Robust Digital Image Watermarking scheme in DCT Domain using FIS and HVS

B.Jagadeesh[1], M.Appala Raju[2], P.Jagan Mohan[3]

[1] Associate Professor, E.C.E. Department,
G.V.P. College of Engg, Visakhapatnam, A.P., India
bjagadeesh76@yahoo.com

[2] E.C.E.Department
G.V.P. College of Engg, Visakhapatnam, A.P., India
rmolleti4311@gmail.com

[3]E.C.E.Department
G.V.P. College of Engg, Visakhapatnam, A.P., India
jaganmohanpanigrahi@yahoo.in

ABSTRACT:

This work concerns with a robust watermarking scheme for copyright protection of images in frequency domain based on the combination of Fuzzy Inference System and Human Visual System (HVS). This scheme provides secure watermarking using Discrete Cosine Transfrom (DCT). The proposed method is robust to various image processing attacks, such as Salt & Pepper noise, Low pass Filtering, JPEG Compression, Gamma Correction, Row-column blanking, Row-Column Copying, Bit plane removal, Cropping, Resize and Histogram Equalization. The experimental results obtained show that the proposed scheme is both robust and blind and the quality of the watermarked image is good interms of Peak Signal to Noise Ratio (PSNR) and acheives good Normalized Cross Correlation (NCC) value .

Keywords- Digital Image Watermarking, Discrete Cosine Transform, Fuzzy Inference System, Human Visual System, Quantization, Blind.

Introduction

Watermarking is one of the best proposed solutions for copyright protection of digital images. The procedure of inserting a watermark i.e. in a multimedia object is defined as watermarking. The watermark can be embedded through visible and invisible means in original image such that it can be extracted as the evidence of rightful ownership. Several attacks may be experienced because the multimedia object can be digitally processed. Thus to improve the robustness and security of watermark, many scholars have made various research based on Fuzzy Logic Tecniques which are based membersip values between input and output.

Charu Agarwal et al [5] have proposed a robust method of embedding watermark coefficients in DCT domain.

The watermark is extracted by the comparison of the watermarked image with the original image. Vaishali et al [8] introduced Discrete wavelet transform (DWT) for digital image watermarking. In their work, both the host image and watermarked image are used for watermark extraction. Mandeep Singh Saini et.al [9] proposed a robust method of embedding watermark coefficients using both DCT & DWT which is an simulink implementation

This work deals with a modified watermarking method using Discrete Cosine Transfrom (DCT) and combination of Fuzzy Logic and HVS for embedding and extracting the watermark based on an algorithm proposed by Sameh Oueslati et al. [1] is presented.

The paper is organized as follows: In section 1 Preliminaries about Discrete Cosine Transform, Color Space Conversion, Human Visual System, Fuzzy Inference System are described. Section 2 explains the proposed watermarking method. Experimental results are shown in section 3. The conclusions are specified in section 4.

I. PRELIMINARIES

A. Discrete Cosine Transform

The DCT transforms a signal from a time domain representation to frequency domain representation. Embedding watermark into lower frequency coefficients will cause imperceptibilty problems,embedding into higher frequency coeffiecients will not sustain to attacks such as compression etc, so to make algorithm more robust to known and unknown image processing attacks in this paper middle frequency coefficients are considered.

Two dimensional DCT used in digital image processing for a given image A of size N*N is defined as in [1]

$$B_{pq} = \alpha_p \alpha_q \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} A_{mn} \cos(\pi(2m)+1)p/2M) \cos(\pi(2m)+1)q/2N) \quad \ldots\ldots\ldots\ldots\ldots[1]$$

$0 \le p \le M-1,\ 0 \le q \le N-1$

$$\alpha(p) = \begin{cases} 1/\sqrt{N}, & p = 0 \\ 2/\sqrt{N}, & 1 \le p \le N-1 \end{cases} \quad \ldots\ldots\ldots\ldots\ldots[2]$$

$$\alpha(q) = \begin{cases} 1/\sqrt{N}, & q = 0 \\ 2/\sqrt{N}, & 1 \le q \le N-1 \end{cases} \quad \ldots\ldots\ldots\ldots\ldots[3]$$

p and q varies from 0 to N-1

Where M * N is size of original image 'A'

