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Comparative Analysis of Digital Watermarking With Different Bands of Watermark

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Abstract- **Digital information has an important property that it is very easy to produce and distribute unlimited number of copies. This property raises various problems pertaining to serious concerns in protection of the intellectual and protection rights, which needs serious focus. In this paper we have proposed a DWT sub-band based watermarking algorithm for copyright protection and ownership rights in transform domain using DWT (Discrete Wavelet Transform-Haar Wavelet), which makes it difficult to uncover the watermark by attacks based on pixel to pixel basis and PCA (Principle Component Analysis), that further reduces the correlation left among the wavelet coefficients. With the use of secret key, we have tuned the visibility of existence of watermark.**

Keywords— **Discrete Wavelet Transform, Principal Component Analysis, Digital Watermarking, Tuning Factor.**

I. INTRODUCTION

Digital multimedia is very powerful media for copying and distribution [1] of digital information on a vast scale in a very short period. Because of which sometimes situations arises where unauthorised persons tackle these information. Therefore, it becomes essential to protect information from such unauthenticated handling. For security and copyright protection of content, watermarking is used. Watermarking is the process that embeds data such as logo or others called a watermark or digital signature into a multimedia message either in a manner that the hidden message cannot be detected, or in a manner that the contents of message is hided (not existence) [2], but in such a way that hided message cannot be removed or replaced, such that it can be detected or extracted later to check the authentication of message.

Watermarking is not a currently immerged technique; beside from the communication sector it has been used since several hundred years (known with proof to us) in handmade paper industries. However, later in 1887 these gained legal authentication power. The term watermark was first used when it inspired the bank notes or stamps [3]. Later on, it got hype that makes it a major topic for study with first paper published in1990 and then onward they become nearly countless but still to be investigated profoundly.

II. THEORETICAL BACKGROUND

A. Digital Watermarking

Today most media is digital and we are marking digital media therefore we confine to digital watermarking. Digital watermarking can be defined as a process applied on actual information in order to produce a proper pattern known only to authenticated persons, which can be used later for identification of authentication or ownership.

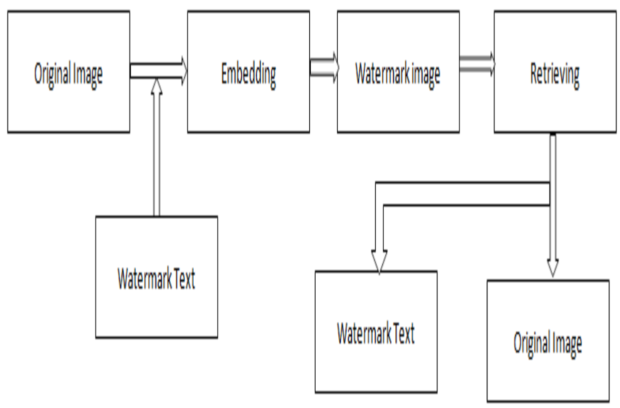


Fig.1 A general watermarking process

The main utilisation of digital watermarking is marking media files to provide copyright information, as well as for source tracking, by which the source of illegal copy of data can be traced irrespective where it is found. There are many more Applications of Watermarking such as authentication, copyright protection, fingerprinting, owner identification, labelling, medical applications, tracking of material on web etc. For effective performance against watermark attacks, the watermark must possess some properties such as perceptual transparency, security, unobtrusive, Irremovable or irreplaceable by unauthorised interceptors, Robust and Lossless.

B. Classification of Digital Watermarking

Digital watermarking technique can be classified on different bases, such as Documentation, working domain and human perception. As message may be a picture, acoustic, or video. Therefore, on documentation bases can be divided into Text, Image, Audio and video.

