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A Novel Image Watermarking Method Using Discrete Wavelet Transform and Back Propagation Neural Network

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Abstract: ***The copyright protection of digital data became a crucial issue nowadays. Watermarking is one of the powerful solutions, in which a specified signal or image is embedded in digital data that can be extracted or detected later for authentication purpose. In this paper, a new watermarking approach based on wavelet coefficient quantization using back propagation neural network in discrete wavelet transform domain is proposed. The host image is decomposed up to three levels using discrete wavelet transform. The secret image is chosen as a watermark. The back propagation neural network is used while embed and extract the watermark. Peak signal to noise ratio and normalized cross-correlation coefficient are computed to measure the image quality of the proposed technique. Experimental results demonstrate that the proposed watermarking algorithm has good imperceptibility and robustness against several types of attacks, such as salt and pepper, Gaussian and speckle noise addition, compression and rotation.***

Keywords: Back Propagation Neural network, compression, discrete wavelet transform, Image Watermarking, Leven-berg algorithm and Rotation.

1. INTRODUCTION

The transmission of multimedia content became daily routine nowadays and it is necessary to find an effective way to transmit through a variety of networks. Copyright protection of multimedia information has become serious issue due to enormous spreading of broadband networks, copying, and new developments in digital technology. Digital watermarking is considered as one of the popular approaches to protect multimedia data from illegal manipulations [10]. It is one of the approaches of information concealment [8], which inserts separate watermark information in certain digital information without significant degradation [12]. Digital watermarking can be used many applications such as Fingerprinting, Copyright protection, Secret Communication, Copy Control, Broadcast Monitoring and Authentication[4].

Digital image watermarking provides copyright protection to image by hiding appropriate information in host image to declare rightful ownership [1]. An efficient image watermarking method includes watermark generation, embedding, detection and watermark attack. There are mainly five important factors are commonly used to determine quality of watermarking scheme.

1. **Imperceptibility:** imperceptibility is the quality of the original image should not be destroyed by the presence of watermark.[7],[13]
2. **Robustness:** Robustness is a measure of immunity of watermark against attempts to image modification and manipulation.[11]
3. **Capacity:** Capacity includes approaches that make it possible to embed main part of information.[1]
4. **Security:** Security is the ability of the watermark to resist attempts by attacker to remove or destroy it without modifying the original data itself so that unauthorized users cannot read or modify the embedded watermark [17]
5. **Effectiveness:** It means that the watermark extraction process should be simple and fast [1], [2].

According to the domain of watermark insertion, the watermarking schemes divided into two categories. One is spatial domain methods and other one is transform domain methods. There are many techniques have been proposed in the spatial domain like Least Significant Bit(LSB) insertion method, texture block coding method and the patch work method [15]. Spatial domain methods process the location and luminance of the image pixel directly. The LSB method has a drawback that the least significant bits may be destroyed by lossy compression easily. Transform domain method based on special transformations, and process the coefficients in frequency domain to conceal the data. Transform domain methods include, Discrete Cosine Transform (DCT), Fast Fourier Transform (FFT), Discrete Wavelet Transform (DWT), Curvelet Transform (CT) and Counterlet Transform (CLT). In these methods, the watermark is embedded in the high and middle frequency coefficients of the host image. The low frequency coefficients are suppressed by some image operations. Hence, the watermark is not inserted in low frequency coefficients. The transform domain method is more robust than the spatial domain method against compression, filtering, rotation and noise attack etc.

In this paper, a new digital image watermarking scheme to embed the watermark in the cover image is presented. This proposed scheme is based on training Back Propagation Neural Network (BPNN) in the discrete wavelet transform domain. BPNN is implemented for embedding and extracting the watermark. From the results it is observed that the proposed watermark method is invisible and robust to attacks such like compression, rotation and some noise attack.