The DCT is an invertible transform, and its inverse is given by

$$A_{mn} = \sum_{p=0}^{M-1} \sum_{q=0}^{N-1} \alpha_p \alpha_q B_{pq} \cos(\pi(2m)+1)p/2M) \cos(\pi(2m)+1)q/2N) \quad \ldots\ldots\ldots\ldots\ldots\ldots..[4]$$

B. Color Space Conversion

Bitmap images uses the RGB planes directly to signify a color image,but according to medical research human eye sensitivity is different to color and brightness,so RGB to YcbCr conversion is done as in Ref[10].

Y-Luminance, Cb-Chrominance Blue,Cr-Chrominance Red. Luminance is awfully alike to gray scale version of host image.

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 16 \\ 128 \\ 128 \end{bmatrix} + \begin{bmatrix} 65.481 & 128.553 & 24.966 \\ -37.79 & -74.203 & 112.00 \\ 112.00 & -93.786 & -18.214 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad \ldots\ldots\ldots\ldots\ldots [5]$$

Matlab has predefined function for this conversion

ycbcr_image= rgb2ycbcr(rgb_image)

A similar transformation converts YcbCr back to RGB

rgb_image=ycbcr2rgb(ycbcr_image)

C. The Human Visual System (HVS)

To embed the watermark in the hostimage, it is helpful to make use of the weaknesses of the human visual system,here we focus on the sensitivity of brightness and texture which are the vital characteristics of human visual system proposed by Sameh Oueslati et. al [1].

Luminance sensitivity (LS_k): The more the brightness there will be less chance for visibility of embedded signal.Luminance Sensitivity is calculated using the formulae

$$LS_k = (V_{DC,k})/(MV_{DC}) \ldots\ldots\ldots\ldots\ldots[6]$$

$V_{DC,k}$ is the DC coefficient of k^{th} block

MV_{DC} is the mean value of all the $V_{DC,k}$ coefficients.

Texture Sensitivity (T_k): For extremely textured areas eye will not be able to make a distinction between the original and watermarked images.Texture Sensitivity is calculated using the formulae

$$T_k = V_k(x,y)/Q(x,y) \ldots\ldots\ldots\ldots\ldots..[7]$$

Where (x, y) represents the location in the k^{th} block, Q(x,y) is the JPEG quantization table given as [7]

$$Q = \begin{bmatrix} 16 & 11 & 10 & 16 & 24 & 40 & 51 & 61 \\ 12 & 12 & 14 & 19 & 26 & 58 & 60 & 55 \\ 14 & 13 & 16 & 24 & 40 & 57 & 69 & 56 \\ 14 & 17 & 22 & 29 & 51 & 87 & 80 & 62 \\ 18 & 22 & 37 & 56 & 68 & 109 & 103 & 77 \\ 24 & 35 & 55 & 64 & 81 & 104 & 113 & 92 \\ 49 & 64 & 78 & 87 & 103 & 121 & 120 & 101 \\ 72 & 92 & 95 & 98 & 112 & 100 & 103 & 99 \end{bmatrix}$$

D. Fuzzy Inference System (FIS)

Fuzzy logic approach is a process inhibited by a human operator. The theory of fuzzy logic tends the human approach in the sense that the variables are treated not as logical variables but as linguistic variables. FIS performs the mapping between given input and output without the use of mathematical modeling concepts[4].

The rule base consists of IF-THEN rules that can be specified by a human proficient. Here Mamdani type DFIS is best suited to model the watermark weighting function.

