HVS based Robust Image Watermarking in DCT Domain using Neural Networks

B.Jagadeesh, P.Jaganmohan and M.AppalaRaju

Abstract: An algorithm based on Discrete Cosine Transform (DCT) and Back Propagation Neural Network (BPNN) using Human Visual System (HVS) is proposed in this paper. Neural networks are used in embedding the watermark and trained network is used in extracting the watermark. Neural networks adapt embedding strength to this algorithm. This algorithm is robust to several attacks. An invisible, imperceptible and semi-blind approach is proposed. Performance of Back Propagation Neural Network is compared with Generalized Regression Neural Network (GRNN) in terms of Peak Signal to Noise Ratio (PSNR) and Normalized Cross Correlation (NCC), which are measures of imperceptibility and robustness of proposed algorithm.

Keywords: Back Propagation Neural Network, Discrete Cosine Transform, Generalized Regression Neural Network, Human Visual System.

I. INTRODUCTION

Image watermarking is a method in which some information is stored in an image known as cover image or host image. This information can be in the form of text or image. This can be retrieved in extraction process. Watermarking methods can classified as visible, invisible; fragile, semi-fragile, robust; perceptible, imperceptible; blind, semi blind, non-blind. Artificial Intelligence techniques are adapted to improve efficiency of image watermarking algorithms while embedding and extracting the watermark.

In this paper artificial neural networks are used for embedding watermark and trained network is used in extracting the watermark. Neural networks adapt embedding strength to this algorithm.

Sameh Oueslati, Adnene Cherif, Bassel Solaimane, proposed a method a method based on DCT and BPNN using HVS. This paper presents an algorithm by choosing two coefficients instead of one coefficient proposed in method [1]. Performance of BPNN is compared with another widely used neural network GRNN.

BPNN has limitations such as slow convergence to the required value and large amount of information may not be trained properly. In such cases other networks like GRNN can be used to solve the problem. In this paper, the data sets used are not that much large, hence GRNN may not show superior performance over BPNN.

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The paper is organized as follows: In section 2 Preliminaries about Discrete Cosine Transform, Human Visual System, Back Propagation Neural Network are described. Section 3 explains the proposed watermarking method. Experimental results are shown in section 4. The conclusions are specified in section 5.

II. 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 imperceptibility problems, embedding into higher frequency coefficients 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

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

$0 \le p \le M\text{-}1,\ 0 \le q \le N\text{-}1$

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

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

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

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

B. The Human Visual System (HVS)

Human eye is less sensitive to particular portions of an image. HVS parameters such as luminous sensitivity, texture sensitivity and frequency sensitivity of an image can be used in digital image watermarking.

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

$$LS_k = (V_{DC,k})/(MV_{DC}) \ldots\ldots\ldots\ldots\ldots[5]$$

$V_{DC,k}$ 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 formula

$$T_k = V_k(x,y)/Q(x,y) \ldots\ldots\ldots\ldots\ldots\ldots..[6]$$

Where (x, y) represents the location in the k^{th} block, Q(x,y) is the JPEG quantization table given as [12]

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

C. Back Propagation Neural Network (BPNN)

A neural network is a highly parallelized dynamic system with a directed graph topology which can receive the output data by means of response of its state on the input nodes. These are intended to abstract and model some of the functionality of the human nervous system in an attempt to partially capture some of its computational strengths. Neural networks are broadly two types, Feed forward and Feedback networks. Back propagation network is a feed forward network. In BPNN the errors are back propagated to the input layer. The back propagation network with input, hidden and output layers is shown in Fig 1.

BPNN has excellent nonlinear approximation capability. It has capability to establish the connection between original wavelet coefficients and the watermarked wavelet coefficients by adjusting the neural network weights and bias before and after embedding watermark. Owning to use of neural network, watermark can be extracted without the host signal and therefore reduce the boundary in practical applications.

