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Fuzzy-Neuro based Robust Digital Image Watermarking Technique

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Abstract: The major source of communication in present day word is digital media (multimedia or digital images), as digital media can be easily manipulated, protection of data by legitimate means becomes difficult. Watermarking offers a better solution to this problem. Over the years many have proposed better watermarking algorithms for copy right protection, i.e. increasing the robustness of the watermarked data. Artificial intelligence techniques for watermarking have proven to offer better robustness and give a blind watermarking approach. In this paper, a blind and robust image watermarking algorithm is proposed using hybrid intelligence techniques i.e. combination of Artificial Neural Networks and Fuzzy Logic. The proposed method uses Fuzzy-Neuro system to offer combined advantages of both Artificial Neural Networks and Fuzzy Logic the input to the system is given from the Human Visual System (HVS) model and the output thus generated is used in watermark embedding. The proposed system gives better robustness against many image processing attacks like rotation, sharpening, image contrast attacks, etc.

Key words: Robustness, Artificial Neural Networks, Fuzzy Logic, Fuzzy-Neuro system, Human Visual System.

I. INTRODUCTION

Editing of digital data is easy because one can access the locations that need to be altered; copying is simple over the internet, so authentication of the data is becoming more complex due it. The easy transmission and manipulation of digital data became a threat for several people [1].One solution for this problem is to restrict the access to the data using some encryption techniques. However this would not provide complete solution as the encrypted data can be decrypted and can be manipulated. The above stated problems can be solved by hiding some data into the digital data, which can be extracted later to prove the proof of ownership. This idea is implemented in currency notes embedded with the watermark which is used to check the authenticity of the note. The same “watermarking” concept may be used in multimedia digital contents for originality the authenticity of the data.

Digital image watermarking is a method of hiding a message in an image. In watermarking the watermark is added to the host data in such a way that it remains present in it. It is a concept closely related to steganography, in a way they both hide a message inside a digital signal. However, what separates them is their goal. Watermarking hide a message related to the actual content of the digital signal, where as in steganography the digital signal has no relation to the message, and it is only used as a cover to hide its existence, watermarking mainly concentrates on the robustness of the data hidden inside the cover. Embedding of the watermark into a host image can be done in three ways, first by placing the watermark into the host image directly as we are embedding the watermark into the pixels directly this method is called as spatial domain method. Second we can transform the host image values into its frequency domain coefficients and embed the watermark into the coefficients this method is called as transform domain method, third type of method make use of both the approaches for embedding watermark this is called as hybrid domain method. Each method has its own merits and demerits based on the application embedding method are chosen. There are three kinds of detection types at the receiver, first it is blind method where the receiver do not know any information about the host image, second it is the semi blind method in this the receiver has some information about the host image and last it is the non-blind method where the receiver need the host image to extract the watermark. In this paper blind method is used.

This paper is organized as following: Section 2 explains about the related work. Section 3 describes the Discrete Cosine Transform, basic model of Human Visual System, Fuzzy-Neuro system, Back Propagation Neural Networks and Fuzzy Inference System. This is followed by Section 4 that explains the embedding and extraction of digital image watermarking. In Section 5, the experimental results are given for various image processing attacks. The conclusions are specified in section 6.

II. LITERATURE SURVEY

Digital image watermarking techniques which are based on artificial intelligence [2-6] are available in the literature. Throughout the years many have proposed algorithms for watermarking some of them are Mehul S Raval et al [2] proposed an algorithm using Fuzzy-Neural system along with super resolution, it uses both Neural Network and Fuzzy Logic for watermark extraction.Charu Agrawal et al. [3] proposed an algorithm based on Fuzzy-Neural system using Discrete Cosine Transform (DCT), it uses 27 fuzzy-bp rules to embed and extract the watermark. Nallagarla et al. [4] proposed a watermarking method using Back Propagation Neural Network (BPNN) and Fuzzy Inference System (FIS), and compared both the techniques for robustness against different image

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processing attacks. Qiao Baoming et al. [5] proposed a watermarking method using Back Propagation Neural Network (BPNN) and Discrete Wavelet Transform (DWT). 2-level DWT is applied to host image. Sameh Oueslati et al. [6] proposed an adaptive watermarking algorithm performed in the wavelet domain which exploits Human Visual System (HVS) and a Fuzzy Inference System (FIS) for medical images.

