Human Visual System Sentient Imperceptible and Efficient Wavelet-Based Watermarking Scheme for Copyright Protection of Digital Images

V. Padmanabha Reddy
Faculty, Department of Information Technology
Vardhaman college of engineering, Shamshabad
Hyderabad, Andhra Pradesh, India

Dr. S. Varadarajan
Associate Professor, Department of EEE
S.V. University College of Engineering
Tirupati, Andhra Pradesh, India

Summary
Contemporary information age facilitates easy duplication, manipulation and distribution of digital content. This has resulted in the necessity for safe guarding the rightful ownership of digital images. Copyright protection and content authentication of digital images have turned out to be a pressing problem to content owners and distributors. Digital watermarking offered an effective solution to this issue. The watermarking scheme needs to be robust and imperceptible in order to provide efficient copyright protection. The incorporation of Human Visual System (HVS) models into watermarking scheme can greatly aid in achieving the same. Lately, wavelet domain based watermarking schemes have attracted attention in watermarking researches. This paper discusses an imperceptible and efficient wavelet-based watermarking scheme for copyright protection of images. The proposed watermarking scheme incorporates HVS models into watermark embedding and watermarking is performed in wavelet domain by means of Haar wavelet transform with lifting scheme. The image components are chosen for embedding on basis of entropy masking. A random matrix is generated based on a key image and is employed in both embedding and extraction processes. The correlation coefficient computation is utilized in the extraction of watermark. The experimental results have demonstrated the robustness and imperceptibility of the proposed scheme.

Keywords:
Digital Watermarking, Copyright Protection, Human Visual System (HVS), Entropy Masking, Robust, Discrete Wavelet Transform (DWT), Haar Wavelet Transform, Lifting Scheme, Correlation coefficient.

1. Introduction

Nearly the entire multimedia production and distribution is in the digital form nowadays [1]. The circulation, replication and alteration of digital images are uncomplicated owing to the swift escalation of digital media such as Internet and Compact Discs. Consequently, copyright enforcement methods for the protection of copyright ownership are vital prerequisites [1], [2]. In case of content owners and distributors, copyright protection and content authentication of digital content has developed into a critical problem. This issue can be resolved by the solution offered by the Digital watermarking. Of late, Digital watermarking has shown rapid escalation [3]. In recent times, ownership protection, authentication, and content integrity verification of intellectual property in digital form have extensively utilized watermarking [4] [5]. The method of embedding data into multimedia elements such as images, audios and videos is known as watermarking. In future, the proof of ownership or other purposes can be offered by the detection or extraction of this embedded data from the multimedia [6].

Diverse manners can be employed to obtain the different classifications of watermarking and watermarking techniques [7]. Generally, the visible and invisible watermarks are the two classes of digital watermarks dealt by the obtainable literature. In case of visible watermark, the ownership of the image is demonstrated by the distinctive visible message or a company logo, whereas, the invisibly watermarked digital content and the original image are extremely alike when visualized [8]. Either the copyright protection or content authentication is the intention of the design of the major accessible invisible watermarking schemes. Robust and fragile watermarks are the two wide categories of the invisible watermarks, the former primarily intends at copyright protection where the need for high resistance against several signal processing operations is indicated by the term “robust”. In contrast, content authentication is the primary objective of the latter [3]. Moreover, non-blind, semi-blind and blind methods are the divisions of watermarking. In case of non-blind methods, the original image are employed for the extraction of watermark, while the certain characteristics of the original image are employed by the semi-blind methods, whereas the detection process in the blind methods do not require the original image [9].

A good watermarking scheme should be robust enough to defend against attacks while being invisible such that the dissimilarity among the watermarked image and the host image should not be differentiated by the human eyes. Alternatively, the removal of the watermark embedded in

Manuscript received April 5, 2009
Manuscript revised April 20, 2009

the host image should not be easy and the quality of the host image should not be damaged very much [10]. The spatial domain techniques which embed the watermark by altering the pixel values of the original image and the frequency domain techniques which embed the watermark in the domain of an invertible transform are the two classes of the digital image watermarking techniques available in the literature, typically classified with the domain of watermarking as the basis [11]. The majority of the researches embed the watermark in the frequency domain in order to improve the robustness [10]. The Discrete Cosine Transform (DCT), the Discrete Wavelet Transform (DWT), the Discrete Fourier Transform (DFT), Discrete Hadamard Transform (DHT), etc are the diverse transformations employed widely in the form of substitute for the spatial domain [12], [13]. The computation efficiency of DWT is the motivation behind its widespread employment in the transformation of an image from spatial domain to frequency domain. DWT is utilized for watermarking digital images by numerous researches accessible in the literature.

In several wavelet-based watermarking schemes, the determination of which wavelet coefficients can be modified to embed the watermark such that the modification is imperceptible or transparent to human eyes is performed by employing Human Visual System (HVS) [14], [15], [16]. Generally, while the discernible quality of the content is at an adequate level, the watermark embedded into the original data is permitted to reside. The watermark should serve the copyright protection in a robust and imperceptible manner. Nevertheless, there is a disagreement among the requirements of imperceptibility and robustness. Intelligent optimization algorithms and HVS based algorithms are the two common types of methods to poise the robustness and imperceptibility [17]. The sensitivity of the human eyes to the input signal (i.e., how our eyes observe invisibility) is modeled by HVS. In order to keep the visual distortion to minimum and to optimize the watermarking methods it is essential to consider the HVS when developing a watermarking system [18], [11]. The specified resolution for viewing is easily personalized by HVS model. Not all the things viewed are recognized by the mind. The watermark embedded on textures has good robustness to general image processing and other attacks owing to the exceptional responses of the HVS on textures. A HVS based invisible watermarking technique is devised on the basis of this knowledge [12], [19]. Several HVS model based watermarking techniques are available in the literature [14, 15, 20, 21, 22].

