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Performance Evaluation of DWT and FIS Based Image Copyright Protection

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ABSTRACT: Exponentially expanding digitization has posed several issues relating to the ownership of creation, data protection and copyright aspects of multimedia data. The current paper provides a novel approach for inserting an invisible watermark in host multimedia data to mark ownership. The non-blind, secure, robust and imperceptible image watermarking scheme is proposed. To enable these characterizing features, robust image watermarking for image copyright protection using Discrete Wavelet Transform (DWT) synergized with Human Visual System (HVS) and Fuzzy Inference System (FIS) is developed. The performance is evaluated in degraded watermarked images due to signal processing as well as de-synchronization or non geometric attacks.

KEYWORDS: Image Copyright Protection, Discrete Wavelet Transform, Human Visual System, Fuzzy Inference System, Watermarking Attacks.

I. INTRODUCTION

There is a pertaining issue of manipulation and duplication of multimedia data especially images in this digitized world. Development of a technique to protect and secure digitized data from illegitimate copying is of utmost importance. Image copyright is an effective tool to handle this issue. Hence an identification mark called watermark is embedded in an image which is imperceptible to human vision. Thus a logo, copyright mark, seal or any other such information is hidden in host image such that it does not degrade quality of host image. At the same time, this hidden information must survive in the host image even after signal processing operation or geometric transformation to prove ownership. A trade off is to be established in imperceptibility criteria and robustness for copyright protection. Imperceptibility feature preserves quality of digitized image. Robustness feature ensures survival of watermark in case of intentional or unintentional signal processing operations or geometric alterations in watermarked image [1-5]. The proposed scheme attributes to high strength of watermark for survival in an image still obviating any perceptual artifacts in the image. Using fuzzy inference system, a computationally intelligent technique to optimize the strength of watermark is developed for image copyright protection.

II. RELATED WORK

The techniques for digital image watermarking are classified as spatial domain and transform domain. Spatial domain techniques involve embedding the copyright information by directly modifying pixel values in the host image. Transform domain techniques apply transform on the host image and then embedding watermark in part of the transform or spectral coefficients. Spatial domain methods are less complex as no transform is used, but are not robust to tampering and attacks and have relatively low bit capacity [6-15]. Embedding watermark in transform domain improves imperceptibility, security and robustness of the copyright protection scheme. The information embedded as watermark is more tolerant to various types of attacks in transform domain. The transform domain techniques are further classified based on type of transform like DFT (Discrete Fourier Transform), DCT (Discrete Cosine Transform), DWT (Discrete Wavelet Transform) etc. The performance can be enhanced with the help of computational models like fuzzy logic, artificial neural network, support vector machine, singular value decomposition and other similar techniques [16-27].

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III. PROPOSED SCHEME

The proposed scheme uses DWT for inserting copyright information. Digital watermark is embedded by modulating magnitude of discrete wavelet transform coefficients. The modification in DWT coefficients is controlled in order to achieve invisibility of embedded watermark. The strength of the watermark is dynamically varied based on human visual system features and FIS [28-30]. HVS features used are brightness, contrast, texture and frequency sensitivity. FIS is developed to establish inter relationship between these non linear HVS features by defining fuzzy membership functions and fuzzy rules. Watermark weight is then calculated adaptively by FIS for inserting watermark in host image.

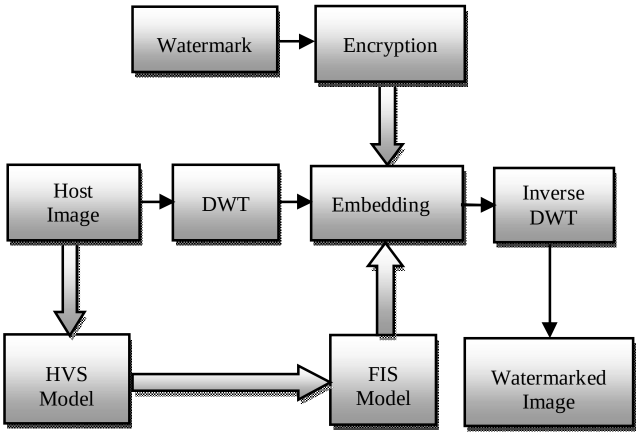

Fig.1 Block Diagram for Watermark Embedding

This approach using fuzzy logic is best suited for modeling non-linear data of human vision and representing imprecise data in easy to understand linguistic fuzzy rules. For embedding procedure, three levels of discrete wavelet transform of host image are computed. Further, watermark is added in sub bands dynamically using FIS model. Security is enhanced by using encryption for watermark.

