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Robust Digital Image Watermarking in Discrete Wavelet Transform Domain using Back Propagation Neural Networks

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ABSTRACT: Digital Image Watermarking offers copyright protection of images by inserting the digital information called watermark. The inserted data can be recovered from the image for recognizing the copyright owner. An algorithm centred on Discrete Wavelet Transform (DWT) and Back Propagation Neural Network (BPNN) is projected in this paper. Neural networks are used in embedding the watermark. Neural networks adapt embedding strength to this algorithm. This algorithm is robust to several attacks viz., Low Pass Filtering, Resizing, Row-Column Copying, Row-Column blanking, Rotation, JPEG, Salt and Pepper Noise, Cropping, Median Filtering, Bit Plane Removal, Blurring, etc. An invisible, imperceptible and oblivious approach is proposed.

Key Words: Discrete Wavelet Transform, Back Propagation Neural Network, Imperceptible, Robust, Blind.

1 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 [1]. Watermarking methods can be classified as visible, invisible; fragile, semi-fragile, robust; perceptible, imperceptible; blind, semi blind, non-blind.

In order to enhance the imperceptibility of watermarked image and robustness of watermark, many scholars have researched Artificial Intelligence methods.There are several Artificial Intelligence techniques such as Genetic Algorithms, Fuzzy Logic and Artificial Neural Networks etc. In this work, Artificial Neural Networks are used in embedding and extracting watermark. Artificial Neural Networks can be classified as Supervised and Unsupervised networks based on their learning rules. A widely used network Back Propagation Neural Network is used in this work.

Qiao Baoming et al. [2] proposed a watermarking method using Back Propagation Neural Network (BPNN) and Discrete Wavelet Transform (DWT). 2-level DWT is applied to host image. Blocks are selected based on standard deviation values. Block values are fed to network as input and target vectors. Trained network and extra information is used in extracting the watermark.

Sameh Oueslati et al. [3] proposed a HVS (Human Visual System) based watermarking method using Back Propagation Neural Network (BPNN) and Discrete Cosine Transform (DCT). This method uses Back Propagation Neural Network for embedding watermark. HVS parameters fed to neural network as input and target vectors. The watermark is reconstructed by using the trained network. Image watermarking algorithms using Artificial Neural Networks [4,5,6,7,8,9,10] are available in the literature.

In Qiao Baoming et al. [2] method one coefficient from the selected block is modified. This is centred on DWT and Back Propagation Neural Network (BPNN). In proposed method, instead of one coefficient, two coefficients are chosen and modified. Performance of watermarking algorithm is assessed in terms of Peak Signal to Noise Ratio (PSNR) and Normalized Cross Correlation (NCC).

The rest of the paper is arranged as follows: In section 2 Preliminaries about Discrete Wavelet Transform and Back Propagation Neural Network is described. The proposed watermarking method is given in Section 3. Experimental results are revealed in section 4. Conclusions are specified in section 5.

2 PRELIMINARIES

2.1 Discrete Wavelet Transformation

A 2-D Discrete Wavelet Transform maps an image from spatial domain to the transform domain by passing the image through a sequence of low-pass filters and high-pass filters. The filters output corresponds to multi-resolution sub-bands each possessing exceptional characteristics making it apt for explicit digital image processing applications. Each level of decomposition generates four bands namely LL, HL, LH, and HH. Multiple sub-band decomposition is possible with discrete wavelet transforms. The two level of decomposition is shown in Figure 1.

2.2 Back Propagation Neural Network (BPNN)

A neural network is an extremely parallelized self-motivated system with a targeted graph topology which receives the output data by means of response of its state on the input nodes. These are projected to abstract and model some of

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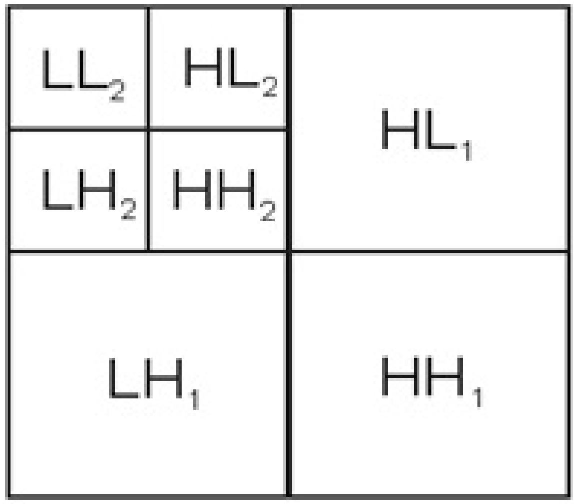

Figure 1: DWT decomposition with two levels

the functionalities of the human nervous system in an effort to partly capture some of its computational strengths. Feed forward and Feedback networks are two types of Neural networks. Back propagation network is a feed forward network. The errors are back propagated to the input layer in BPNN. Figure 2 shows the back propagation network with input, hidden and output layers.