Mehul S Raval et al [2] proposed a novel watermarking algorithm which uses Fuzzy-Neuro system, in this method a binary watermark is embedded into a gray scale image, Fuzzy Inference System (FIS) is used for obtaining the watermark weights and Neural Network has been trained to DWT approximate band coefficients, in which the watermark is embedded. At extraction side the Neural Network output and FIS out is compared to obtain the watermark bits.

In the proposed method, single mid band coefficients from each 8x8 block is selected and embedding procedure is performed. When extraction of the watermark the mid band coefficient is compared with a threshold and determined whether the extracted bit is 0 or 1.

III. 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 [7]

$$Bpq= \alpha p \alpha q \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} Amn\left(\frac{\cos(2\pi m+1)p}{2M}\right)\left(\frac{\cos(2\pi n+1)q}{2N}\right),$$

For, $0 \le p \le M-1$, $0 \le q \le N-1$ (1)

$$\alpha p = \begin{cases} \frac{1}{\sqrt{M}} , & p = 0 \\ \frac{2}{\sqrt{M}} , & 1 \le p \le M-1 \end{cases} \quad (2)$$

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

p and q varies from 0 to M-1 ,0 to N-1 respectively ,where M*N is size of original image. The DCT is invertible transform and its inverse is given by

$$Amn= \alpha p \alpha q \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} Bpq \left(\frac{\cos(2\pi m+1)p}{2M}\right)\left(\frac{\cos(2\pi n+1)q}{2N}\right) \quad (4)$$

B. *Human Visual System*

The sensitivity of human eye to various spatial frequencies is determined by the frequency sensitivity. The effect of the imperceptibility to noise on a constant background is calculated by luminance sensitivity. We focus here on the sensitivity of brightness, frequency, texture and edge. The HVS model used in this work has been suggested in [6,8]. This model is also used in many insertion algorithm and detection of the watermark.

1. *Luminance sensitivity (L_k):*

Brightness masking proves to be effective towards detectable noise thresholds on a constant background. The brighter the background is, the larger the size of embedded signal. The luminance sensitivity is estimated by the following formula:

$$L_k=X_{DC,k}/\text{mean}(X_{DC}) \quad (5)$$

Where $X_{DC,k}$, is the DC coefficient of the DCT of the k^{th}block, X_{DC} is the mean value of all DC coefficients of a specific image.

2. *Frequency sensitivity (F_k):*

If we divide the image into 8x8 blocks and DCT is applied to each block, there will be 8x8 matrix of DCT coefficients for each block. This matrix is separated into three areas, high frequency (H), low frequency (L), and medium frequency (M). The 2D DCT matrix's top left comer represents low frequency coefficient while the bottom right comer is the high frequency coefficients. The Energy content of image is placed in low frequency DCT coefficients. Image can be distorted if low frequency coefficients are modified. On the other hand if high frequency coefficients are modified by watermark causes the watermark to be removed from the image after the image is compression, since compression process causes the DCT coefficients to be removed in high frequencies. So the medium frequency coefficients are used to embed the watermark.

3. *Edge Sensitivity (E_k):*

As the edge is detected within the image using threshold operation. The Matlab image processing toolbox implements graythresh() routine which computes the block threshold using histogram – based [7]. The implementation of this routine is as follows:

$$E_k = \text{graythresh}(f) \quad (6)$$

where f is the host sub-image (block) in question and T is the computed threshold value.

4. *Threshold Sensitivity (T_k):*

The image is divided into smooth, texture, and edge blocks. The texture sensitivity can be estimated by quantizing the DCT coefficients of an Image using the jpeg quantization table. The result is rounded to nearest integers. The number of non zero coefficients is then computed, this method can be calculated by

$$T_k = \sum_{x,y=1}^{N} cond\left(\frac{Vk(x,y)}{Q(x,y)}\right) \quad (7)$$

Where (x,y) is location in k^{th} block, cond(R) gives rounded value to 1 if value $\neq 0$, else 0.

C. *Fuzzy-Neuro system*

Every intelligent technique has particular computational properties (e.g. ability to learn, explanation of decisions) that make them suited for particular problems and not for others. Therefore fusion of two or more techniques can bring out the best quality from each technique and give a system suitable for all scenarios. Fusion of Fuzzy Logic and Neural Networks overcomes their individual

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drawbacks, and benefits from each other's advantages Fuzzy-Neuro systems are of two types a) Fuzzy systems for designing neural networks, b) Neural networks for designing fuzzy systems. In the present paper Fuzzy systems for designing neural networks is used. By using Neural Networks and Fuzzy Logic combination, the chances of making the test inputs equal to the original trained input increases, for the test inputs similar simulated outputs can be obtained, same as the original outputs used at the embedding block, by using Fuzzy-Neuro combination the simulation time for the test inputs can be reduced.

