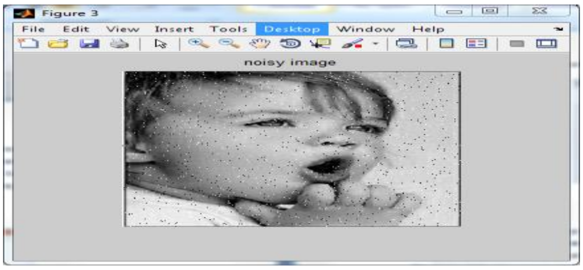

Fig 3.8 Noise added watermarked image

The above figure is the salt and pepper noise added watermarked image.

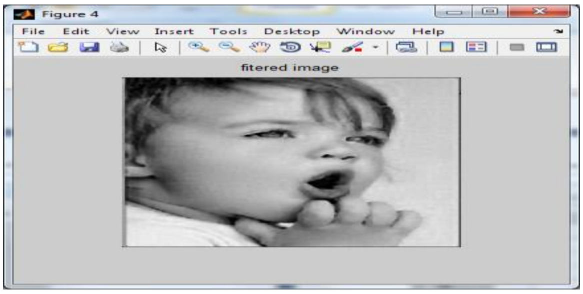

Fig 3.9 Filtered watermarked image

The noise added image is filtered by using median filter. That filtered image is as show in the figure.

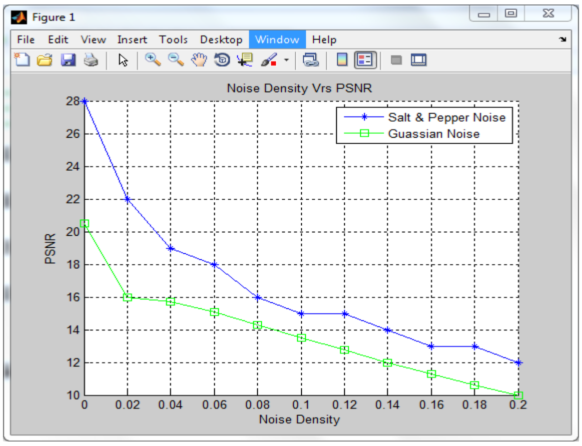

Fig 3.10 Graph of Noise density v/s PSNR

The above figure is the graph showing PSNR value v/s the noise density for both the text and logo watermarks.

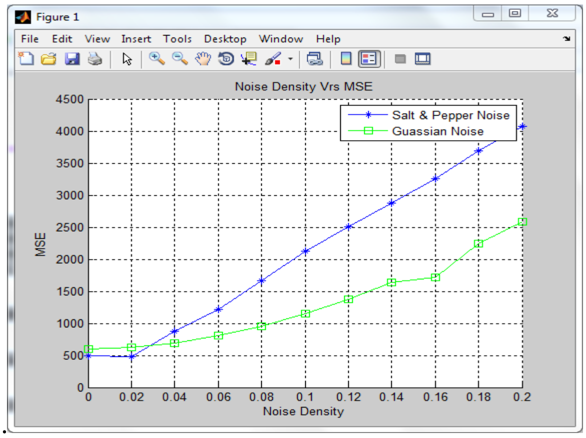

Fig 3.11 Graph of noise density v/s MSE

The above figure is the graph showing MSE value v/s the noise density for both the text and logo watermarks.

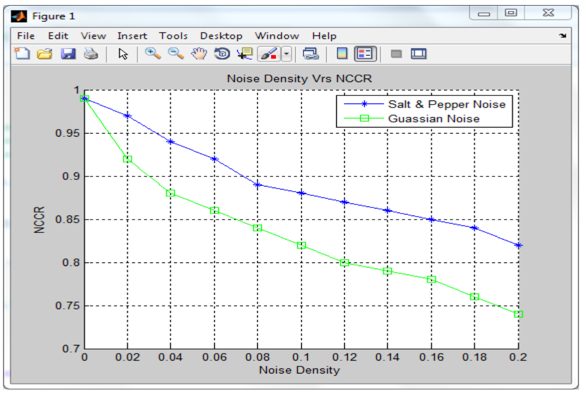

Fig 3.12 Graph of noise density v/s NCCR

The above figure is the graph showing NCCR value v/s the noise density for both the text and logo watermarks.