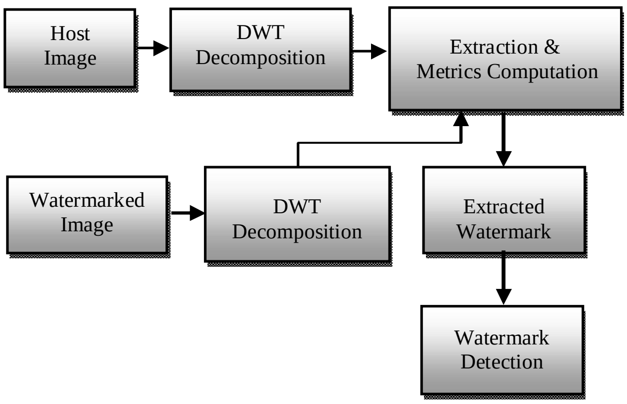

Fig.2 Block Diagram for Watermark Extraction

The watermark insertion is performed as per equation (1).

$$C'\,band\,(i,j) = C\,band\,(i,j) + \alpha\,\beta(i,j)\,f(l,\theta)\,w(i,j) \quad (1)$$

Where,
$C\,band\,(i,j)$: Original wavelet coefficient
$C'\,band\,(i,j)$: Watermarked wavelet coefficient
α : Watermark strength / Modulation index

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$w(i,j)$: Watermark signal
$\beta(i,j)$: Weight of watermark
$f(l,\theta)$: Sensitivity factor for frequency and orientation

The human eye sensitivity factor to frequency and orientation f (l, θ) can be computed as given in equation (2). This equation takes into consideration that human visual system is less sensitive to disturbances in higher resolution bands and diagonal bands with 45° orientation.

$$f(l,\theta) = (\text{level}) \times (\text{theta}) \quad (2)$$

Where,
theta = √2 if θ=1
= 1 otherwise
& level = 1.00 if l=1
= 0.32 if l=2
= 0.16 if l=3

Weight of watermark ß (i,j) is computed from fuzzy inference system.

IV. Attacks on Watermarked Images

Watermarked image is transmitted through communication channel. The process involves possible attacks on watermark in a watermarked image. The attack may be signal processing or de-synchronization. These attacks may be malicious or accidental. The process ultimately results in degradation of watermarked image. The signal processing attacks are also called as image processing attacks or non geometric attacks [31-34].

The signal processing attacks include addition of various types of noise like Gaussian noise, salt and pepper noise, speckle noise etc. These attacks further include operations on watermarked image such as compression, gamma correction and change in brightness.

Geometric attacks also called as de-synchronization attacks attempt to destroy synchronization of watermark detection. Thus it makes detection process difficult and sometimes even impossible. Geometrical distortions are classified basically into two types. Global geometric attack affects all the pixels of the image in the similar manner. Local geometric attack affects different portions of an image in different ways. Geometric distortions are specific to images and videos and include such operations as rotation, translation, scaling and cropping. The basic transformations which come under geometrical distortion are scaling, rotation, cropping, row-column blanking etc. The proposed scheme is tested for most of these attacks successfully showing survival of watermark in the degraded image [35-37].

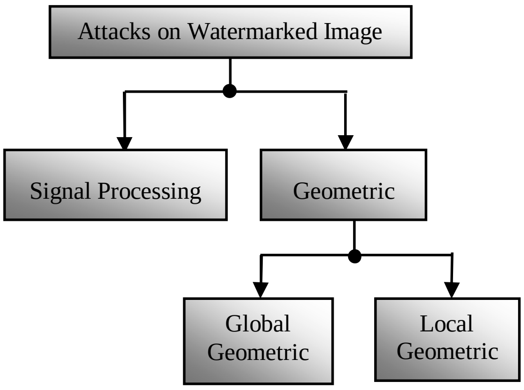

Fig. 3 Classification of Attacks on Watermarked Image

V. Experimental Results

Performance evaluation is carried out by subjective or qualitative evaluation as watermark used is logo as against pseudorandom binary sequence generator which is difficult to detect. This is possible with human visual system. But for objective analysis or quantitative approach, performance parameters are calculated. The two performance