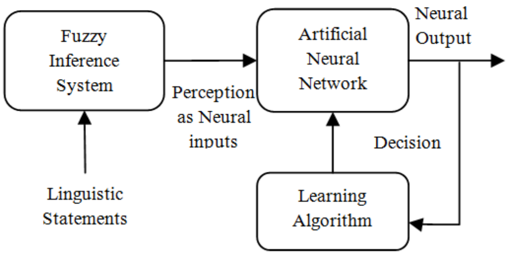

Fig 1: Fuzzy System for designing Neural Network

D. Back Propagation Neural Network

For simulation of biology neural computation neural networks are introduced. It has self-learning, self-organizing, etc. and has great compatibility with Human Visual System [10]. Therefore, the selected Neural Network in this paper is a feed-forward Neural Network. There are three hidden layers along with an input layer, and an output layer. The desired outputs of Neural Network are the approximate DCT coefficients. Figure shows the architecture of this network. The first layer is to present the input variables to the network. Threshold sensitivity parameter is an input variable to the network, along with Fuzzy Inference System output. These inputs are then fed to a hidden layer using tan sigmoid activation functions (output in the range frequency sensitivity values); this is then fed to the output layer. During training, error information is given back to the network and used to update link weights. It repeats learning many times for every example in the training set until it has minimized the output errors. This system does not fully replace humans; they are still needed to generate the training data and should check the results periodically to ensure the neural network is working at peak performance.

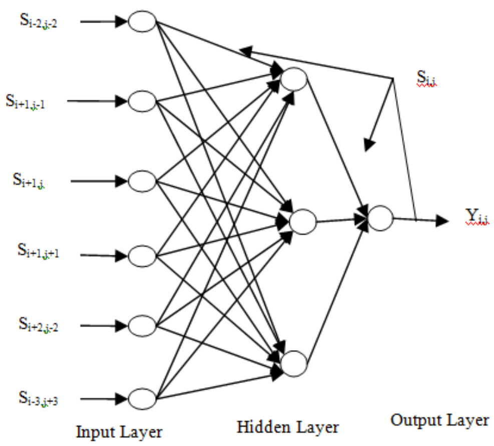

Fig 2: Back Propagation Neural Network

E. Fuzzy Inference Engine

Fuzzy logic is a form of many-valued logic; it deals with reasoning that is inexact rather than exact. Compared to traditional binary sets fuzzy logic variables may have a truth value that ranges in degree between 0 and 1.In fuzzy logic, exact reasoning is viewed as a limiting case of approximate reasoning [9].FIS performs the mapping between given input and output without the use of mathematical modeling concepts 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. The human visual system parameters luminous sensitivity and Edge sensitivity are given as inputs to the Fuzzy inference system. Fuzzy Inference System technique is used to classify blocks which are more suitable to embed watermark based on fuzzy membership value.

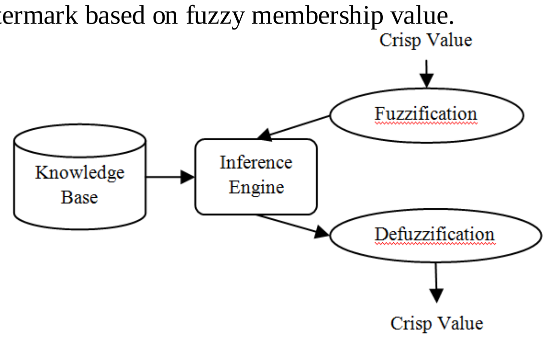

Fig 3: Fuzzy Inference System

IV. PROPOSED METHOD

Split the host image of size 512x512 color image into its Red, Green, Blue color planes, divide the green plane into non overlapping blocks and apply DCT for each 8x8 block, calculate the HVS parameters edge sensitivity, luminous sensitivity, frequency sensitivity, texture sensitivity give the luminous and edge sensitivity as inputs to the Fuzzy Inference System (FIS). Train the neural network to frequency sensitivity values, with input from FIS output and Texture sensitivity these values are used in embedding process by doing so the frequency domain coefficients of the sub image are not varied by an unknown quantity instead replaced by one of the frequency sensitivity values, thus the blocks coefficients values remain unchanged even after inverse DCT is applied. At the extraction side the trained neural network along with FIS is used so as to obtain a similar set of data which is used to embed the watermark into the host image and by performing the inverse operation the watermark is extracted from the watermarked image.