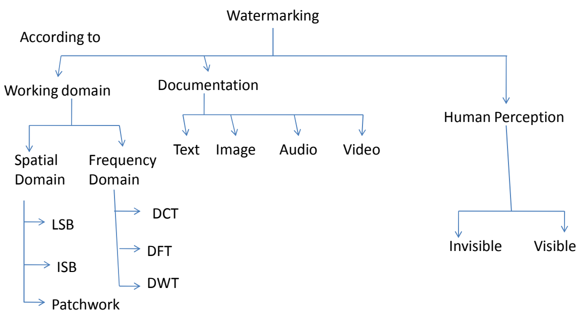


Fig. 2 Classification of Watermarking

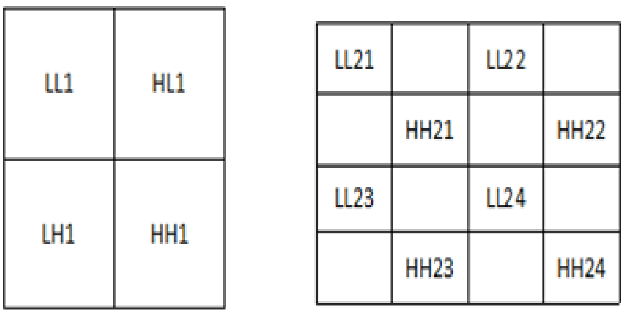
Based on Human perception (transparency level) the watermarks are divided into invisible and visible watermarking. In visible watermarking, a secondary image is embedded into primary image or host image video, so that watermark is perceptible to Human Visual System (HVS). Where as in invisible watermarking the embedded watermark is not perceptible to Human Visual System (HVS) but can be extracted for authentication purpose. On the stand of Working, field watermark can be categorised into spatial domain and Transform domain. When the watermark is embedded by modifying the pixel values of the host image or video directly by the pre-determined embedding scheme then this scheme is spatial domain techniques. Whereas when the coefficients of the transformed video frames are modified according to the pre-determined embedding scheme then it is considered as Transform domain. The watermark is embedded distributive on the whole domain of original information. It becomes hard to take away the embedded watermark proving Transform-domain technique to be more effectual, hardly noticeable, and more robust then spatial-domain technique. The predominantly used transform-domain techniques are Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) [4-5]. Now a day’s watermarking scheme mostly utilises Discrete Wavelet Transform (DWT) because of its multi resolution characteristics, its excellent capacity of localizing spatial-frequency and as it is very suitable to identify areas where watermark can be embedded imperceptibly. PCA technique has the inherent property of removing the correlation left, it then distributes the watermark bits over the sub-bands used for embedding, making the watermarking to be more robust.

III. PROPOSED TECHNIQUE

We have used two schemes of the watermarking technologies: DWT and PCA, to perform the embedding process.

A. Discrete Wavelet Transform (DWT)

Wavelet investigation is a mathematical procedure used to signify data or functions [6]. A wavelet is a waveform of limited period that has an average value of zero. Many wavelets also display a property ideal for compressed signal representation: orthogonality. The basic idea of the wavelet transform is to represent any arbitrary occupation as a superposition of a set of such wavelets or basis functions. The discrete wavelet transform serves as an authentic opportunity to the cosine transform. It is based on the hierarchy structure having N levels that can be processed by choosing a proper filter bank. Wavelet based watermarking methods exploit the frequency information and spatial information of the transformed data in multiple resolution to gain robustness [7].The discrete wavelet transform domain is more appropriate for image watermarking. The DWT provides fascinating space-frequency localization of pertinent image characteristic like textures and edges. In particular, the high frequency content of the image corresponds to large coefficient in the detail sub bands. The discrete wavelet transform stipulates great form of the human visual system [8]. In the integument of discrete wavelet transform, a time-scale portrayal of the digital image content is achieved by applying digital filtering schemes. The contents that are to be validated are gone through filter banks with distinct cut-off threshold frequencies at various indexes. Hungarian mathematician named Alfréd Haar simulated the first discrete wavelet transform. For an input that are represented by a list of numbers, the Haar wavelet transform may be considered to simply pair up those input values, storing the difference of those numbers and passing over the sum.



(a) (b)

Fig. 3 DWT sub-band in (a) level 1, (b) level 2

This procedure is recurring for every step, coupling up those sums to supply the next scale values, finally resulting in their differences and one final sum of them. The Haar Wavelet Transformation is in general a simple form of compression that involves averaging and differencing terms, storing detail coefficients, eliminating data, and reconstructing the matrix such that the resulting matrix is similar to the initial matrix [9].