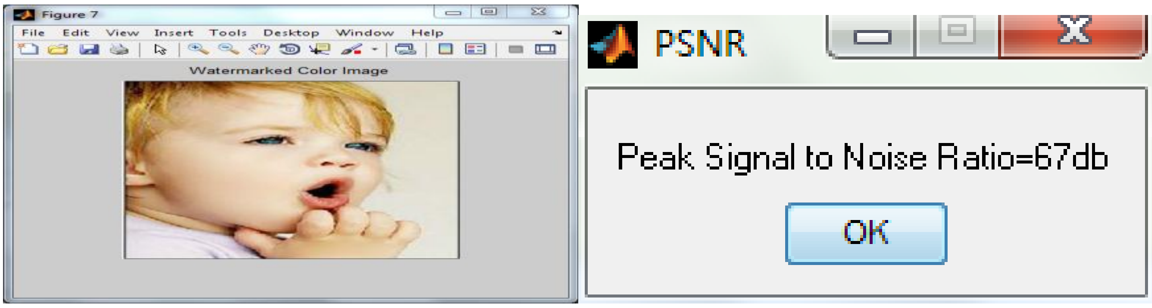

Fig 3.13 Watermarked image for the alpha value 0.1

The above figure is the watermarked image got for the embedding factot alpha of 0.1, the PSNR valur got for this is 67db and the MSE is 0.0045

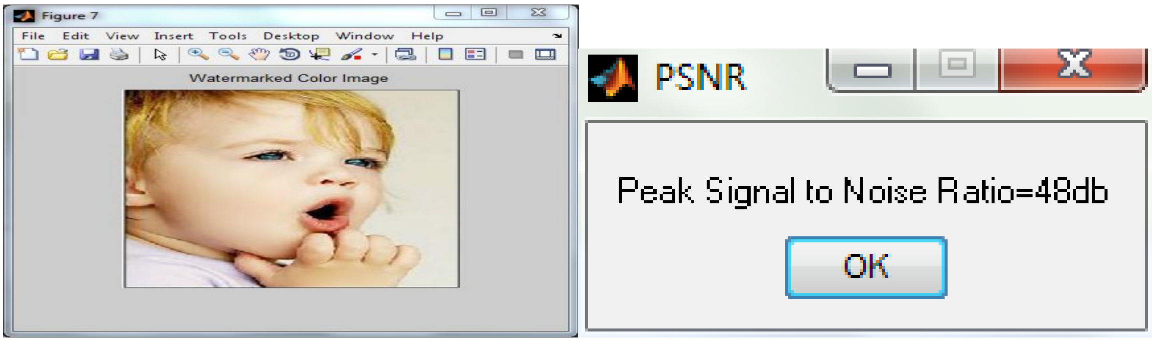

Fig 3.14 Watermarked image for the alpha value 0.5

The above figure is the watermarke dimage got for the embedding factot alpha of 0.1, the PSNR valur got for this is 48db and the MSE is 0.3702

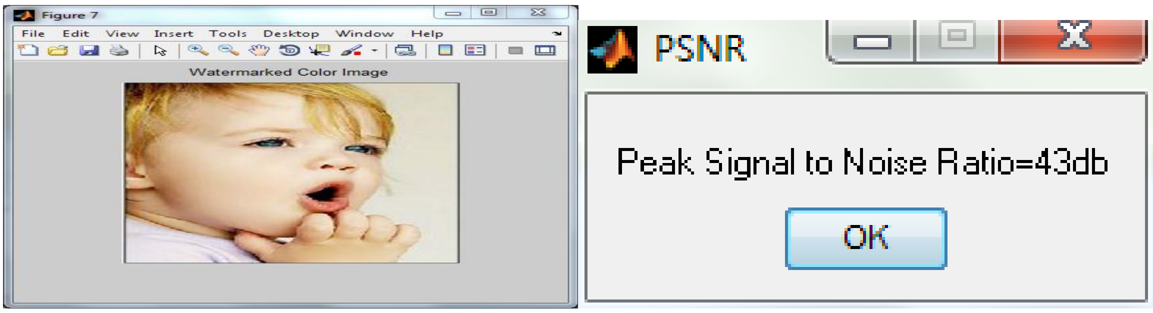

Fig 3.15 Watermarked image for the alpha value 1.0

The above figure is the watermarke dimage got for the embedding factot alpha of 0.1, the PSNR value got for this is 43db and the MSE is 1.3450

IV. CONCLUSION

In this project the implemented method used for embedding digital watermark is based on bi-orthogonal wavelet transform. The watermark is embedded into the second level sub band of the discrete wavelet transform decomposition. By using bi-orthogonal wavelets for decomposition, the distortion in the watermarked image is very less compared to the Haar wavelet transform. The implemented method presents a robust watermarking scheme. By using this technique I have tried to extract the watermark even if the watermarked image is attacked. Primarily, the embedded watermark should not be responsible for the degradation of the quality of the image. And it should be perceptually invisible for maintain the secrecy. Then, the watermark must be robust enough to resist image processing attacks and should not be easily removable. Only the owner of the image should be able to extract the embedded watermark.

The performance of the proposed method is tested by applying various image processing and geometric attacks, such as adding Gaussian, salt and pepper noise, scaling and cropping attack to the watermarked image. By results obtained we got to know that when the alpha or embedding factor value increases the distortion in the watermarked image also increases. And the exacted image quality also improves.

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