In this paper, we have presented an imperceptible and efficient wavelet-based watermarking scheme for copyright protection of digital images. The proposed watermarking scheme considers HVS characteristics for embedding watermark robustly and imperceptibly. The binary watermark image is embedded into the host image in wavelet domain. A random matrix is generated from a key image with the aid of the approach discussed and employed in the embedding process. Initially, the host image is decomposed by means of Haar wavelet transform with the lifting scheme to obtain the four sub-bands LL, LH, HL, HH. The entropy masking of HVS model is utilized in the selection of appropriate sub-band. Afterwards, the sub-bands except LL are considered and the one with maximum entropy is chosen for watermark embedding. Subsequently, the watermark image is embedded into the selected sub-band with the aid of the generated random matrix. Finally, the modified sub-band is mapped back into its original position and inverse Haar wavelet transform with lifting scheme is applied to obtain the watermarked image.

The watermark extraction requires the watermarked mage, key image, the embedded sub-band information and the size of watermark image. As discussed in embedding process, initially the watermarked image is decomposed into four sub-bands by means of Haar wavelet transform with lifting scheme followed by the selection of the watermark embedded sub-band and the extraction of watermark through the correlation coefficient computation and generated random matrix. Since the watermarking is performed in wavelet domain with the aid of HVS model, the proposed scheme is imperceptible and robust against image processing attacks. The experiments with attacked host images have demonstrated the robustness of the proposed scheme.

The rest of the paper is organized as follows: A brief review of some of the recent researches in watermarking that incorporate HVS for copyright protection of digital images is given in Section 2. The basics of Human Visual System and its application in watermarking and Haar wavelet transform with lifting scheme are presented in Section 3 and Section 4 respectively. The proposed imperceptible and efficient watermarking scheme is explained in Section 5. The experimental results and analysis are presented in Section 6. The conclusions are provided in Section 7.

2. Review of Related Works

Our work has been inspired by a number of previous works in the literature related to watermarking for copyright protection of digital images. A brief account of some of the recent researches is as follows:

A digital watermarking technique for copyright protection was proposed by Xiaojun Qi [20]. They intended to adaptively embed the digital watermark by determining the positions and the magnitudes using the qualified significant wavelet coefficients and the texture and luminance content across two different coarse scales (level 2 and level 3 wavelet decompositions). The characteristics of the human visual system are exploited by the approach to hide a robust watermark in an effective manner. The correlations between the wavelet coefficients and the watermarking code at level 2 and level 3 and the stored side information were compared in order to detect the watermark. The robustness of their method against JPEG compression and a variety of image processing techniques was illustrated through the experimental results.

An imperceptible wavelet-based watermarking scheme was proposed by Ching-Sheng Hsu and Shu-Fen Tu [10]. They defined the degree of transparence of coefficients of LL band by employing the variation. Later, the coefficients of HL3 and LH3 bands for embedding were determined. In the watermark embedding phase, they also employed the modular operation. In addition, the robustness of their method against most attacks was illustrated and the watermarked image was highly imperceptible in nature.

An Image Adaptive watermarking method based on the Discrete Wavelet Transform was proposed by Franco A. Del Colle and Juan Carlos Gomez [23]. They employed state-of-the-art watermarking techniques for comparison with the estimated robustness and fidelity of their method. They introduced an image fidelity factor based on a perceptual distortion metric in order to evaluate the transparency of the watermark. In contrast, they intended to evaluate the robustness of the watermark against JPEG compression and resizing by introducing a degradation factor. A perceptually aware objective quantification of image fidelity is permitted by the fidelity metric. They illustrated a good correlation of the metric with the subjective assessment through the preliminary results.

An adaptive watermarking algorithm which exploits a bi-orthogonal wavelets-based human visual system and a Fuzzy Interference System (FIS) intending to protect the copyright of images in learning object repositories were presented by Nizar Sakr et al. [24]. An efficient extraction of the masking information by HVS depends on the linear-phase property of bi-orthogonal wavelet filters (symmetric wavelets) provide that the local characteristics of the image are considered. In order to compute the optimum watermark weighting function that would enable the embedding of the maximum-energy and imperceptible watermark, they employed the FIS. Their algorithm dealt with both signal processing and geometric attacks in a robust manner.

A method for image watermarking was presented by John N. Ellinas and Panagiotis Kenterlis [11]. They considered the CSF characteristics of the HVS in order to embed the watermarking data on selected wavelet coefficients of the input image. The selected coefficients dwell on the detail sub bands and the information about the edges of the image were contained in them. Hence, the embedded information becomes invisible by exploiting the HVS which was less sensitive to alterations on high frequencies. The success of their method in terms of robustness and transparency was illustrated by results of the experiments conducted. Their approach performed against the diverse widespread signal processing methods as compression, filtering, noise and cropping splendidly.

A scaling based image-adaptive watermarking system which exploits human visual model for adapting the watermark data to local properties of the host image was presented by Mohammad Ali Akhaee et al. [25]. Embedding in the low-frequency wavelet coefficients and optimal control of its strength factor from HVS point of view is the reason behind its enhanced performance. The channel side information facilitated the employment of the Maximum Likelihood (ML) decoder. Experimental results established that in comparison with the other existing watermarking methods, the method was imperceptible and highly robust against attacks.