A. Embedding algorithm:

1) Extract the green plane from the input cover image of size 512x512.
2) Divide into 8x8 non overlapping sub images and take DCT for each sub image.
3) Calculate HVS parameters for each sub image. Luminous, Texture, Edge, Frequency sensitivity.
4) Calculate FIS values for the input Luminous, Edge sensitivity from the rule base.

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5) For calculated FIS output and Texture sensitivity as input to the neural network train it for the frequency sensitivity values.
6) Take a binary watermark of size 64x64 for each sub image embed single the watermark bit by
7) If w(i)==1

X'=y(i)+15

else

X'=y(i)-15

X'= new DCT coefficients
y(i) = neural network output
w(i) = watermark bit

1) Take inverse DCT for each sub image and recombine them all to form the original image, and combine with the red the blue plane to form the color image.

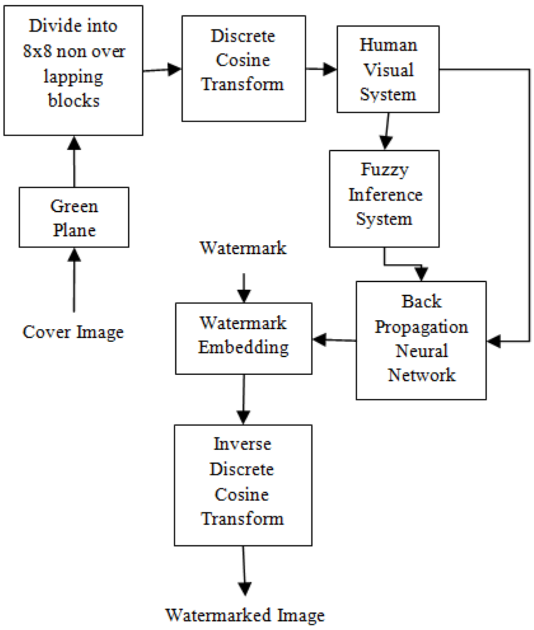

Fig 4: Embedding Block diagram

B. Extraction algorithm:

1) Extract the green plane from the image of size 512x512.
2) Divide into 8x8 non overlapping sub images and take DCT for each sub image.
3) Calculate HVS parameters for each sub image. Luminous, Texture, Edge, Frequency sensitivity.
4) Calculate FIS values for the input Luminous, Edge sensitivity from the rule base.
5) For calculated FIS output and Texture sensitivity as input to the neural network and simulate it.
6) Sort the output of neural network in descending order..
7) Take each sub block and perform
8) If X"-y1(i)>0

w'(i)==1

else

w'(i)==1

X" = DCT coefficients
y(i) = neural network output
w'(i) = watermark bit

1) Rearrange the watermark bits and calculate cross correlation value for original and extracted watermark.

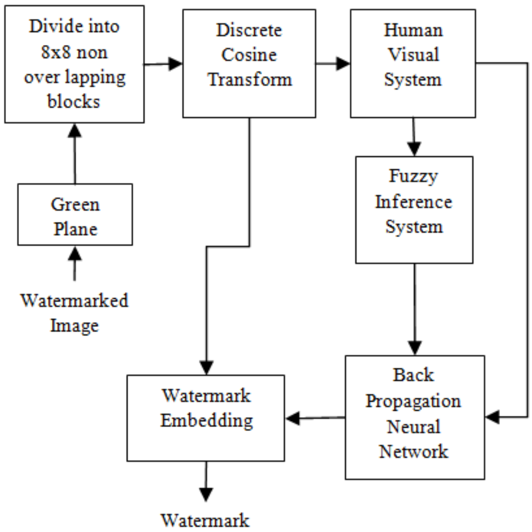

Figure 5: Extraction Block diagram

V. EXPERIMENTAL RESULTS AND DISCUSSIONS

Experiments are performed to evaluate the effectiveness of the method on host 512x512 pixels color image 'LENA', shown below.