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parameters used are Peak Signal to Noise Ratio (PSNR) for imperceptibility analysis and Correlation Coefficient (CRC) for robustness evaluation [38]. The two parameters are calculated mathematically by equation (3) and equation (4).

$$PSNR(dB) = l0 \cdot log_{10}\frac{255\times255}{MSE} \quad (3)$$

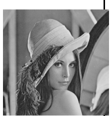
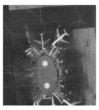
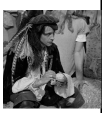
Where,
$MSE = \frac{1}{Nt}\sum_{i,j}(X(i,j) - X'(i,j))^2$
$X(i,j)$: Original image,
$X'(i,j)$: Watermarked image, and
Nt : Size of an image

$$CRC = \frac{\sum_i\sum_j W(i,j)\cdot W'(i,j)}{\sqrt{\sum_i\sum_j W(i,j)^2 \times \sum_i\sum_j W(i,j)^2}} \quad (4)$$

Where,
$W(i,j)$: Original Watermark and
$W'(i,j)$: Extracted Watermark

The proposed scheme is tested with different types of images and wide variety of watermarks. The host images include images having broad range of contents like scenery images, facial images, synthetic images and texture images. The watermarked images are shown in table 1 showing no perceptual degradation compared to the host image.

Table 1 Watermarked Images

Watermarked Images									
IM1	IM2	IM3	IM4	IM5	IM6	IM7	IM8	IM9	IM10
									
IM11	IM12	IM13	IM14	IM15	IM16	IM17	IM18	IM19	IM20
									

Different types of watermark images are used for experimentation. There are 5 watermark images used and results for extracted watermark without any attack are shown in table 2. Experimentation is carried out by embedding each watermark in all the images of image database.

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Table 2 Extracted Watermark Images

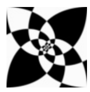
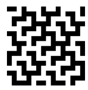
Extracted Watermark Images				
WM1	WM2	WM3	WM4	WM5
				

Table 3 shows PSNR and CRC values for different modulation index values. It further shows comparison of these values for DWT and Discrete Cosine Transform (DCT). DWT shows higher values of PSNR resulting in better imperceptibility of watermarked image. DWT also shows higher values of correlation coefficient of extracted watermark leading to robust watermarking scheme as compared to DCT method. This results into higher probability of survival of watermark in watermarked image in case of watermarking attacks. PSNR value decreases as modulation index increases. CRC value increases as modulation index increases indicating increase in strength of watermark. The results show superiority of DWT compared to DCT for robustness evaluation.

Table 3 Comparison of PSNR and CRC Values using DWT and DCT

Modulation Index	**0.01**	**0.03**	**0.05**	**0.07**	**0.09**	**0.10**
PSNR (DWT)	58.00	50.18	48.69	47.41	43.57	43.01
CRC (DWT)	0.9350	0.9910	0.9959	0.9955	0.9940	0.9930
PSNR (DCT)	52.33	43.48	39.20	36.34	34.20	33.17
CRC (DCT)	0.6250	0.8276	0.8740	0.8447	0.9221	0.9457

The results are plotted graphically as shown Fig. 4 (a). It shows relation between PSNR value Vs modulation index for DWT and DCT. PSNR values are better for DWT as compared to DCT. Fig. 4(b) shows relation between CRC Vs modulation index for these two techniques.