A digital watermarking scheme for copyright protection against piracy of color images was presented by Shang-Lin Hsieh et al. [26]. In order to enhance the tolerance to attacks, their approach encoded the watermark prior to watermark embedding. The feature extracted from the host image by the discrete wavelet transform was utilized with secret sharing scheme in the proposed scheme. Besides, their methodology automatically calculates the scaling factor for different images while still preserving robustness and imperceptibility which is dissimilar from other watermarking schemes that require manual adjustment in the embedding scaling factors to embed the watermark. The resistance of their approach against several attacks including cropping, scaling, and JPEG compression was illustrated.

An adaptive image watermarking algorithm based on HMM in wavelet domain was presented by Zhang Rong-Yue et al. [27]. The algorithm considered both the energy correlation across the scale and the different sub bands at the same level of the wavelet pyramid and employed a vector HMM model. Intended for the HMM tree structure, they optimized an embedding strategy. They enhanced the performance by employing the dynamical threshold schemes. The performance of the HMM based watermarking algorithm against Stir mark attacks, such as JPEG compression, adding noise, median cut and filter was radically enhanced.

A multi-resolution watermarking method based on the discrete wavelet transform for copyright protection of digital images was presented by Zolghadrasli and S. Rezazadeh [21]. The watermark employed was a noise type Gaussian sequence. Watermark components were added to the significant coefficients of each selected sub band by considering the human visual system in order to embed the watermark robustly and imperceptibly. They enhanced the HVS model by performing some small modifications. The extraction of the watermark involved the host image. They measured the similarities of extracted watermarks using the Normalized Correlation Function. The robustness of their method against wide variety of attacks was illustrated.

An entropy-based method for non-blind watermarking of still gray level images using discrete wavelet transform was presented by Shiva Zaboli et al. [1]. In addition, the embedding phase of their watermarking algorithm employed the Discrete Wavelet Transform (DWT) feature and Human Visual System (HVS) characteristic. The performance of their method was better in comparison with well-known DWT based methods and against the existence attacks in literature.

3. Human Visual System (HVS) in Watermarking

The role played by the human visual system in digital image processing is a very vital one. Mannos and Sakrison introduced the HVS model for the first time in 1974 [28]. Several researchers have been studying the HVS [29], [30]. The HVS is a complicated system, which is a nonlinear and spatially varying [19]. The design requirements of HVS are simplicity, visual sensitivity and selectivity to model and improve perceived image quality. The psychophysical process that relates psychological phenomena (contrast and brightness etc.) to physical phenomena (light sensitivity, spatial frequency and wavelength etc.) serves as the basis for the HVS. Three basic properties of human vision: frequency sensitivity, luminance sensitivity and masking effects are employed by the majority HVS models in image processing. The sensitivity of human eye to various spatial frequencies is determined by the frequency sensitivity. The effect of the detectability threshold of noise on a constant background is calculated by luminance sensitivity. In accordance with the change of background luminance, the frequency sensitivity is corrected. The effect of decreasing visibility of one signal in the presence of another signal called masker is known as masking [22].

Numerous HVS models have been developed for the purposes of quality assessment or image compression [31]. Moreover, digital watermarking of images can be performed by employing similar visual models. Robustness, perceptual transparency and capacity are the three basic requirements of digital watermarking techniques. However, there is a disagreement among these requirements. Integrating HVS into watermarking process can assist in satisfying these conflicting requirements. Selection of perceptually significant image components for watermark embedding and scaling of watermark elements before embedding into original data are the functions of the HVS models incorporated into watermarking [22]. The literature provides several HVS model based watermarking techniques [14, 15, 20, 21, 22]. The watermark embedding process in our scheme utilized the entropy masking of HVS model. The higher complexity and uncertainty exist in high entropy regions of an image, while an image has weak entropy if it contains a lot of redundancy in its pixel values and vice versa [32]. The human eye is less sensitive to the modifications in the areas with higher entropy owing to this higher complexity [6]. This property serves as the basis for our selection of image components with high entropy value for watermark embedding.

4. HAAR Wavelet Transform with Lifting Scheme

Recently, the attention towards the frequency domain based watermarking schemes have escalated massively. Since, the watermark is in fact spread through out the image, not just operating on an individual pixel, the frequency-based techniques defend against attacks involving image compression and filtering in an extremely robust manner. Amongst the available frequency domain based watermarking approaches, the attention of watermarking researchers towards DWT-based (Discrete Wavelet Transform) techniques has escalated. Analysis and compression of signals can be predominantly performed by the wavelet transform tool which performs the transformation by employing the two functions – scaling and wavelet functions. Haar wavelet transform with lifting scheme has been employed in our scheme.

The Haar wavelet presented in 1909 by Alfréd Haar is probably the easiest wavelet, containing certain sequence of functions [33]. The encoding of information in the Haar wavelet transform is in accordance with the levels of detail". The mother wavelet function $\psi(t)$ of Haar wavelet can be given as [35]

$$\psi(t) = \begin{cases} 1 & 0 \le t < 1/2\,, \\ -1 & 1/2 \le t < 1\,, \\ 0 & otherwise \end{cases}$$

and its scaling function $\phi(t)$ can be described as

$$\phi(t) = \begin{cases} 1 & 0 \le t < 1, \\ 0 & otherwise \end{cases}$$

Wim Sweldens introduced the lifting scheme [34]. This method enhances the computation speed of conventional DWT as well for digital design in an efficient manner [36]. The features such as Generic Method, Easier to understand and implement, faster, the inverse transform is easier to find, in-place computation requires less memory, can be used on arbitrary geometrics, can be used on irregular samplings, can be extended for weighting functions and simple extension to an integer transform possible are the merits of the lifting scheme in comparison with the classical wavelet transform. The lifting scheme can be employed for the implementation of any wavelet filter. All sub-band data in an interleaved form ('in-place' transform) are obtained as the outcome of the wavelet transform using the lifting scheme [37].