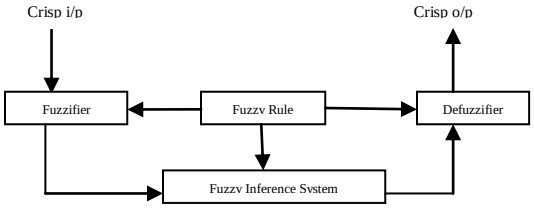

Figure 3. Fuzzy Inference Model

Fuzzy Inference System technique is used to classify blocks which are more suitable to embed watermark based on fuzzy membership value. The Membership Function Editor, Rule Editor, Surface Editor are the GUI's that are available under Fuzzy Logic ToolBox in Matlab using which, a set of inputs can be matched to set of outputs for obtaining the desired results[6]. In this proposed method fuzzy output is considered as weight of a particular block.

II. PROPOSED METHOD

A. Watermark Embedding using DCT

The procedure for embedding the watermark is :

1. The host image is of size 512x512x3 color image.
2. Y,Cb,Cr planes are separated and Luminance (Y) plane is selected to embed watermark.
3. The binary image of size 32x32 is chosen as watermark.
4. Divide the 'Y' component into 8*8 non-overlapping blocks and DCT is computed for each block.
5. Luminance sensitivity and Texture sensitivity for each block are calculated as stated in Eq.(6&7), and these are fed as inputs to FIS and rules are created in FIS rule editor.i.e; shown in Table1

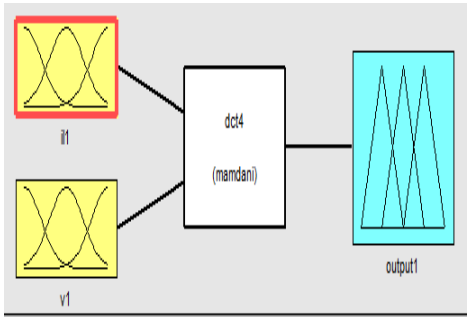

Figure 4: Fuzzy Inference System

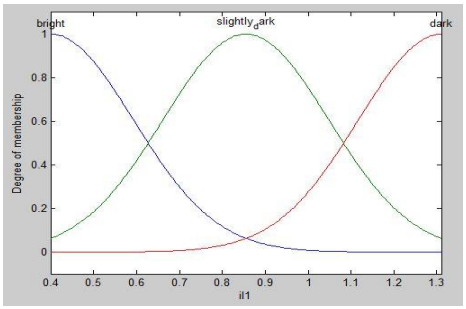

Figure 5: Membership Function of LS_K

6. 1024 blocks are selected based on 'α_k' i.e; weight of each block which is the fuzzy output.
7. The selected block numbers is provided as secret key1 that is used for extraction of watermark.
8. Two coefficients (c1,c2) from each block are choosen which are of the same value of quantization by JPEG quantization table.
9. The position of these two coefficients are considered as secret key2.
10. Linearize the watermark into a vector 'wmk' i.e; of size 1x1024.

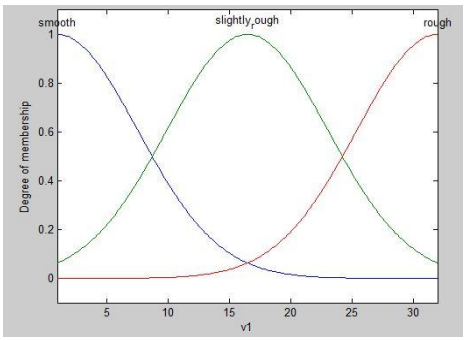

Figure 6: Membership Function of T_k

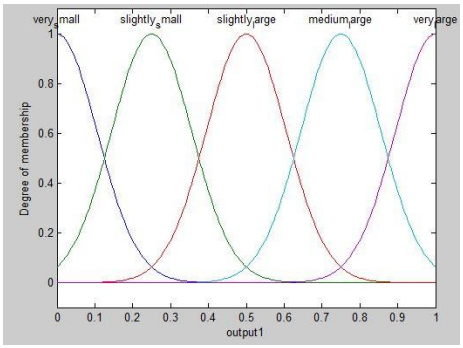

Figure 7: Output Membership Function

Luminance	Texture	Output
Bright	Smooth	Very small
Bright	Slightly rough	Very small
Bright	Rough	Slightly small
Slightly dark	Smooth	Slightly small
Slightly dark	Slightly rough	Slightly small
Slightly dark	Rough	Slightly large
Dark	Smooth	Slightly large
Dark	Slightly rough	Medium large