The rest of this paper is organized as follows: Section 2 describes some related work. In section3, the preliminaries including DWT and neural network in digital watermarking are briefly provided. Section 4 presents the proposed watermarking approach. The experimental results and performance comparisons are given in section 5. Finally, Section 5 concludes this paper followed by relevant references.

2. RELATED WORK

A number of studies have been conducted for watermarking in spatial and frequency domains. In this section, we will briefly review some of the previous work related to this area.

Cheng-Ri. Piao et al. [4] have introduced a new blind watermark embedding and extracting algorithm using HVS and RBF Neural Network. Chenthalir Indra et al. [5] have introduced a system based on Fine Facet Digital Watermark (FFDW) mining from the Color Image Using Neural Networks. Chen Yongq inang et al.[6] presents a DWT domain image watermarking scheme, where genetic algorithm is used to select the fit wavelet coefficients to embed watermarking bits into the cover image. In [19] presents an adaptive image watermarking scheme based on Full Counter Propagation Neural Network (FCNN).Reference [14] proposed a new approach to neural network watermarking for uncompressed video in the wavelet domain. He Xu et al.[9]have developed an adaptive image watermarking algorithm which is based on synthetic human visual system (HVS) characteristic and associative memory function of neural network. Nallagarla Ramamurthy et al. [16] have developed a Digital Image Watermarking Scheme With Back Propagation Neural Network and Fuzzy Logic Approach. The back propagation neural network is implemented to embed and extract the watermark in one method, while the dynamic fuzzy inference system is utilized to generate the watermark weighting function to embed and extract the watermark in the other method. Pao-Ta. Yu et al. [17] developed watermarking techniques based On neural networks for color images, The authors integrating both color image processing and cryptography, to achieve content protection and authentication for color images. Summrina Kanwal Wajid et al. [20] have proposed the robust and imperceptible image watermarking using Full Counter Propagation Neural Network with lesser complexity and easy apprehension. Yanhong Zhang [21] presents a blind watermark embedding and extracting algorithm using HVS and Radial Basis Function Neural Network [RBFN] in DWT Domain. Yonghong Chen et al.[22] presents a blind image watermarking method that embeds watermark messages at different wavelet blocks based on the training of BPNN in wavelet domain.

3. PRELIMINARIES

3.1. Discrete wavelet transform

Discrete wavelet transform (DWT) is one of the promising transformation algorithms for digital image watermarking in frequency domain. DWT provides both spatial and frequency domain description of an image. It is a good mathematical tool for decomposing an image hierarchically [23]. DWT decomposes the image into three spatial directions: horizontal, vertical and diagonal. The multi-resolution of wavelet allows representing an image at more than one resolution level. It divides the image into four sub-bands which are lower resolution approximation image (LL), horizontal (HL), vertical (LH) and diagonal (HH) detail sub-bands [8], [13]. This process of separation can be repeated many times to compute multi-level wavelet decomposition .The LL sub-band is not suitable for the watermark embedding based on HVS model, because it contains more vital information about the image and causes image distortion. In addition, embedding a watermark in the HH sub-band is not suitable, because this sub-band is less robust against some image processing operations. Thus, the appropriate areas for watermark embedding are the mid-frequency sub-bands LH and HL, where acceptable performance of imperceptibility and robustness could be achieved. Figure.1 illustrates the sub-band decomposition of an image using 2D wavelet transform after 3 levels of decomposition. Where, L represents low-pass filter, H be a symbol of high-pass filter. An original image can be decomposed of frequency districts of LH1, HL1, and HH1. The low-frequency region information also can be decomposed into sub-level frequency district information of LL2, LH2, HL2 and HH2. By doing this the original image can be decomposed for *n* level wavelet transformation.