5. Imperceptible and Efficient Watermarking Scheme

The proposed imperceptible and efficient watermarking scheme is described in this section. The entropy masking of HVS model is employed in the selection of appropriate image components for embedding watermark. The watermarking is performed in wavelet domain by means of Haar wavelet transform with lifting scheme. A key image is utilized in the generation of a random matrix, which is employed in the embedding process. The watermarked image, key image, size of watermark image and the information about the watermark embedded sub-band are needed in the extraction. Apart from the aforementioned, the correlation coefficient computation and generated random matrix are utilized in the extraction process. The steps involved in the watermark embedding and extraction are explained in the following sub-sections.

5.1 Watermark Embedding

The process of embedding the watermark image into the host image is presented in this sub-section. The watermark image should be a binary image and the host image's size needs to be dyadic ($2^n x 2^n$). The embedding is performed in wavelet domain by means of Haar wavelet transform with lifting scheme. Initially, the host image is decomposed into four sub-bands LL, LH, HL and HH using haar wavelet transform with lifting scheme. Afterwards, the entropy of the LH, HL, and HH sub-bands are calculated and the sub-band with maximum entropy value is selected for watermark embedding. A random matrix is generated on the basis of a key image. Subsequently, the binary watermark image is embedded into the chosen sub-band using the generated random matrix and the embedding strength β. Finally, the watermark embedded sub-band is mapped back into its original position and inverse transform is applied to obtain the watermarked image. The block diagram of the watermark embedding process is shown in Fig. 1.

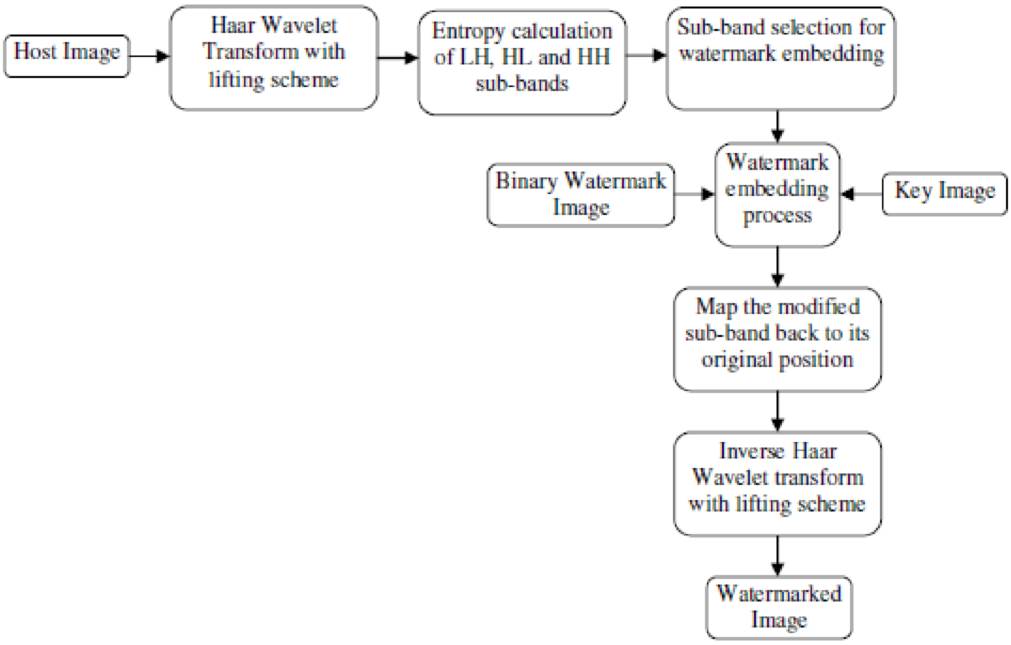

Fig. 1 Watermark embedding process

Steps in Watermark Embedding Process:

Input: Host Image (I), Binary Watermark Image (W), Key Image (I_k)

Output: Watermarked Image (I_W)

1. Decompose the host Image I into four sub-bands by means of Haar wavelet transform with lifting scheme.
2. Calculate the entropy masking of all sub-bands except LL sub-band. The entropy value of a sub-band is calculated with the aid of the following equation.
$$E = -sum(p.*\log(p))$$
Where p contains the histogram counts.
3. A sub-band that consists of maximum entropy value is chosen from the three sub-bands (LH, HL, HH) for embedding the watermark image (W) denoted as I_M .
4. Generate an initial random matrix R using the following steps.
(i) The pixel values in the key image (I_k) are summed and denoted as R_{seed} .
$$R_{seed} = \sum_{i=1}^{n} \sum_{j=1}^{n} I_{k_{ij}}$$
(ii) A random matrix R is generated with selected sub-band's size with the aid of the pseudo random matrix generator with R_{seed} value as seed value. If the image's size is 2^n x 2^n, the sub-band's size will be ($2^n/2$ x $2^n/2$).
$$R = PRMG[R_{seed}]_{(2^n/2 \times 2^n/2)}$$
5. Generate final random matrix RM is generated by means of R using the following steps:
(i) 0.5 is subtracted from the generated random matrix R and the resultant matrix is multiplied by 2. The final resultant matrix is denoted as R_t .
$$R_t = (R - 0.5) \times 2$$
(ii) Finally, the intended random matrix RM is generated using the pseudo random matrix generator with R_t matrix as seed value.
$$RM = PRMG[R_t]_{(2^n/2 \times 2^n/2)}$$
6. The binary watermark image pixels are embedded into the selected sub-band as described subsequently. For embedding pixel value '0', the random matrix RM is multiplied by the embedding strength β and the resultant matrix is added with the selected sub-band I_M values. For pixel value '1', no operation is performed. The aforesaid process is denoted as follows.
$$[I_M] = [I_M] + (\beta * [RM]) \quad ; where\ \beta = 2$$
7. Repeat steps 5 and 6 until all the watermark pixels are embedded. The initial random matrix R for every iteration is generated from the $PRMG$ initiated with seed R_{seed} .
8. Map the modified sub-band (I_M) back to its original position and apply inverse haar wavelet transform with lifting scheme to obtain the watermarked image I_W .