B. Principle Component Analysis (PCA)

Principal component analysis (PCA) is a mathematical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of uncorrelated variables called principal components. Principal component is a way to picture the structure of the data as completely as possible by using as few variables as possible. The key ingredient is combined data set normally distributed, therefore guaranteed to be independent. PCA Karl Pearson was invented in 1901 by [10] as an analogue of the principal axes theorem in mechanics; it was later independently developed (and named) by Harold Hotellingin 1930s [11]. Principal component analysis can be achieved by disintegration of eigen-values of an image correlation matrix or single value disintegration of an image matrix, basically after mean centering the image matrix for every variable [12]. Principal component analysis is the easiest form of the true eigenvector that works on multivariate synthesis.

C. Methodology

In the proposed method we have to decompose the watermark image into DWT sub-bands followed by the application of PCA, then the sub-band PCA of one band is embedded into the cover image by decomposing it into DWT sub bands, followed by the application of block based PCA on the sub-block of one sub-band. The principal component of the watermark is embedded into the principal components of the sub-blocks. Algorithms for proposed watermarking scheme are given below:

A. Algorithm for embedding :

Step 1: Calculate PCA Scores of selected DWT sub-band formed by applying DWT on the extracted Y (Luminance) component of YUV format watermark image (size n x n) using Algorithm (c).

Step 2: Apply DWT on the extracted Y (Luminance) component of YUV format cover image (size 2n x 2n).

Step 3: Divide the selected sub-band into k non-overlapping, completely covering sub-blocks each of dimension equal to sub-band of watermark.

Step 4: Calculate PCA Scores of so obtained sub-blocks using Algorithm (c) and modify it according to equation given below using a tuning factor (V_b).

Score-new=Score-cover(i) + V_b*Score-watermark (1)

Where :

- Score-cover(i) represents the principal component score of the 'ith' sub-block, of the sub-band of image (frame) of video.
- Score-watermark represents the principal component score of the sub-band of watermark image.
- Score-new represents the new modified score which used to develop the new watermarked image.

Step 5: Obtain new modified sub-blocks by applying inverse PCA on the modified PCA components of sub-blocks.

Step 6: Arrange all sub-blocks and merge to form modified sub-band (horizontal) of cover image.

Step 7: Inverse DWT is conducted to obtain the watermarked luminance component of the image.

Step 8: Replace this new modified luminance component with U and V components of cover image.

Step 9: Transform the new YUV to RGB colour image.

B. Algorithm for extraction :

Step 1: Apply DWT on the extracted Y (Luminance) component of YUV format watermarked image.

Step 2: Divide the selected sub-band (horizontal) into k non-overlapping, completely covering sub-blocks each of dimension equal to sub-band of watermark.

Step 3: Calculate PCA Scores of so obtained sub-blocks using Algorithm (c) and extract the watermark scores from the score of each watermarked sub-blocks of the selected sub-band according to equation given below using a tuning factor (V_b).

Scores-watermark-extracted=[Scores-new – Score-cover(i)] / V_b ...(2)

Where,

- Score-cover(i) represents the principal component score of the ith sub-block, of the sub-band of cover image,
- Score-new represents the new modified score which used to develop the new watermarked image,
- Score-watermark-extracted represents the principal component score of the sub-band of extracted watermark image.

C. Algorithm for calculation of Principal Component Analysis :

Step 1: Sub-block is converted into a row vector.

Step 2: Compute the mean and standard deviation of the elements of vector.

Step 3: Compute Z(i) according to the following equation

Z(i)=(row vector(i) – mean) / standard deviation ..(3a)

Here Z(i) represents a centred, scaled version of row vector(i) of the same size as that of row vector(i)

Step 4: Apply principal component analysis on Z(i) to obtain the principal component coefficient scores .

Step 5: Calculate vector Score(i) as

Score(i) = Z(i) x Coefficient(i) ....(3b)

Where

- Score(i) represents the principal component Scores of the 'ith' sub-block.