Table1: Fuzzy Inference Rules

11. Based on watermark bit sequence, embedding algorithm is

if wmk(i) bit is '0' then make c1>c2
if wmk(i) bit is '1' then make c1<c2

12. The insertion procedure is then applied as follows

If c1-c2≤ α and c1>c2

$$\begin{cases} c1=c1+(\alpha/2) \\ c2=c2-(\alpha/2) \end{cases} \text{otherwise} \begin{cases} c1=c1-(\alpha/2) \\ c2=c2+(\alpha/2) \end{cases}$$

…….. [8]

B. Watermark Extraction

The watermark extraction process from a watermarked image is:

1. The watermark extraction process is reverse process of watermark embedding.
2. Extract 'Y' component from the watermarked image and divide it into 8*8 non-overlapping blocks and compute DCT of each block
3. Based on the provided secret key1, 1024 blocks are selected.
4. Based on secret key2 two coefficients (c1,c2) are selected.
5. if c1>c2 wmk(i) bit is '0' else '1'

The performance metrics Peak Signal to Noise Ratio (PSNR) and Normalized Cross Correlation (NCC) are used to test the proposed algorithm . Consider the original image is of size NxN is *f(i,j)* and watermark is *F(i,j).*then PSNR in dB is given by

$$PSNR=10\log_{10}\left(\frac{\sum_{i=1}^{N}\sum_{j=1}^{N}(F(i,j))^2}{\sum_{i=1}^{N}\sum_{j=1}^{N}(f(i,j)-F(i,j))^2}\right) \quad \ldots\ldots[9]$$

Let the watermark image is denoted by $w(i,j)$ and the extracted watermark is denoted by $w'(i,j)$ then NCC is defined as

Let the watermark image is denoted by and the extracted watermark is denoted by $w'(i,j)$ then NCC is defined as

$$NCC=\left(\frac{\sum_{i=1}^{N}\sum_{j=1}^{N}(w(i,j)-w_{mean})(w'(i,j)-w'_{mean})}{\sqrt{\sum_{i=1}^{N}\sum_{j=1}^{N}(w(i,j)-w_{mean})^2\sum_{i=1}^{N}\sum_{j=1}^{N}(w'(i,j)-w'_{mean})^2}}\right) \quad \ldots\ldots[10]$$

w(i,j) is the original watermark
w'(i,j) is extracted watermark

In Eq.(10), w_{mean} and w'_{mean} indicate the mean of the original watermark image and extracted watermark image respectively.

III. Experimental Results And Discussion

Experiments are performed to test the effectiveness of the method using host color image 'MANDRIL' shown in Figure 8.

In Figure 8 host image MANDRIL are shown

Figure.8.512x512x3 Mandril (Host Image)

The size of the host image is 512x512x3. The watermark image is 32 x 32 as shown in Figure 9.

Figure.9. Watermark Image

In Figure 10 watermarked MANDRIL is shown

Figure.10. 512x512x3 Mandril (Watermarked Image)

In Figure.11 extracted watermark is shown

Figure.11. Extracted Watermark

Table. 2 PSNR & NCC values for Mandril for Sameh Oueslati et.al and proposed method

Type of Attack	Sameh Oueslati et.al method		Proposed method	
	PSNR(dB)	NCC	PSNR(dB)	NCC
No attack	54.53	0.9721	42.43	0.9907
Row-Column copying	33.92	0.7829	39.28	0.8398
Row-Column blanking	38.76	0.9026	35.86	0.8941
Intensity transformation	31.65	0.7851	20.21	0.8971