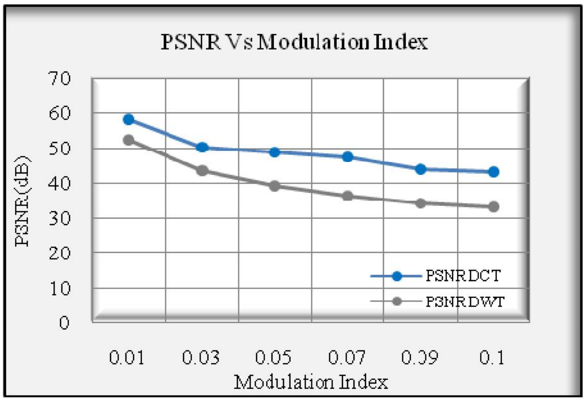


Fig. 4(a) PSNR Vs Modulation Index

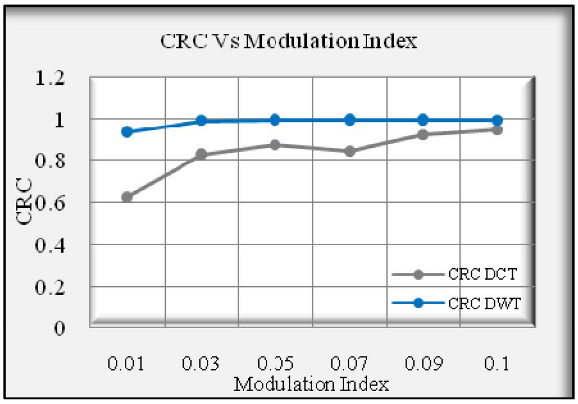


Fig. 4(b) CRC Vs Modulation Index

The proposed scheme is evaluated for various types of attacks. Few of these attacks are illustrated below. The sample results for tulip as host image and flower as watermark are shown. The result of addition of Salt and Pepper noise is shown in table 4. Salt and pepper noise with varying noise densities are added to watermarked image. The density varies from 0.01, 0.02 and 0.03 are tested. The resulting PSNR values along with degraded images are shown. The watermarked image is seriously damaged when variance is 0.0035. The value for PSNR is degraded as low as 24. But it can still extract identifiable clear watermark required to prove ownership. The extraction is quantified by CRC

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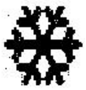
which is above 0.5. Thus the proposed scheme proves to be robust against salt and pepper noise. The effect of salt and paper noise is illustrated in table 4. The results are plotted graphically in Fig. 5(a) and 5(b).

Table 4 Salt and Pepper Noise Attack

Salt and Pepper Noise				
Noise Density	0	0.01	0.02	0.03
Degraded Image				
PSNR (dB)	42.6623	25.1878	22.1171	20.2936
Extracted Watermark				
CRC	1	0.8625	0.7484	0.6445

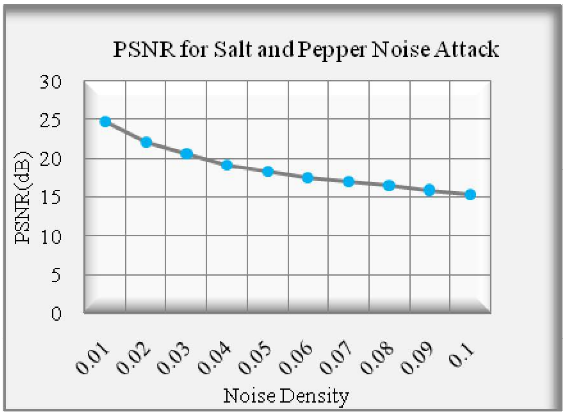


Fig.5 (a) PSNR Vs Noise Density

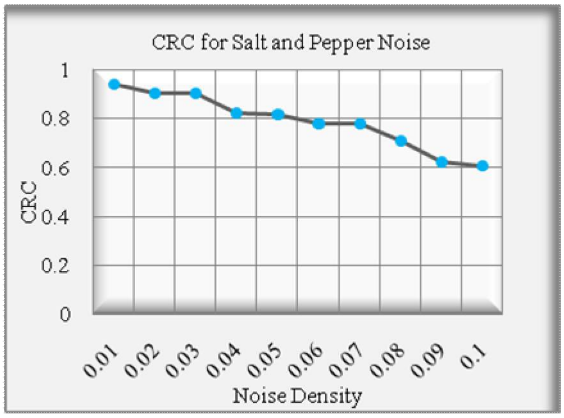


Fig. 5 (b) CRC Vs Noise Density

The proposed scheme is evaluated for cropping attack of watermarked image. Cropping is an example of geometric or de-synchronization attack in which portion of the watermarked image is removed and it is not available for extraction purpose.