D. Efficiency of watermarking

The efficiency of watermarking depends on two factors Peak Signal-To-Noise Ratio and Normalised Coefficients. The benchmark for identifying best watermarking scheme is that MSE value should be lower and the NC value must be greater. NC is measure of the robustness of watermarking and its peak value is 1.It depends directly on the original and extracted watermark. PSNR is measure of the deviation of watermarked images (frames) from the original image (frame). PSNR depends on the value of MSE (mean square error). Where mean square error is a function, the pixel values at identical position of the original and corrupted watermarked frame. Higher values of PSNR indicate the more imperceptibility of watermarking.

If the noise free original image (size m x n) is denoted by I and K is its noisy approximation then MSE is given by:

$$MAX_i = \frac{1}{mn\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j)-K(i,j)]^2} \quad \ldots\ldots..(4)$$

In same situation the PSNR is calculated by:

$$PSNR = 10.\log_{10}\left(\frac{MAX_i^2}{MSE}\right) \quad \ldots\ldots\ldots.(5)$$

$$= 20.\log_{10}\left(\frac{MAX_i^2}{MSE}\right)$$

$$= 20.\log_{10}(MAX_i) - 10.\log_{10}(MSE)$$

Where:

MAX_i represents the maximum possible pixel value of the image and when the pixels are represented using 8 bits per sample, this is 255.

The extraction fidelity NC which is given by:

$$NC = \frac{\sum_i\sum_j RW(i,j).EW(i,j)}{\sqrt{\sum_i\sum_j RW(i,j)^2}\sqrt{\sum_i\sum_j EW(i,j)^2}} \quad \ldots..(6)$$

Where:

RW is the reference watermark,
EW is the extracted watermark

E. Experimental Results

This section presents the experimental results of embedding watermark image (Fig. 4) into the cover images (Fig. 5&6) according to the proposed scheme.

Fig. 4 Watermark image

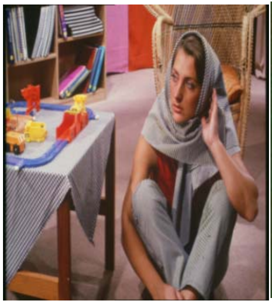


Fig. 5 Cover image 1 Fig. 6 Cover image 2

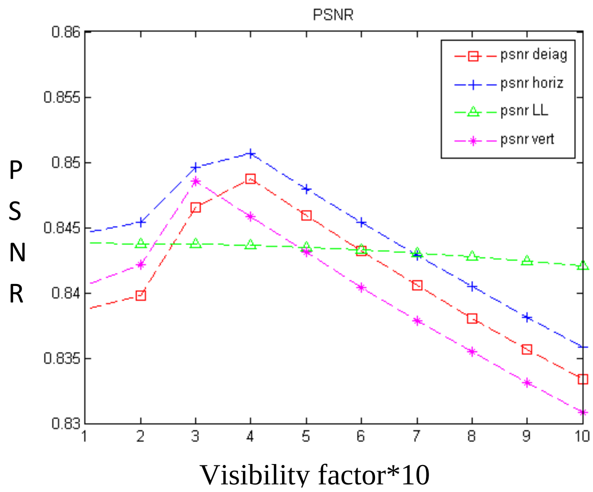


Fig. 7 Plot of PSNR

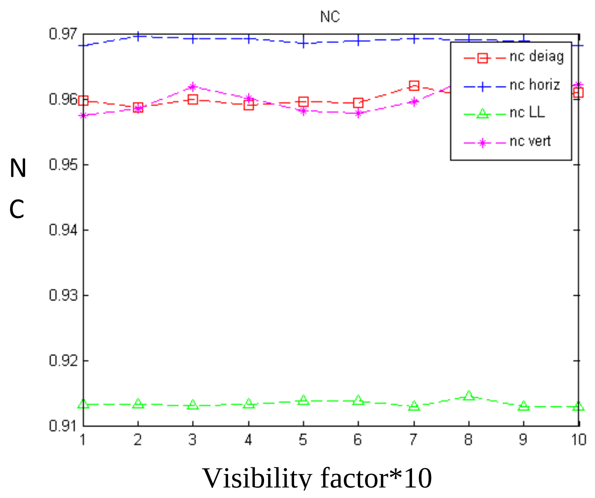


Fig. 8 Plot of NC

Fig. 7 & 8 show the PSNR and NC plots for cover image 1 embedded with diagonal band of watermark over tuning factor range 0.1 to 1.0