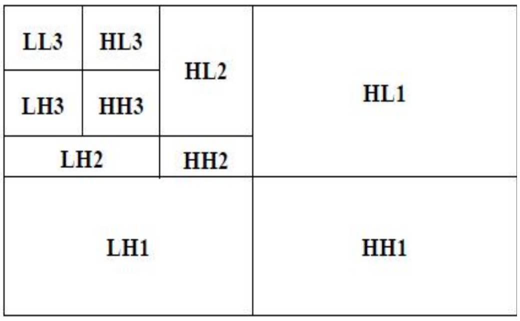


Figure.1. Wavelet decomposition of an image

3.2. Back propagation neural network

Artificial Neural Networks (ANNs) are powerful tools that provide an optimization procedure with high-speed computation. ANNs are massively parallel adaptive networks of simple non liner computing elements called neurons which 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. ANN may be classified to feed-forward and feedback, and supervised or unsupervised for training of each group. Back propagation network is of Feed-

forward Neural Networks (FNN) and most widely used among. It is a supervised learning neural network that uses steepest descent method to approximate arbitrary non-linear relations between input and output. There are many training algorithms of BPNN have been proposed including gradient descent with momentum, adaptive learning rate, resilient BP, conjugate gradient, quasi-Newton, and Levenberg-Marquardt (LM) algorithms. The LM algorithm is used to increase the training speed and make the training avoid getting into local minimum. It acts as a compromise between the steepest-descent method with stable but slow convergence and the Gauss-Newton method with opposite characteristics [16].

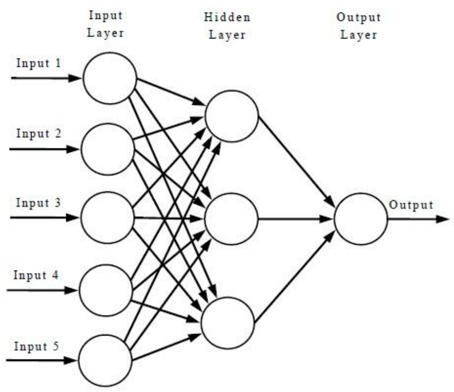


Figure.2. Back propagation neural network

Fig.2. shows back propagation network with input, hidden and output layers. The goal of this network is to train the network to achieve the balance between the ability to respond correctly to the input pattern that are used for training and the ability to provide excellent response to the input that are similar. BPNN has good nonlinear approximation ability. It can found the relationship between original wavelet coefficients and watermarked wavelet coefficients by adjusting the network weights and bias before and after embedding watermark [16]. Owning to the use of neural network, we can extract watermark without the original signal and thus reduce the limit in practical applications.
The weight updating formula for BPNN is,

$$W_{jk}(t+1) = W_{jk}(t) + \alpha\delta k\, y_j + \mu\, [W_{jk}(t) - W_{jk}(t-1) \ldots (1)$$

$$V_{ij}(t+1) = V_{ij}(t) + \alpha\delta_j\, x_i + \mu\, [V_{ij}(t) - V_{ij}(t-1)] \ldots \quad (2)$$

Where,
W_{jk} - Weights between hidden layer and output layer
V_{ij} - Weights between input layer and hidden layer
α - Learning rate parameter
μ - Momentum factor
t - Time
δk- Error signal between output and hidden layers and
δj -Error signal between hidden and input layers
A new embedded technique of transform domain is developed in this paper. And in order to improve the robustness, neural network is introduced, since it can approximate any complicated non-linear relationship. Thus, the neural network model can well illustrate the relationship between selected wavelet packet coefficients and their neighborhood. For the multi-layer network, the number of input units and output units are determined by the problem itself. Choosing the size of network is mainly determining the size of nodes in hidden layer. The selection of nodes in hidden layer is very important for network training and testing. If hidden nodes are very few, the network will not have the necessary ability to learn the necessary information processing capabilities. Conversely, too many hidden nodes increase the complexity of network structure greatly, and is easier for neural network to fall into local minimum in the learning process. Meanwhile, it makes the network learn very slowly. The common method of selection is the trial and error method, generally based on experience to select the hidden layer of nodes, is very random. The empirical formula for determining the number of hidden nodes is

$$h = (kn + an + b)^{1/2} \quad (3)$$

Where h is the hidden nodes; n is the number of input nodes; k is the number of output nodes; a and b are the parameters to be determined. In general, the following posterior formula is used.