5.2 Watermark Extraction

The extraction of watermark image from the watermarked image is explained in this sub-section. The extraction of the watermark image requires watermarked image, size of watermark image, key image and the information about the sub-band in which the watermark is embedded. A random matrix is generated from the key image through the steps discussed in the previous sub-section followed by the computation, with the aid of correlation coefficient computation and the generated random matrix, the watermark pixels are extracted. The block diagram of the watermark extraction process is portrayed in Fig 2.

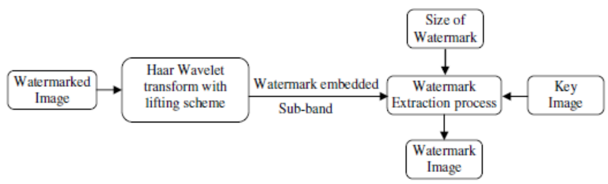

Fig. 2 Watermark Extraction Process

Steps in Watermark Extraction Process:

Input: Watermarked Image (I_W) , Size of Watermark Image (I_W) , Key Image (I_k), Sub-band information..

Output: Watermark Image (W).

1. Decompose the watermarked image (I_W) using haar wavelet transform with lifting scheme and select the watermark embedded sub-band (I_M)on the basis of the sub-band information.
2. Generate a random matrix RM using the steps (4 and 5) cited in the previous sub-section. In accordance with the previous sub-section, the initial random

matrix R for every iteration is generated from the $PRMG$ initiated with seed R_{seed}.

3. Compute the correlation coefficient (r) between the sub-band (I_M) and the generated random matrix [RM] using the following equation,

$$r = \frac{\sum_m \sum_n (A_{mn} - \overline{A})(B_{mn} - \overline{B})}{\sqrt{\left(\sum_m \sum_n (A_{mn} - \overline{A})^2\right)\left(\sum_m \sum_n (B_{mn} - \overline{B})^2\right)}}$$

Where,

$A_{mn} \rightarrow$ sub-band (I_M)

$B_{mn} \rightarrow$ *Random* Matrix[RM]

$\overline{A} \rightarrow$ *Mean value of* A

$\overline{B} \rightarrow$ *Mean* value of B

4. Divide the calculated correlation coefficient value (r) by two and denote the resultant value is as R_V.

$$R_V = r/2;$$

5. Repeat steps 2 to 4 for the size of watermark image and store the resultant values R_V in a vector VR_V.
6. Calculate the mean value of the vector VR_V.

$$\overline{VR_v} = \sum_{i=1}^{k} VR_v^i \Big/ k \quad ; \textit{ where } \mathrm{k} = |\mathrm{VR_v}|$$

7. The elements of the vector VR_V are compared against the mean value $\overline{VR_v}$ for the extraction of watermark image pixels. If the element's value is greater than the mean value, the extracted watermark image pixel is '0' otherwise the pixel value is '1'. The above process is described as follows:

$$W(x,y) = \begin{cases} 0, & VR_v^i > \overline{V}R_v \\ 1, & Otherwise \end{cases} \quad ; \textit{ where } \mathrm{n} = |\mathrm{VR_v}|$$

8. Eventually, the extracted pixel values are placed in a matrix with size of watermark image in order to obtain the watermark image (I_W).

6. Experimental Results and Analysis

The experimental results and analysis of the proposed watermarking scheme are presented in this section. The proposed watermarking scheme is programmed in Matlab (Matlab 7.4). The experiments are carried out with the aid of texture images obtained from Brodatz Texture Image data base [38]. The size of the texture images in the database is 640 x 640. The key image is an image of size 35 x 1. The random matrix is generated successfully from the key image using the discussed approach. The watermark image is embedded into the host image and extracted back from the watermarked image effectively using the technique discussed in the paper. The watermarked images have superior Peak Signal to Noise Ratio (PSNR) and visual quality. The watermark and watermarked images of four different host images are shown in Fig. 3 along with the PSNR values.