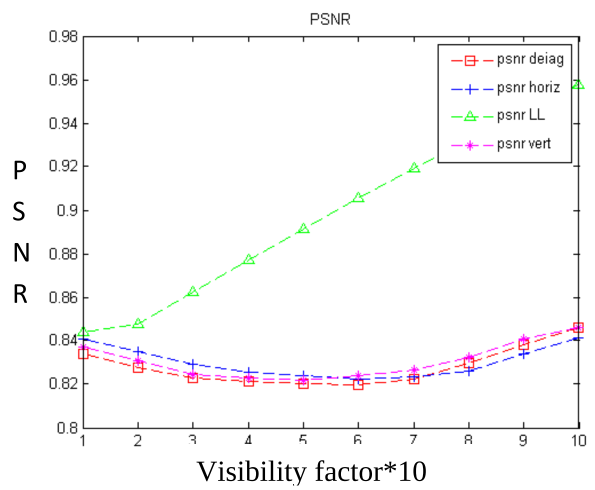


Fig. 9 Plot of PSNR

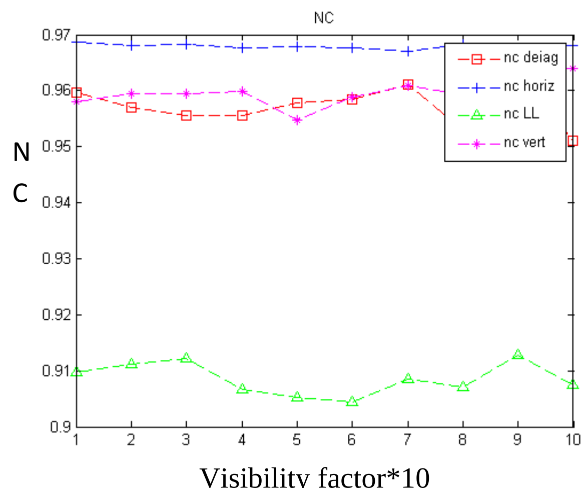


Fig. 10 Plot of NC

Fig. 9 & 10 show the PSNR and NC plots for cover image 1 embedded with horizontal band of watermark over tuning factor range 0.1 to 1.0

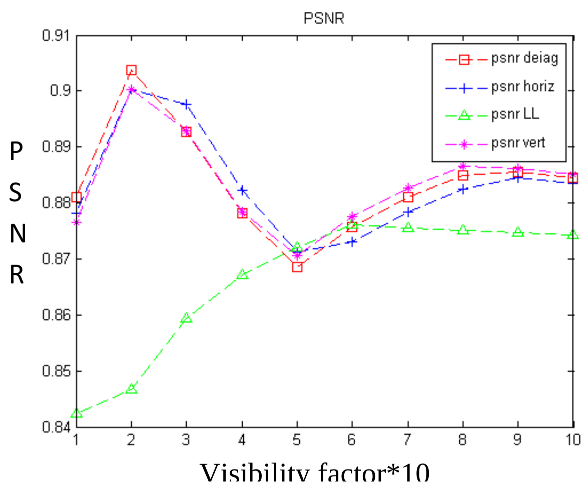


Fig. 11 Plot of PSNR

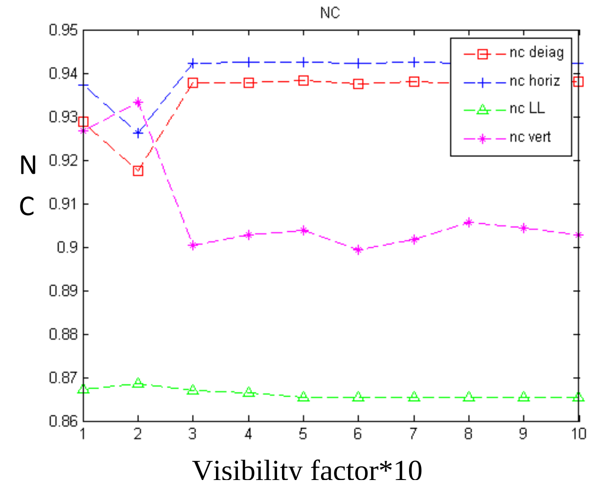


Fig. 12 Plot of NC

Fig. 11 & 12 show the PSNR and NC plots for cover image 1 embedded with lower resolution approximation (LL) band of watermark over tuning factor range 0.1 to 1.0