BPNN has excellent nonlinear approximation capability. It has capability to determine the connection between primary wavelet coefficients and the watermarked wavelet coefficients by altering neural network weights and bias before and after inserting watermark.

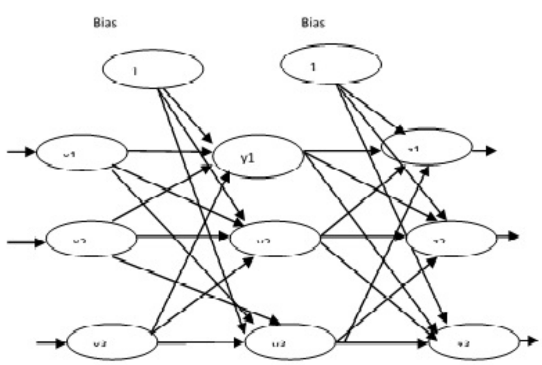

Figure 2: 3 Layered Back Propagation Neural Network

3 PROPOSED METHOD

3.1 Watermark Embedding using BPNN:

1. The host image is of size 512x512 gray level image.
2. The binary image of size 32x32 is chosen as watermark.
3. 2-Level DWT is applied to host image and cA2 is divided into 3x3 non-overlapping blocks.
4. 1024 blocks are selected based on their standard deviation values (in ascending order).
5. Selected block numbers is provided as secret key1 that is used for extraction of watermark.
6. Centre value in each block is provided to BPNN as target vector, and neighbouring eight elements are fed as input vector.
7. Two coefficients (c1, c2) from each block are chosen for embedding watermark.
8. The position of these two coefficients can be considered as secret key2.
9. Based on watermark bit sequence, arrange co-efficient values as follows
   - i. if wmk bit is 0 then make c1 $>$c2
   - ii. if wmk bit is 1 then make c1 $<$c2

10. Embedding formula is as follows

i. if wmk bit is 0 then

$$c1 = c1 + (2 * \alpha + 1) and c2 = c2 - (2 * \alpha + 1) \tag{1}$$

ii. if wmk bit is 1 then

$$c1 = c1 - (2 * \alpha + 1) and c2 = c2 + (2 * \alpha + 1) \tag{2}$$

Where alpha is adaptive weight of watermark (BPNN output).

3.2 Watermark Extraction using BPNN:

1. Two-Level DWT is applied to watermarked image and cA2 is divided into 3x3 non-overlapping blocks.
2. Based on the key1, 1024 blocks are selected.
3. For the selected blocks, Centre value in each block is provided to BPNN as target vector, and neighbouring eight elements are fed as input vector.
4. By using an extra information and BPNN output, watermark can be extracted as follows

i. Let c1 & c2 be two matrices of same size (compared to watermark) and representing result of mathematically reverse embedding equation

ii. if c1 $>$c2 wmk bit is 0 else 1.

The performance metrics exercised to verify the suggested algorithm are Normalized Cross correlation (NCC) and the peak signal to noise ratio (PSNR). Let host image be f(i,j) and the equivalent watermarked image be F(i,j), then PSNR in dB is given by:

$$PSNR = 10 \log_{10} \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} (F(i,j))^2}{\sum_{i=1}^{N} \sum_{j=1}^{N} (f(i,j) - F(i,j))^2} \tag{3}$$

Let watermark image signal be denoted by w(i,j) and the extracted watermark image be denoted by w'(i,j) then, NC is defined as :

$$NC = \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} (w(i,j) - w_{mean})(w'(i,j) - w'_{mean})}{\sqrt{\sum_{i=1}^{N} \sum_{j=1}^{N} (w(i,j) - w_{mean})^2 \sum_{i=1}^{N} \sum_{j=1}^{N} (w'(i,j) - w'_{mean})^2}} \tag{4}$$

In Eq.(4), Wmean and W'mean denote the mean of the original watermark image signal and extracted watermark image signal respectively.