$$h = (kn + 1.6799n + 0.9298)^{1/2} \quad (4)$$

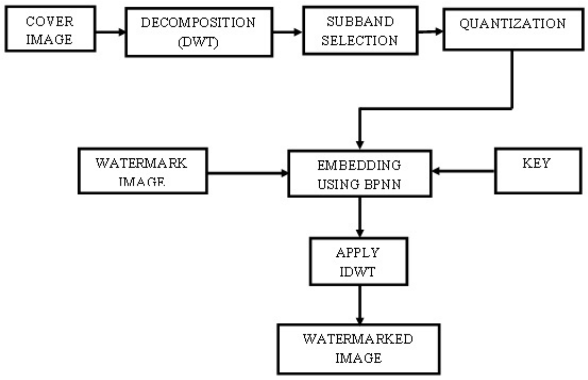
4. PROPOSED WATERMARKING METHOD

In the proposed scheme, the cover image is decomposed to the required level using DWT. Particular sub band is selected for watermarking. BPNN is used for embedding and extracting the watermark. The training process is completed before embedding. After getting the coefficients from the watermark image, the relationship between the high frequency wavelet coefficients and the watermark can be established. The additional information is used to train the neural network to make it sure it must have the capability of memorizing the characteristics of relations between the watermarked image and the watermark. The hidden layer transfer function is considered to be sigmoid, and linear for the output layer.

Watermark embedding using BPNN in wavelet domain is shown in Fig.3.The DWT is applied to the cover image. Sub band is selected from the decomposed image for watermarking. The back propagation neural network is used to insert and extract watermark. The training process is completed before embedding. After getting the coefficients from the watermark image, the relationship between the high frequency wavelet coefficients and the watermark can be established. The extra information is used to train the neural network to make it sure it must have the capability of memorizing the characteristics of relations between the watermarked image and the watermark. Sigmoid activation function is used in the hidden layer and linear activation function is used in the output layer.

Watermark Embedding Algorithm

1. Read the original image I and watermark image W.
2. Apply DWT to decompose the original image to three levels.
3. The frequency subcomponents {HH1, HL1, LH1, {HH2, HL2, LH2},{HH3, LH3, LL3}}} are obtained by computing the third level DWT of the cover image.



4. Select suitable sub band for embedding.
5. Quantize the DWT coefficient (sc) by s as the input to the BPNN and then get the output of BPNN.
6. Watermark is embedded by using equation
   W'=BPNN (round (sc/s) +W (5)
   Where W'-watermarked image and sc-selected sub band coefficient.
7. Perform Inverse Discrete Wavelet Transform (IDWT) on each coefficient to get watermarked image.
8. Compute peak to signal noise ratio between watermarked image and the original image.

Figure.3. Watermark embedding in wavelet domain

The watermark extraction process is the reverse process of watermark embedding. The trained neural network is used in the extraction process, because neural networks have associative memory which can realize blind detection. Watermark extraction procedure using BPNN is shown in Fig.4.

Watermark Extraction Algorithm

1. Decompose the watermarked image by DWT.
2. Quantize the DWT coefficient sc' by s as the input of BPNN and then get the output of BPNN
3. Extract the watermark W using the equation
   EW=sc'- BPNN (round (sc'/s)) (6)
4. Measure the normalized correlation coefficient between extracted watermark EW and the original watermark W.