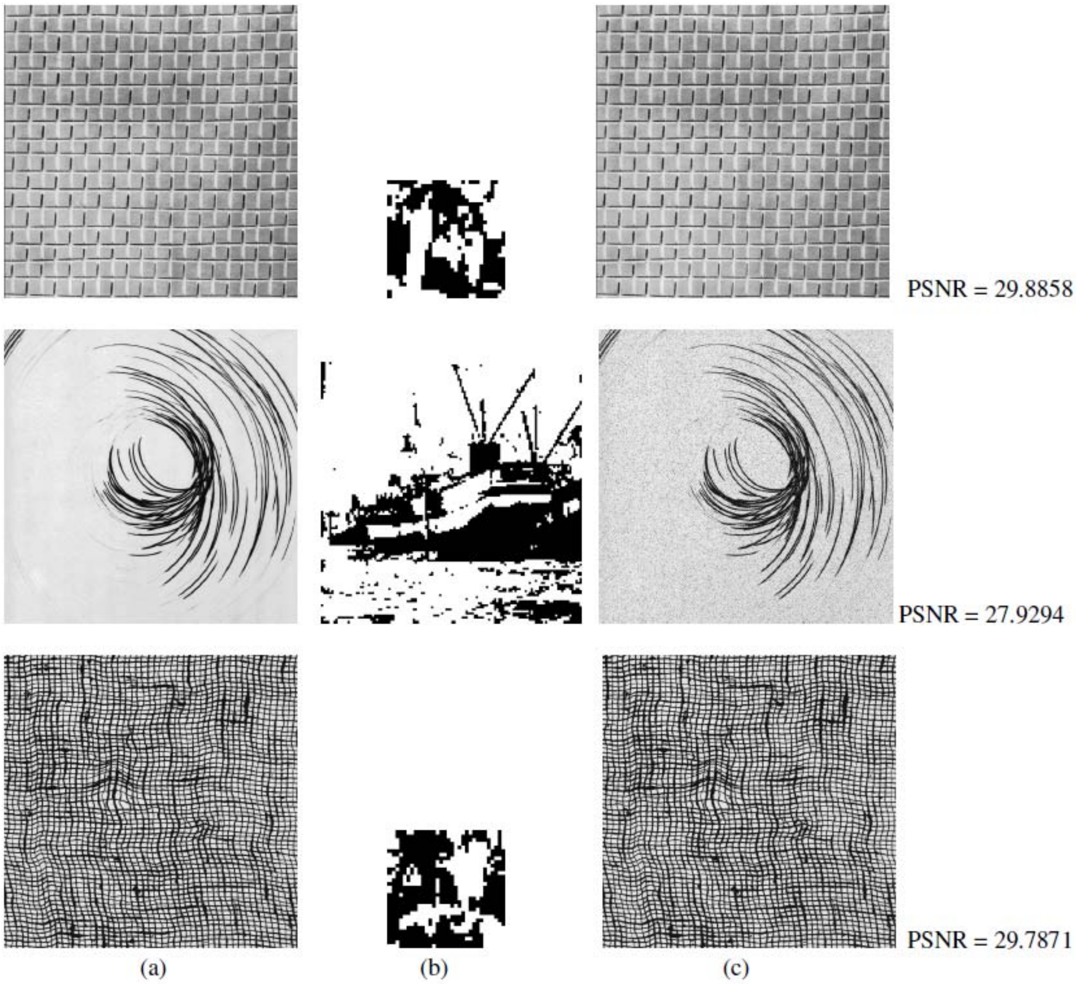

Fig. 3 (a) Host Image (b) Watermark image (c) Watermarked Image with PSNR value

In order to prove the robustness of the proposed watermarking technique, we have carried out a range of attacks on watermarked images in our experiments. Fig. 4 shows the results of different image attacks such as Gaussian blurring, Gaussian noise, Gaussian filter, Intensity value adjustment. The watermark images have been extracted from the attacked watermarked images effectively. Table 1 displays the correlation coefficient between the original watermark and the extracted watermark from the attacked watermarked images. The experimental results demonstrate that the correlation coefficient's value is above 0.5. The robustness of the proposed scheme is evident from the experimental evaluation

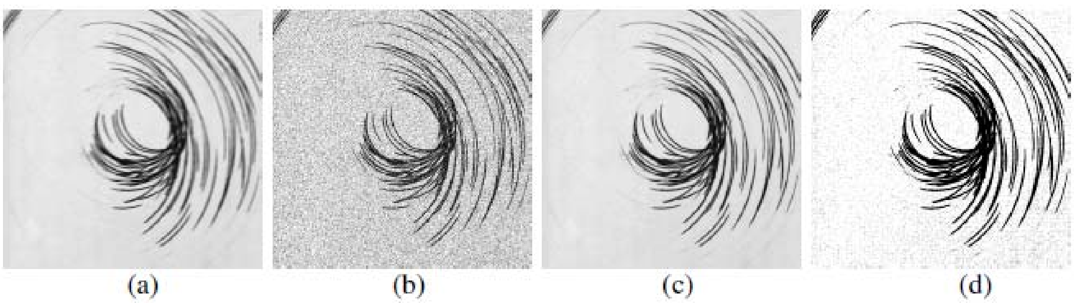

Fig. 4 Attacked Images (a) Gaussian Blur (σ=8) (b) Gaussian Noise (σ=75) (c) Gaussian filter (3x3 – 0.8) (d) Image Intensity Value (Low 0.6, High 0.8)

Fig. 5 Extracted watermarks from attacked Images (a) Gaussian Blur (σ=8) (b) Gaussian Noise (σ=75) (c) Gaussian filter (3x3 – 0.8) (d) Image Intensity Value (Low 0.6, High 0.8)

Table 1: Correlation coefficients of the extracted watermark against original watermark