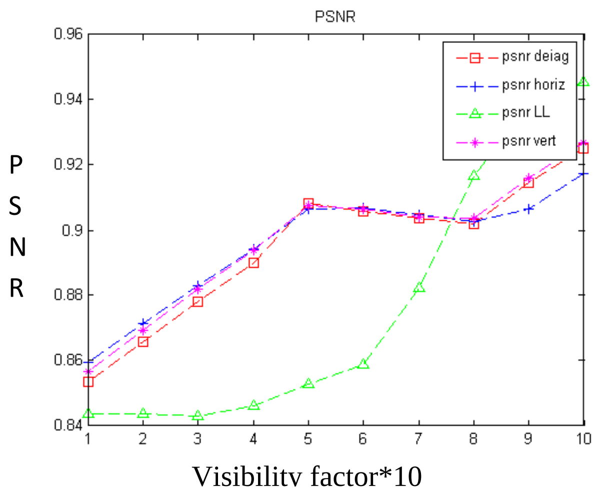


Fig. 13 Plot of PSNR

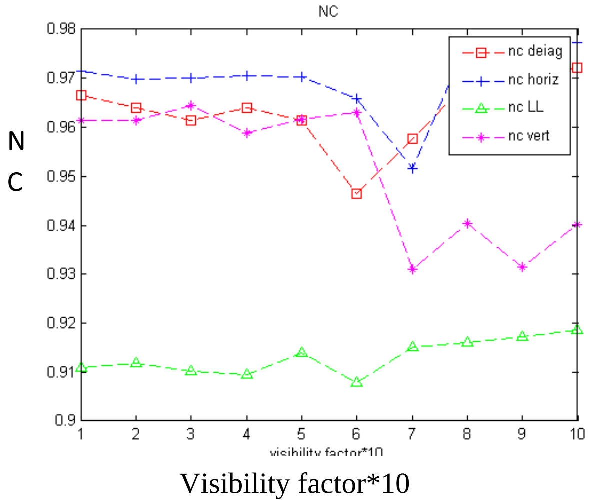


Fig. 14 Plot of NC

Fig. 13 & 14 show the PSNR and NC plots for cover image 1 embedded with vertical band of watermark over tuning factor range 0.1 to 1.0