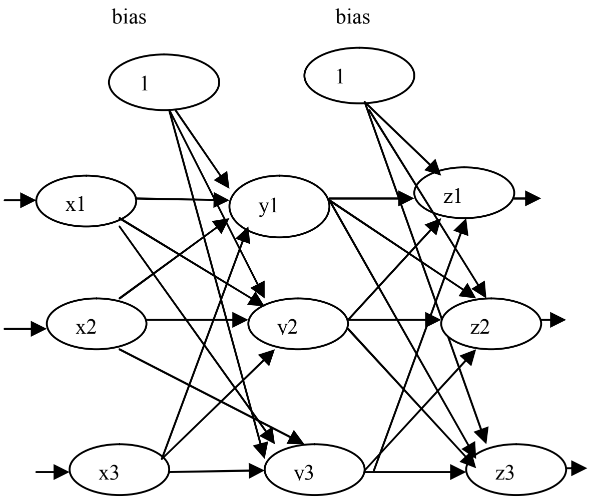


Fig 1: 3 Layered Back Propagation Neural Network

The embedded technique using frequency domain is introduced in this paper, and in order to get better robustness, neural network is introduced, because it can totally approximate any complex non-linear relationship. Thus the BPNN model can illustrate the relationship among the selected wavelet packet coefficients and their neighbourhoods well.

III. PROPOSED METHOD

A. Watermark Embedding using BPNN

The procedure for embedding the watermark is:

1. The host image is of size 512x512 gray level image.
2. The binary image of size 32x32 is chosen as watermark.
3. Host image is divided into 8x8 non overlapping blocks and DCT is applied to the 4096 blocks.
4. 1024 blocks are selected based on their mean values (in descending order).
5. The selected block numbers is provided as secret key1 that is used for extraction of watermark.
6. HVS parameters (luminous sensitivity & texture sensitivity) values of these blocks are computed and fed to BPNN as input vector.
7. Based on HVS properties, a middle frequency coefficient is chosen in every block and fed to BPNN as target vector.
8. Two coefficients (c1, c2) from each block are chosen for embedding watermark.

9. The position of these two coefficients can be considered as secret key2.
10. Based on watermark bit sequence, arrange co-efficient values as follows

    a. if wmk bit is '0' then make c1>c2
    b. if wmk bit is '1' then make c1<c2

11. Embedding formula is as follows
    a. if wmk bit is '0' then
        i. c1=c1+ (2*α+1)
        ii. c2=c2- (2* α+1)
    b. if wmk bit is '1' then
        i. c1=c1- (2*α+1)
        ii. c2=c2+ (2*α+1)

Where 'α' is adaptive weight of watermark (BPNN output).

B. Watermark Extraction

The watermark extraction process from a watermarked image is:

1. The watermarked image is is divided into 8x8 non overlapping blocks and DCT is applied to the 4096 blocks.
2. Based on the key1, 1024 blocks are selected.
3. For the selected blocks, luminous sensitivity & texture sensitivity values are calculated and fed as input vector to BPNN.
4. By using an extra information and BPNN output watermark can be extracted as follows.

Let d1 & d2 be two matrices of same size (compared to watermark) and representing result of mathematically reverse embedding equation.

if d1>d2 wmk bit is '0' else '1'.

The same algorithm is implemented with Generalized Regression Neural Network. The corresponding results are tabulated and performance of these two networks is analyzed in terms of PSNR and NCC.

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

$$\text{PSNR}=10\log_{10}\left(\frac{\sum_{i=1}^{N}\sum_{j=1}^{N}(F(i,j))^2}{\sum_{i=1}^{N}\sum_{j=1}^{N}(f(i,j)-F(i,j))^2}\right) \quad \ldots\ldots[7]$$

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

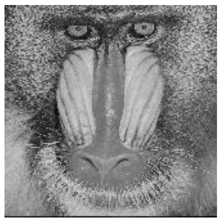
$$\text{NCC}=\left(\frac{\sum_{i=1}^{N}\sum_{j=1}^{N}(w(i,j)-w_{mean})(w'(i,j)-w'_{mean})}{\sqrt{\sum_{i=1}^{N}\sum_{j=1}^{N}(w(i,j)-w_{mean})^2\sum_{i=1}^{N}\sum_{j=1}^{N}(w'(i,j)-w'_{mean})^2}}\right) \ldots\ldots[8]$$

In Eq.(8), w_{mean} and w'_{mean} indicate the mean of the original watermark image and extracted watermark image respectively.