Attacks	**Correlation Coefficient**		
Gaussian Blur	**σ = 6**	**σ = 8**	**σ = 22**
	0.5326	0.8189	0.7731
Gaussian Noise	**σ = 50**	**σ = 75**	**σ = 100**
	0.9778	0.9290	0.8643
Gaussian Filter	**3x3 – 0.7**	**3x3 – 0.8**	**3x3 – 0.9**
	0.9878	0.9240	0.7080
Image Intensity Value	**Low- 0.3, High- 0.7**	**Low- 0.2, High- 0.5**	**Low- 0.6, High- 0.8**
	0.7949	0.6991	0.9980

7. Conclusion

The illegal exploitation of digital images has resulted in an imperative necessity for copyright enforcement techniques that aid in the protection of copyright ownership. In this paper, we have presented an imperceptible and efficient watermarking scheme for copyright protection of digital images. The watermarking has been performed in wavelet domain by means of Haar wavelet transform with lifting scheme. The incorporation of HVS model into the proposed scheme has resulted in an efficient watermarking scheme for effective copyright protection of images. The entropy masking of HVS model is used in the selection of image components appropriate for embedding. A random matrix has been generated with the aid of a key image and employed in watermarking. The correlation coefficient computation has been utilized in the extraction process. The proposed scheme has satisfied both the requirements of effective copyright protection scheme: imperceptibility and robustness. The experimental results have demonstrated the same.

References

[1] Shiva Zaboli, Arash Tabibiazar and Reza Safabakhsh, "Entropy-Based Image Watermarking Using DWT and HVS", in proceedings of 3rd International Conference: Sciences of Electronic, Technologies of Information and Telecommunications, March 2005.

[2] Ching-Tang Hsieh and Yeh-Kuang Wu, "Digital Image Multi-resolution Watermark Based on Human Visual System Using Error Correcting Code", Tamkang Journal of Science and Engineering, vol. 4, no. 3, pp. 201-208, 2001

[3] Jun Tian, "Wavelet-based reversible watermarking for authentication", in proceedings of SPIE vol. 4675, pp. 679-690, 2002.

[4] Santi P. Maity, Malay K. Kundu, "An Image Watermarking Scheme using HVS Characteristics and Spread Transform," in proceedings of, 17th International Conference on Pattern Recognition (ICPR'04),vol. 4,pp.869-872, 2004.

[5] Pei-chun chen, Yung-sheng Chen and Wen-Hsing Hsu, "A Digital Image Watermarking System: Modeling, Peformance Analysis, and Application", in Proc. of 12^{th} IPPR Conference on Computer Vision, Graphics and Image Processing, pp. 199-206, 1999.

[6] Soroosh Rezazadeh, and Mehran Yazdi, "A Non-oblivious Image Watermarking System Based on Singular Value Decomposition and Texture Segmentation", in Proceedings of World Academy of Science, Engineering And Technology, vol. 13, May 2006, ISSN 1307-6884.

[7] Saraju P. Mohanty, Elias Kougianos an N. Ranganathan, "VLSI architecture and chip for combined invisible robust and fragile watermarking", Computers & Digital Techniques(IET), vol.1, no.5, pp.600-611, September 2007.

[8] Zhe-Ming Lu, Wei-Min Zheng, Jeng-Shyang Pan and Zhen Sun, " Multipurpose Image Watermarking Method Based on Mean-removed Vector Quantization" Journal of Information Assurance and Security vol.1, no.1, pp.33-42, March 2006.

[9] Yong C. Kim and Byeong C. Choi, "Two-Step Detection Algorithm in a HVS-Based Blind Watermarking of Still Images", in proceedings of Lecturer Notes in Computer Science, Springer-Verlag Heidelberg, vol. 2613, pp. 235-248, January 2003.

[10] Ching-Sheng Hsu and Shu-Fen Tu, "An Imperceptible Watermarking Scheme Using Variation and Modular Operations", International Journal of Hybrid Information Technology, vol. 1, no. 4, October 2008.

[11] John N. Ellinas, Panagiotis Kenterlis, "A Wavelet-Based Watermarking Method Exploiting the Contrast Sensitivity Function", International Journal of Signal Processing, vol. 3, no. 4, pp. 266-272, 2006.

[12] C. De Vleeschouwer, J. F. Delaigle, and B. Macq, “Invisibility and application functionalities in perceptual watermarking an overview”, in proceedings of IEEE, vol. 90, no. 1, pp. 64-77, 2002.

[13] G.S.El-Taweel, H.M. Onsi, M.Samy, M.G. Darwish, "Secure and Non-Blind Watermarking Scheme for Color Images Based on DWT", GVIP Special Issue on Watermarking, 2007.

[14] A. A. Reddy and B. N. Chatterji, “A new wavelet based logo-watermarking scheme”, Pattern Recognition Letters, Vol.26, No.7, pp. 1019-1027, 2005

[15] M. Barni, F. Bartolini, and A. Piva, “Improved wavelet-based watermarking through pixel-wise masking”, IEEE Transactions on image processing, Vol.10, No.5, pp. 783-791, 2001.

[16] X. D. Zhang, J. Feng, and K. T. Lo, Image watermarking using tree-based spatial-frequency feature of wavelet transform, Journal of Visual Communication and Image Representation, Vol.14, No.4, pp. 474-491, 2003.