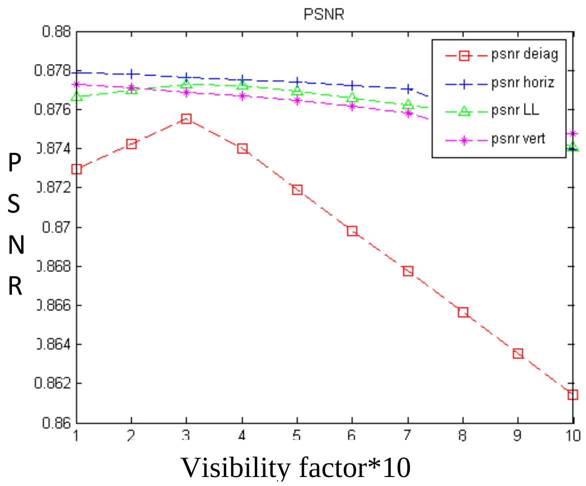


Fig. 15 Plot of PSNR

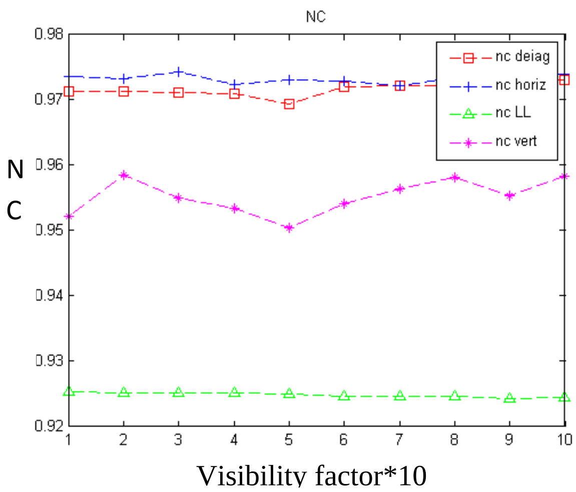


Fig. 16 Plot of NC

Fig. 15 & 16 show the PSNR and NC plots for cover image 2 embedded with diagonal band of watermark over tuning factor range 0.1 to 1.0

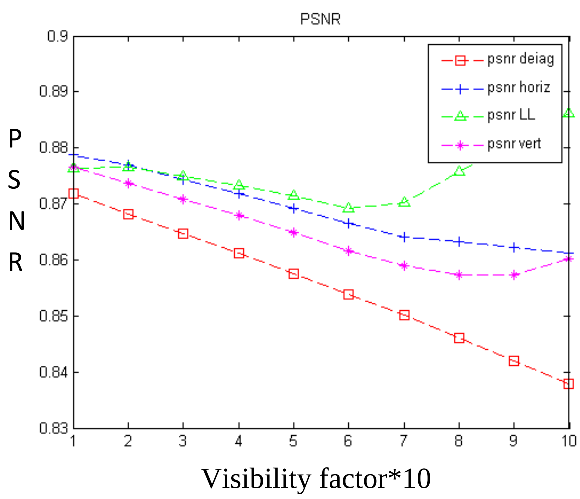


Fig. 17 Plot of PSNR

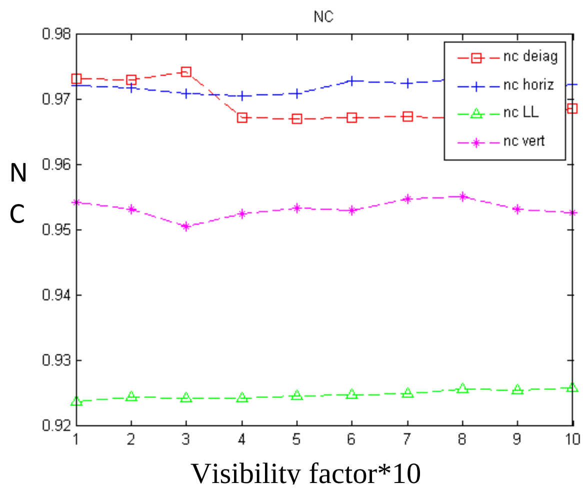


Fig. 18 Plot of NC

Fig. 17 & 18 shows the PSNR and NC plots for cover image 2 embedded with horizontal band of watermark over tuning factor range 0.1 to 1.0