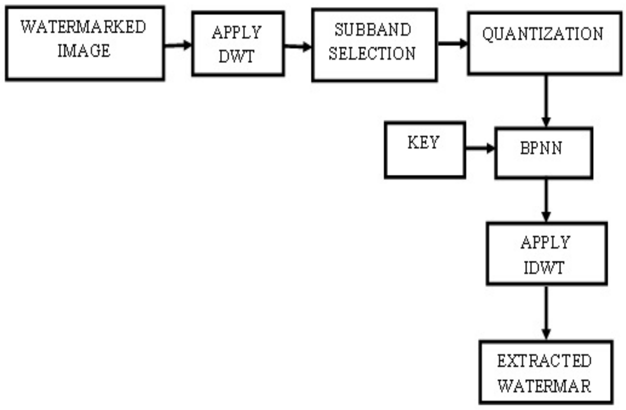


Figure.4. Watermark extraction in wavelet domain

5. EXPERIMENTAL RESULTS AND DISCUSSION

To evaluate the performance of the proposed technique, MATLAB simulations are performed by using a variety of popular cover and watermark images. Here results are given Lena image only. The imperceptibility and the robustness of the watermarked image are tested with peak signal to noise ratio (PSNR) and Normalized Correlation Coefficient (NC) is used to measure the similarity and difference between the original and extracted watermarks. PSNR is used to measure the imperceptibility of the watermarked image. The robustness of the watermarked image is tested by attacks such as JPEG compression, various noise attack and rotation.

The PSNR of the watermarked image is calculated using the formula

$$PSNR = 10\log_{10}\frac{P*P}{MSE} \quad (7)$$

Where P=256, MSE is the mean square error, which is defined as:

$$MSE = \sum_{i=1}^{M}\sum_{j=1}^{N}\frac{[I(i,j)-I'(i,j)]^2}{M*N} \quad (8)$$

Where I is the original image and I' is the watermarked image. PSNR is measured in decibels (db) and the bigger the PSNR value is, the better the watermark conceals.
The NC of the watermark image is computed using the formula

$$NC = \frac{\sum_{i=1}^{M1}\sum_{j=1}^{M2} w(i,j).w'(i,j)}{\sqrt{\sum_{i=1}^{M1}\sum_{j=1}^{M2}[w(i,j)]^2}\sqrt{\sum_{i=1}^{M1}\sum_{j=1}^{M2}[w'(i,j)]^2}} \quad (9)$$

Where W is the original watermark image and W' is the extracted watermarked image. The value of NC is between 0 and 1. And the bigger the value is, the better the watermark robustness. The example of opted original and watermark images are as follows:

Figure.5. Original images

Figure.6. Watermark images

An important property of the watermarking algorithms is that they should be robust against various typical image processing operations For robustness inspection of the proposed method, the watermarked image was tested against several types of attacks namely JPEG compression, Salt & Pepper noise, Gaussian noise, Speckle noise and Rotation. Some examples of extracted watermarks after applying various operations on the watermarked Lena image are shown in Figure.8. The results of the proposed scheme, watermark imperceptibility and robustness are illustrated in Fig.7, Fig.9 and Table 1.

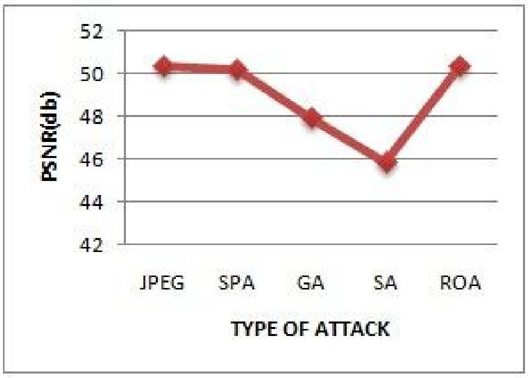


Figure.7. Variation of PSNR for different attacks

Table1: Comparison of Various attacks Performed using BPNN

IMAGE TYPE	PSNR	NC
WITHOUT ATTACK	50.3722	1
COMPRESSION	50.3842	1
SALT & PEPPER	50.2175	0.9696
GAUSSION	47.9591	0.9374
SPECKLE	45.8551	0.9374
ROTATION	50.3722	0.9229