[17] Raymond B. Wolfgang, Christine I. Podilchuk and Edward J. Delp, "Perceptual Watermarks for Image and Video", in proceedings of the IEEE, vol. 87, no. 7, July 1998.
[18] Yanhong Zhang, "Blind Watermark Algorithm Based on HVS and RBF Neural Network in DWT Domain", WSEAS Transactions on Computers, vol. 8, no. 1, January 2009.
[19] K.Veeraswamy , S. Srinivaskumar, B.N.Chatterji, "Designing Quantization Table for Hadamard Transform based on Human Visual System for Image Compression", ICGST-GVIP Journal, vol. 7, no. 3, November 2007.
[20] Xiaojun Qi, "An Efficient Wavelet-based Watermarking Algorithm," in proceedings of Hawaii International Conference on Computer Sciences, pp: 383-388, Jan. 15-18, Honolulu, Hawaii, 2004.
[21] A. Zolghadrashli and S. Rezazadesh, "Evaluation of Spread Spectrum Watermarking Schemes in the Wavelet Domain Using HVS Characteristics", International Journal of Information Science and Technology, vol. 5, no. 2, December 2007
[22] P. Foriš, and D. Levický, "Implementations Of HVS Models In Digital Image Watermarking", Journal of Radio engineering, vol. 16, no. 1, Pp. 45-50, April 2007.
[23] Franco A. Del Colle and Juan Carlos G´omez, "DWT based Digital Watermarking Fidelity and Robustness Evaluation", Journal of Computer Science & Technology, vol. 8, no. 1, April 2008
[24] Nizar Sakr, Nicolas D. Georganas, and Jiying Zhao, "Copyright Protection of Image Learning Objects using Wavelet-based Watermarking and Fuzzy Logic", in proceedings of Intelligent Interactive Learning Object Repositories (I2LOR 2006) Conference, Montreal, Canada, November 2006.
[25] Mohammad Ali Akhaee, S. Mohammad Ebrahim Sahraeian, Bulent Sankur and Farokh Marvasti, "Robust Scaling Based Image Watermarking Using Maximum Likelihood Decoder with Optimum Strength Factor", IEEE Transactions on Multimedia, October 2008.
[26] Shang-Lin Hsieh, I-Ju Tsai, Bin-Yuan Huang, and Jh-Jie Jian, "Protecting Copyrights of Color Images using a Watermarking Scheme Based on Secret Sharing and Wavelet Transform, Journal Of Multimedia, vol. 3, no. 4, October 2008.
[27] Zhang Rong- Yue, Ni Jiang-Qun and Huang Ji-Wu, J.-W. , "An adaptive Image Watermarking Algorithm Based on HMM in Wavelet Domain", ACTA AUTOMATICA SINICA, vol. 31, no. 5, pp. 705-712, 2005.
[28] J.Sullivan, L.Ray and R.Miller. Design of minimum visual modulation halftone patterns. IEEE Transactions on Systems, Man and Cybernetics, Vol: 21, 33-38, 1991.
[29] P.Poda and A.Tamtaoui. On the enhancement of unequal error protection performances in images transmission over time-varying channels, IJCSNS international journal of computer science and network security, Volume No.6,168-174, Sept 2006.
[30] J. L. Mannos, D. J. Sakrison, "The effect of a visual criterion in the encoding of images," IEEE Transaction on Information Theory, vol. 20 (July 1974). pp. 525-536.
[31] C. De Vleeschouwer, J. F. Delaigle, and B. Macq, "Invisibility and application functionalities in perceptual watermarking an overview," Proc. IEEE, vol. 90, no. 1, pp. 64-77, 2002.
[32] A. B. Watson, R. Borthwick, and M. Taylor, "Image Quality and Entropy Masking," Proceedings of SPIE on Human Vision and Electronic Imaging, Vol. 3016, pp. 2-12, 1997.
[33] Haar, Alfred; On the Theory of the orthogonal function systems. Mathematische Annalen, 69, no 3, 331-371, 1910.
[34] W. Sweldens, "Wavelets and the lifting scheme: A 5 minute Tour", Journal of Applied Mathematics and Mechanics, Vol. 76 (Suppl. 2), pp. 41-44, 1996.
[35] "HAAR wavelet" from http://en.wikipedia.org/wiki/Haar_wavelet.
[36] Amit Phadikar, Santi P. Maity , Malay K. Kundu, "Quantization Based Data Hiding Scheme for Efficient Quality Access Control of Images using DWT via Lifting", Sixth Indian Conference on Computer Vision, Graphics & Image Processing, pp:265-272, 2008.
[37] G.Uytterhoeven, D. Roose, and A. Bultheel, "Wavelet transforms using lifting scheme", Technical Report ITA-Wavelets Report WP 1.1, Katholieke Universities Leuven, Department of Computer Science, Belgium, April 1997.
[38] "Brodatz Textures" from http://www.ux.uis.no/~tranden/brodatz.html

V.Padmanabha Reddy received the B.Tech in Electronics and Communication Engineering from Regional Engineering College, Warangal, Andhra Pradesh, India and M.Tech in Digital systems and Computer Electronics from J.N.T. University college of Engineering, Hyderabad, Andhra Pradesh, India. He is working towards his Ph. D., at Sri Venkateswara University College of Engineering, Tirupati, Andhra Pradesh, India. He has eleven years experience of teaching under graduate students and post graduate students. Currently working as a faculty in the department of Information Technology, Vardhaman College of Engineering, Hyderabad, Andhra Pradesh, India. His research interests are in the areas of Digital Image Processing and Digital Image watermarking.

Dr S Varadarajan received the B.Tech degree in Electronics and Communication Engineering from Sri Venkateswara University in 1987 and M.Tech degree from NIT, Warangal. He did his Ph.D in the area of radar signal processing. He is fellow of Institute of Electronics & Telecommunication Engineers (IETE) and member IEEE. Currently working as Associate Professor in the Department of EEE, Sri Venkateswara University, Tirupati, Andhra Pradesh, India.