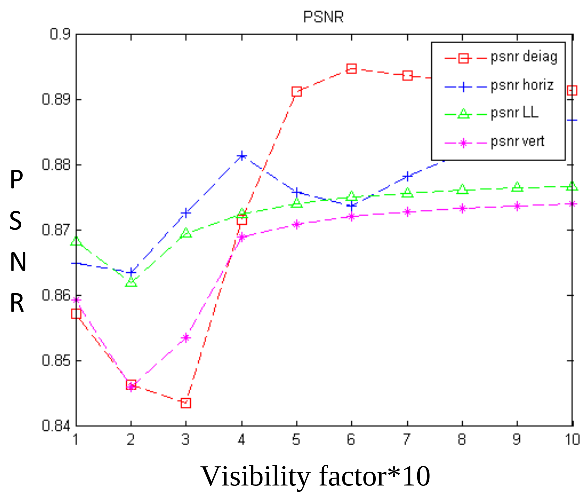


Fig. 19 Plot of PSNR

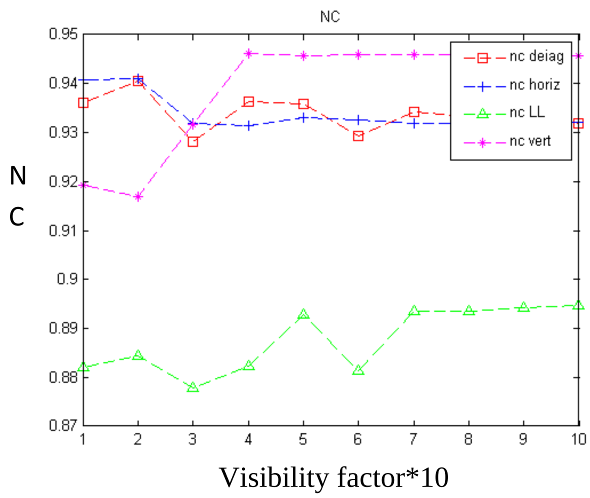


Fig. 20 Plot of NC

Fig. 19 & 20 show the PSNR and NC plots for cover image 2 embedded with lower resolution approximation (LL) band of watermark over tuning factor range 0.1 to 1.0

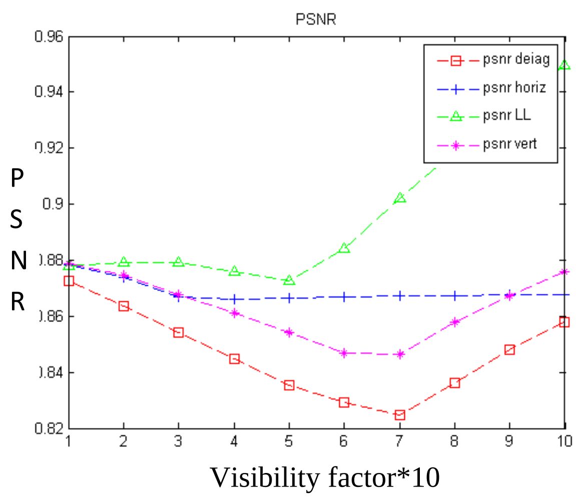


Fig. 21 Plot of PSNR

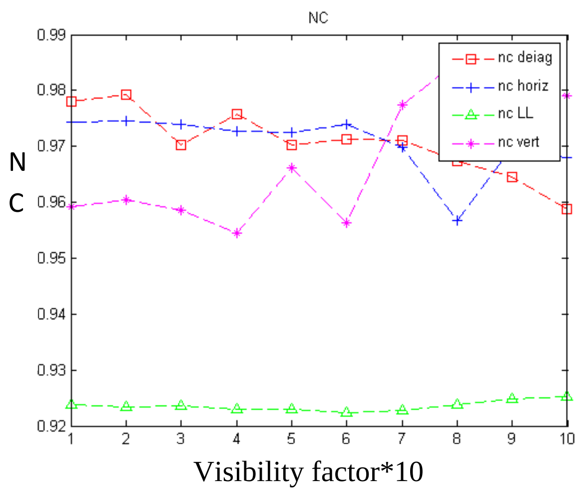


Fig. 22 Plot of NC

Fig. 21 & 22 show the PSNR and NC plots for cover image 2 embedded with vertical band of watermark over tuning factor range 0.1 to 1.0

Comparing for cover image 1, the PSNR and NC graphs obtained by embedding different sub-bands of watermark images, we observe that embedding with diagonal sub-band of watermark image gives better PSNR and NC plots as compared with vertical, horizontal and lower resolution approximation (LL) sub-bands. Similar results were observed for cover image 2, which concludes that embedding with diagonal sub-band of watermark image gives better performance on the scale of PSNR and NC.

IV CONCLUSIONS

In this paper, we have proposed a new scheme of watermarking, in which a range is shown from imperceptible watermarking to perceptible watermarking, with different levels of perceptibility. This work has outlined a scheme for embedding watermark in the cover image in such a manner, that watermark is not visible, but it only shows its existence. The visibility of watermarks existence may be varied on demand on a semi-visible range. Here we have also compared the watermarked cover image, embedded with different sub-bands of watermark based on PSNR and NC values. Our experimental result shows, that embedding the cover image with diagonal band of watermark is better and widely applicable. As a future aspect, it is possible to add some error correction codes, to provide robustness to scheme.

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