Fig 6: LENA 512x512 size color image

The watermark image is 64x64 pixels, a logo having the letters 'ECE' as shown below. The watermark

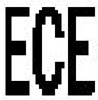

Fig 7: Binary Watermark "ECE" 64x64 sizes

Fig 8: Watermarked LENA image (PSNR 42.12 dB)

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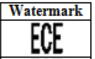
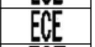
is a binary image having only single color either black or white and while considering the pixel values for embedding black pixels are considered as 0 and white pixels are considered as 1.

The simulated results show that the proposed algorithm is robust against many image processing attacks. Different image processing attacks are applied to the watermarked image; and watermark is extracted from the watermarked image. The different image processing attacks applied to the watermarked image include row column blanking, random rows/columns in the image are made zero, in the present result rows 372, 508, 110, columns 240,452,111 are made zero. In the rotation attack the watermarked image is rotated by angle 10 degrees. All the edges in the image are enhanced in sharpening attack. In histogram equalization attack the watermarked image is enhanced using histogram equalization method and watermark is retrieved from that enhanced image. Watermarked image is passed through low pass filter, median filter for filtering attack, by filtering the image is smoothened, and from this image watermark is extracted. The experimental results are compared with the algorithm proposed by Mehul S Raval et al [2], the Table I shows the Normalized Cross Correlation values. The Normalized Cross correlation (NCC) is used as a metric to compare the robustness is summarized in Table II.

Table I. Comparison of Proposed method with Fuzzy-Neuro based method

S.No.	Attack	Mehul S Raval et al [2]	Proposed Method
1	Row/Column Blanking	0.7919	0.9979
2	Row/Column Copy	0.8696	0.9942
3	Low Pass Filtering	0.7259	0.8808
4	Salt and Pepper noise	0.9087	0.8704
5	Rotation	0.9225	0.9085
6	Blurring	0.9083	0.9504
7	Bit Plane Removal	0.5640	1
8	Gaussian Noise	0.7579	0.9473

Table II. Experimental Results

S. No.	Attack	NCC	Watermark
1	Bit Plane Removal	1	
2	Sharpening	0.9984	
3	RC Blank	0.9979	
4	Intensity Transformation	0.9974	
5	RC Copying	0.9942	
6	Image Contrast attack	0.9921	
7	Gamma Correction 2	0.9738	
8	Blurring	0.9504	
9	Gaussian Noise	0.9473	
10	Rotation	0.9085	
11	Low Pass Filtering	0.8808	
12	Salt & Pepper	0.8704	
13	Poisson Noise	0.8535	
14	Median Filtering	0.8195	
15	Cropping	0.7922	

The below shown bar plot for different image processing attacks applied on the watermarked image obtained by the proposed method and the algorithm proposed by Mehul S Raval et al [2], from the graph it is evident that the proposed method is robust to several image processing attacks. Fig 9. Shows the bar plot.

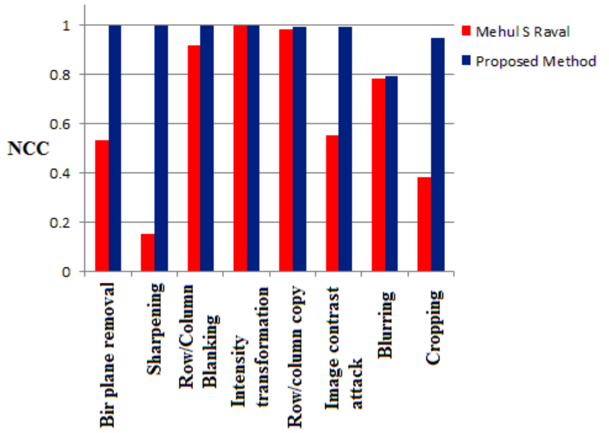


Fig 9. Bar plot for NCC values for proposed method and [2]

VI. CONCLUSIONS

In this paper, a robust blind watermarking algorithm based on Fuzzy-Neuro system is proposed. The watermark bits are embedded into a coefficient in the mid frequency band of the DCT coefficients such that the host image is not distorted so as to yields a better PSNR value. In the embedding process the Fuzzy-Neuro system is used to remember the watermark embedding weights, this network is used at the extraction process to get back the watermark bits. Experimental results show that the proposed algorithm is robust to many image processing attacks and for imperceptibility it yields good PSNR value.

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