4 Experimental Results

Experimentations are executed to assess the efficiency of the scheme using host image MANDRILL as shown in Figure 3. The dimension of the host image is 512 x 512 pixels. The watermark image signal is of size 32 x 32 pixels which is a logo having the letters GVPCOE as shown in Figure 4. Figure 5 shows the watermarked MANDRILL image. Different attacks exercised to assess the robustness of the watermark are Rotation, JPEG, Salt and Pepper Noise, Cropping, Median Filtering, Bit Plane Removal, Blurring, etc. All the above mentioned attacks were assessed using MATLAB 7.8.0. The performance metrics used to compare the robustness and imperceptibility are Normalized Cross correlation (NC) and the Peak signal to noise ratio respectively and these are revieweded in Table 1. The extracted watermark images from the watermarked image are shown in Table 2.The visual quality of the watermarked image is found to be generally acceptable for PSNR values exceeding 35dB. The robustness of the algorithm against the various image processing attacks has been validated with high Normalized Cross Correlation (NCC) values. The range for this NCC values are from 0 to 1.

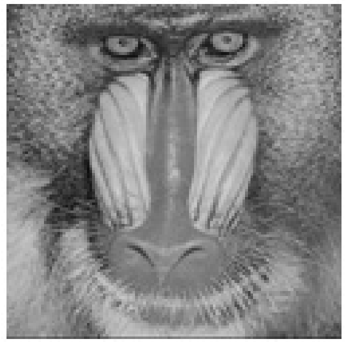

Figure 3: 512x512 pixels Mandrill (Host Image)

Figure 4: Watermark Image

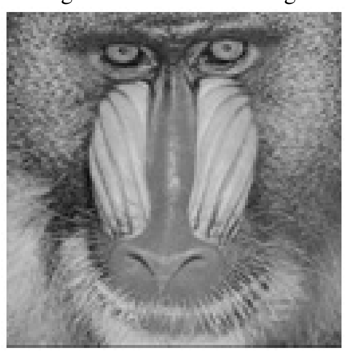

Figure 5: 512x512 pixels Watermarked Mandrill (43.36dB)

Table 1: The PSNR and NCC values of Mandrill image under various attacks

S.No.	Attacks	Qiao Baoming et al. Method		Proposed Method	
		PSNR(dB)	NCC	PSNR(dB)	NCC
1	No Attack	43.44	0.7513	43.36	1
2	Low Pass Filtering (3x3 mask)	29.20	0.0118	29.20	0.6388
3	REsizing(512-256-512)	29.54	0.0746	29.54	0.6387
4	Row-Column blanking	30.20	0.0031	30.19	0.6949
5	Row-Column Copying	36.72	0.0101	36.69	0.8241
6	Rotation	27.04	0.0281	27.33	0.7676
7	JPEG(QF:95)	42.24	0.5240	42.18	0.8588
8	Salt & Pepper Noise(0.001)	39.35	0.0915	39.42	0.8797
9	Croppig	17.83	0.0257	17.83	0.8640
10	Median Filtering	29.66	0.0185	29.66	0.5629
11	Bit Plane Removal	41.18	0.0895	42.69	0.8478
12	Blurring	30.91	0.0505	30.91	0.6995

Table 2: Extracted watermark images from the watermarked image and NCC values

S.No.	Type of Attack	Extracted WAtermark	Normalized Cros correlation
1	Low Pass Filtering (3x3 mask)		0.6388
2	Resizing(512-256-512)		0.6387
3	Row Column Blanking		0.6949
4	Row Column Copying		0.8241
5	Rotation		0.7676
6	Jpeg (QF : 95)		0.8588
7	Salt & Pepper Noise (0.001)		0.8797
8	Cropping		0.8640
9	Median Filtering		0.5629
10	Bit Plane Removal		0.8478
11	Bluring		0.6995

5 Conclusion

An algorithm centred on Discrete Wavelet Transform technique and Back Propagation Neural Network method is suggested in this paper. This algorithm is invisible and imperceptible (can be interpreted from PSNR values). The suggested method is shown to be robust to Rotation, JPEG attack, Resizing, Salt and Pepper Noise, Cropping, Median Filtering, Bit Plane Removal, Blurring attacks, etc. and is efficient compared to Qiao Baoming et al. [2] method.

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