Image contrast attack		21.14	0.6713	22.08	0.8275
Salt&Pepper noise		20.23	0.7371	38.81	0.8690
Rotation Clockwise Anti-Clockwise		 29.91 30.10	 0.6163 0.6269	 29.79 30.97	 0.6479 0.6639
Low Pass Filtering(3x3 Kernel)		38.73	0.7196	37.65	0.7778
Sharpening		21.60	0.6277	22.53	0.6716
Cropping		19.59	0.7222	23.79	0.7244
JPEG Compression attack	QF=85	36.24	0.6780	38.26	0.8715
	QF=90	37.41	0.7266	39.74	0.8934
	QF=95	38.57	0.6970	41.45	0.9177
Gamma Correction	γ=1	27.24	0.7421	42.30	0.9814
	γ=2	20.47	0.7103	18.79	0.8343
	γ=3	17.64	0.6365	15.32	0.7286

All the attacks were tested using MATLAB 7.8.0. The proposed method is also resistant to various image processing attacks such as cropping, gamma correction and histogram equalization attacks, as shown above in Table 2.

IV. CONCLUSION

In this paper, a robust Image Watermarking method using Discrete Cosine Transform based on the Fuzzy Inference System and Human Visual System have been presented. The quality of the watermarked image is of good quality in terms of perceptibility and PSNR.

REFERENCES

[1] Sameh Oueslati, Adnane Cherif, Basel Solaiman ,*"A Fuzzy Watermarking Approach Based on the Human Visual System",* International Journal Of Image Processing (IJIP), Volume (4): Issue (3), 2011.

[2] B.Jagadeesh,P.Rajesh Kumar,P.Chenna Reddy, "*Robust Digital Image Watermarking Scheme in Discrete Wavelet Transform domain using Support Vector Machines*", International Journal of Computer Applications, Volume 73, July 2013.

[3] Nallagarla Ramamurthy,Dr.S.Varadarajan,*"Robust Digital Image Watermarking Scheme with Neural Network and Fuzzy Logic Approach*", International Journal of Emerging Technology, Advanced Engineering, Volume 2, Issue 9, September 2012.

[4] RezaMortezaei, Mohsen Ebrahimi Moghaddam, 2010, "*A New Lossless Watermarking Scheme Based On fuzzy integral and DCT domain"*,International Conference on Electronics and Information Engineering, 2010.

[5] Charu Agarwal, Anurag Mishra,*"A Novel Image Watermarking Technique Using Fuzzy-BP Network",* Sixth International Conference on Intelligent Information Hiding and Multimedia Signal Processing, 2010.

[6] Nizar Sakr, Jiying Zhao, and Voicu Groza, "*Dynamic Fuzzy Logic Approach to Adaptive HVS-based Watermarking",*International Workshop on Haptic Audio Visual Environments and their Applications Ottawa, Ontario, Canada, 1–2 October, 2005.

[7] Srinivasa Rao Dammavalam, Seetha Maddala, Krishna Prasad "*Quality Assessment Of Pixel-Level Image Fusion Using Fuzzy Logic*", International Journal on Soft Computing, Vol.3, February 2012.

[8] Vaishali S. Jabade, Sachin R. Gengaje, *"Logo based Image Copyright Protection using Discrete Wavelet Transform and Fuzzy Inference System",* International Journal of Computer Applications, Volume 58, pp.22-28, November 2012.

[9] B.Jagadeesh, P.Rajesh Kumar, P.Chenna Reddy, *"Genetic Algorithm approach for Singular Value Decomposition and Quantization based Digital Image Watermarking",* International Journal of Engineering Research and Applications (IJERA), Vol. 2, pp.1229-1235, Apr 2012.

[10] Mandeep Singh Saini, Venkata Kranthi B, Gursharanjeet Singh Kalra, "*Comparative Analysis of Digital Image Watermarking Techniques in Frequency Domain using MATLAB SIMULINK*", International Journal of Engineering Research and Applications, Vol. 2, pp.1136-1141, Jun 2012.

[11] Xie Bin, 2011, *"A Blind Watermarking Algorithm Based on Color Space Conversion in DCT Domain",* International Journal of Computer Applications,2010.