Cropping is used for removal of the outer parts or middle parts of an image. This process is usually carried out to improve framing, emphasize subject matter or change aspect ratio. Image cropping is a geometric attack that may occur to watermarked image. It may remove some watermark information. Cropping is the easiest operation among popular image manipulations. Here minimum or maximum pixel value is inserted in the cropped portion. The cropped portion may be either replaced by black pixels or white pixels in the watermarked image. The watermarked image can be cropped from borders or in middle portions.

Table 5 shows cropping attack on watermarked image with different percentage of cropping ratio. It is seen by white portions in the watermarked image. With 40% cropping, watermarked image is very much degraded with PSNR value of 12dB only. But the watermark is extracted successfully with large CRC value of 0.815. Image is of no commercial use if further degraded resulting in still lower values of PSNR.

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Table 5 Cropping Attack

Cropping Attack				
Cropping Ratio	10%	20%	30%	40%
Cropped Image				
PSNR (dB)	19.869	16.552	13.260	12.000
Extracted Watermark				
CRC	0.9956	0.9657	0.8752	0.8150

The results for PSNR and CRC are plotted graphically for cropping attack as shown in Fig. 6(a) and Fig. 6(b). The PSNR and CRC values go on decreasing as percentage of cropping ratio goes on increasing. It indicates deterioration in the quality of watermarked image but still giving satisfactory value of CRC above 0.8.

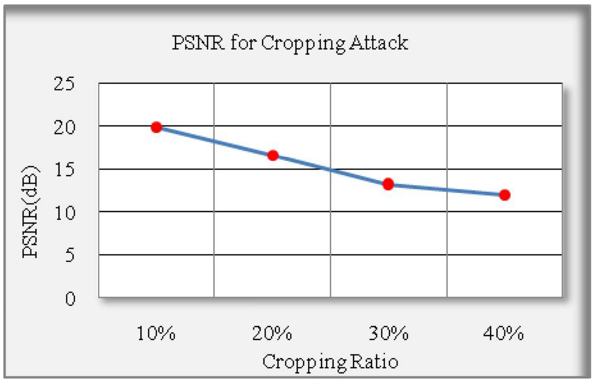

Fig.6 (a) PSNR for Cropping Attack

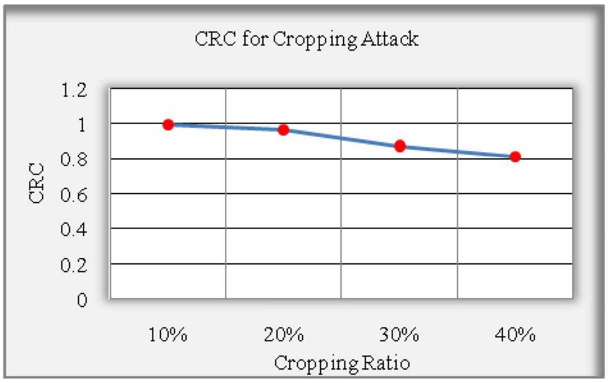

Fig.6 (b) CRC for Cropping Attack

The proposed scheme also depicts robustness against signal processing operations like JPEG compression, Gaussian noise, Speckle noise, Gaussian filter (3X3, 5X5) and Histogram equalization along with salt and pepper noise. It exhibits robustness against geometric transformations like scaling and row column blanking along with cropping attack.

VI. Conclusion and Future Work

The results for PSNR and CRC without attack and with attack are better for the proposed scheme. The discrete wavelet transform exhibits better results as it can utilize anisotropic properties of human vision in a better way by analyzing image at multiple resolutions. The fuzzy inference system developed establishes interrelationship among HVS parameters resulting in optimum strength of watermark at different locations. The scheme is capable of evaluating

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performance with subjective as well as objective analysis. The qualitative and quantitative analysis is possible as copyright information used is visually recognizable pattern such as logo. The synergic approach combining DWT, HVS and FIS to exploit human vision give better results for PSNR as well as CRC. The scheme thus leads to achieve imperceptibility and robustness criterion. The experimental results demonstrate that the proposed scheme has excellent robustness against image processing as well as de-synchronization attacks. It is evaluated in case of worst possible degradation of watermarked image and still successfully extracting identifiable watermark to prove ownership. The scheme can be extended for videos and 3-D images. It can be applied in diversified fields such as biomedical, e-commerce, e-governance and distant learning.

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BIOGRAPHY

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