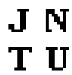
IV. Experimental Results And Discussion

A Gray MANDRILL image of size 512x512 is chosen as host image. A Binary Logo of size 32x32 with letters JNTU is chosen as watermark.

Host image and watermark are shown below.



MANDRILL

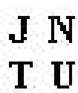


WATERMARK

Watermarked MANDRILL image and extracted watermark are shown below.

Watermarked image

(PSNR=46.59dB)



Extracted watermark

(NCC=0.9907)

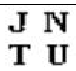
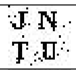
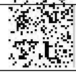
The experimental results obtained are shown in Tables as follows. The PSNR and NCC values obtained by using Sameh Oueslati et.al method and the Proposed Method for various attacks are provided in Table 1.

All the attacks were tested using MATLAB 7.8.0. Proposed algorithm based on BPNN is robust to several attacks such as row-column blanking, copying; smoothing(blurring), sharpening; low pass filtering, median filtering; JPEG compression; intensity transformation, gamma correction; histogram equalization (image contrast attack); resizing and bit plane removal. It is not robust to rotation, cropping and speckle noise. GRNN based method is robust to several attacks such as row-column blanking, copying; smoothing(blurring), sharpening; JPEG compression; intensity transformation, gamma correction,histogram equalization (image contrast attack) and bit plane removal. It is not robust to low pass filtering, median filtering and resizing.

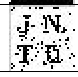
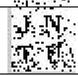
TABLE.1 THE PSNR AND NCC VALUES FOR THE SAMEH OUESLATI ET.AL METHOD AND THE PROPOSED METHOD FOR VARIOUS ATTACKS

Type of Attack	Sameh Oueslati et.al Method(BPNN)		Proposed Method using BPNN		Proposed Method using GRNN	
	PSNR (dB)	NCC	PSNR (dB)	NCC	PSNR (dB)	NCC
No Attack	64.31	0.9059	46.59	0.9861	46.59	0.9907
Row Column Blanking	30.40	0.3466	30.30	0.8142	30.30	0.8669
Row Column Copying	37.72	0.2565	37.20	0.8310	37.21	0.8244
Rotation Anticlockwise Clockwise	27.12 27.41	0.0352 0.1026	27.09 27.38	0.2990 0.2828	27.09 27.38	0.7761 0.7928
JPEG Attack	48.30	0.8344	44.42	0.9861	44.42	0.8904
Low Pass Filtering	29.31	0.0156	29.29	0.6510	29.29	0.4863
Salt & Pepper Noise	42.13	0.2416	40.72	0.8760	40.20	0.8399
Speckle Noise	41.47	0.1969	40.33	0.2557	40.33	0.6568
Cropping	17.84	0.0274	17.83	0.2235	17.83	0.7385
Median Filtering	29.79	0.0125	29.76	0.5189	29.76	0.3627
Re Sizing	29.68	0.0217	29.66	0.5679	29.66	0.3045
Gamma Correction	19.01	0.2292	19.00	0.7478	19.00	0.8675
Bit Plane Removal	50.91	0.6715	45.32	0.8948	45.31	0.8857
Image Contrast Attack	23.64	0.0877	23.58	0.8442	23.58	0.8580
Blurring	31.09	0.0306	31.04	0.5587	31.04	0.6892
Sharpening	21.14	0.0731	21.11	0.8182	21.11	0.8012
Intensity Transformation	25.72	0.1186	25.60	0.9328	25.60	0.8811

JPEG Attack: for various quality factors, extracted watermark is obtained and tabulated below.

JPEG Quality Factor	Extracted Watermark	NCC
95		0.9861
90		0.8516
85		0.5605
80		0.4165

Gamma Correction: for various gamma values, extracted watermark is obtained and tabulated below.

Gamma Correction Value	Extracted Watermark	NCC
γ=0.2		0.7501
γ=0.9		0.6884
γ=2		0.7478
γ=3		0.5739

V. CONCLUSIONS

An algorithm based on DCT, HVS and BPNN is proposed in this paper. Performance of BPNN is compared with GRNN. This algorithm is semi-blind, invisible and imperceptible (can be interpreted from PSNR values) .

Experimental results (NCC) show that this is robust to various attacks and efficient as compared to Sameh Oueslati et.al method [1].

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