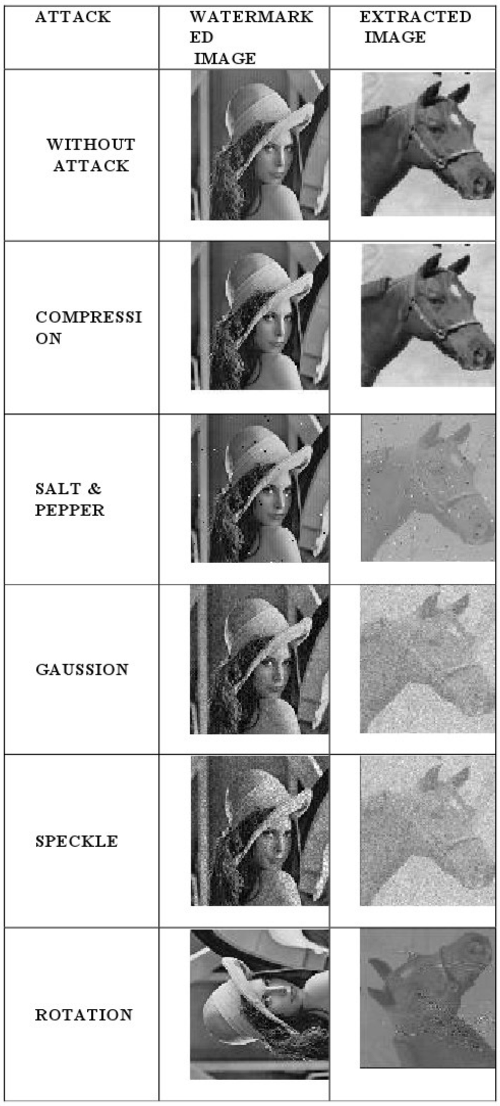


Figure.8. Extracted watermarks after applying different attacks on watermarked Lena image

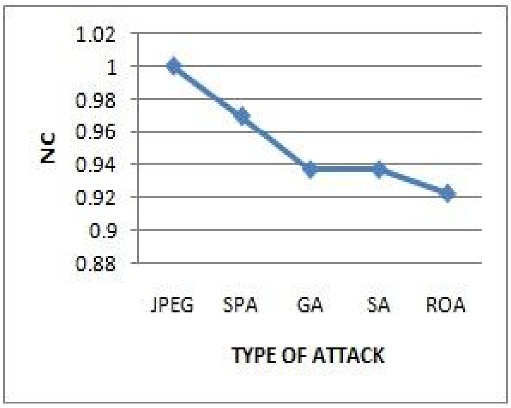


Figure.9. Variation of NCC for different attacks

Finally the proposed method is compared with the methods presented in [14, 24-27], which also apply wavelet transform for watermarking using the Lena image. The results are shown in Table2. The proposed method gains a better PSNR for the watermarked image and is more capable of resisting several attacks.

Table.2. Comparing watermark NC values of the proposed method with the methods presented in [14],[24],[25],[26],[27] for various attacks

ATTACK	COMPRESSION	GAUSSIAN	SALT-PEPPER
REF.[14]	0.82	NA	0.98
REF.[24]	1	NA	NA
REF.[25]	1	0.89	0.88
REF.[26]	0.99	0.81	NA
REF.[27]	0.98	0.90	0.88
PROPOSED SCHEME	1	0.93	0.96

6. CONCLUSION

In this paper, a digital watermarking algorithm based on BPNN was presented. The cover image was decomposed to required level in wavelet domain. The wavelet coefficients were embedded by changing the values of appropriately selected sub-band coefficients in DWT domain using neural network. The novelty of the algorithms is that the watermark is embedded into high and middle frequency components of the cover image using debauches wavelet. Experimental results demonstrates that the values of PSNR of the watermarked images in the proposed method are always greater than 40 db and it can represent acceptable robustness against more frequent attacks such as compression, noise addition and rotation.

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