A Study in Image Watermarking Schemes using Neural Networks

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Abstract*—*The digital watermarking technique, an effective way to protect image, has become the research focus on neural network. The purpose of this paper is to provide a brief study on broad theories and discuss the different types of neural networks for image watermarking. Most of the research interest image watermarking based on neural network in discrete wavelet transform or discrete cosine transform. Generally image watermarking based on neural network to solve the problem on to reduce the error, improve the rate of the learning, achieves goods imperceptibility and robustness. It will be useful for researches to implement effective image watermarking by using neural network.

Keywords*— *Image Watermarking, Discrete Wavelet Transform, Discrete Cosine Transform, Neural Network.

I. INTRODUCTION

Watermarks are identification marks produced during the paper making process and the watermarks first appeared in Italy during the 13th century. Andrew Tirkel and Charles Osborne are first coined the term of digital watermark in 1992. Image watermarking is an important specific area for the advancement of image processing technology. A variety of watermarking schemes have been reported in recent years which can be broadly classified in two categories: spatial transform and frequency transform technique [1].

An artificial neural network commonly referred to us neural networks is an information processing systems which are implemented to model the human brain. Artificial neural networks perform certain computations (pattern matching and classification, optimization function, approximation, vector quantization and clustering) many times faster than the traditional system [2]. In 1988, DARPA studied a neural network is a system composed of many simple processing elements operating in parallel whose function is determined by network structure, connection strengths, and the processing performed at computing elements or nodes.

Meva et al. [3] discussed some of the possible ways to incorporate neural network approach in covert communication. When you want to hide the data from intruders, you can use different methods for covert communication. The most useful methods are steganography and digital watermarking. Actually with steganalysis, can be finding the loop holes in their algorithm and digital watermarking, can be making their algorithm more robust and fast with the help of the neural approach. The performance of their methods can be further improved with the use neural network approach adoption. Bibi Isac et al. [4] have given a review of a few of the proposed image and video watermarking techniques using neural networks. Digital watermarks have been recently proposed for authentication of both video and still images.

This study paper is discussed in the following sections, first we will introduce the related theories of digital watermarking; then we will discuss the related theories of neural networks; at last the image watermarking using neural networks are explained; Finally, conclude this study are discussed.

II. DIGITAL WATERMARKING

Watermarking is the process of embedding information into a multimedia object such as, text, image, audio and video. The watermarking information can be detected or extracted later to make an assertion about the multimedia object. The digital watermarks can be divided into visible and invisible watermark. The visible watermark the information is visible to a viewer in video or documents only on careful inspection. For example, the logo displayed at one corner of different television. The invisible watermark is completely imperceptible.

2.1. General Framework

The watermark can be embedded a visual watermark or Pseudo Random Number (PRN) sequence [5]. The embedding and extraction process is given below

2.1.1. Embedding Process

The inputs are original data and watermark and the output is watermarked data. The watermark is embedded into the original data we get the watermarked data in the embedding process. The block diagram of embedding process is shown in Fig 1.

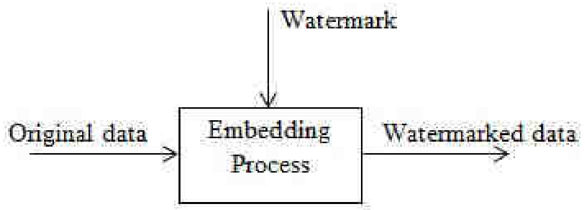

Fig. 1: Block Diagram of Embedding Process

2.1.2. Extraction Process

The inputs are original data and watermarked data and the output is watermark. The watermark is extracted from the original data and the watermarked data in the extraction process. The block diagram of extraction process is shown in Fig 2.

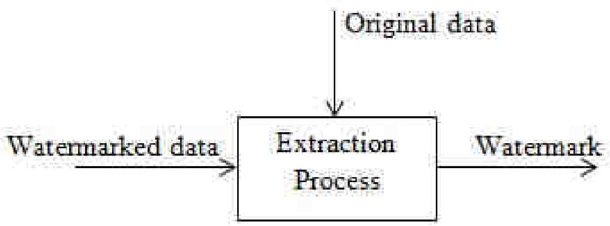

Fig. 2: Block Diagram of Extraction Process

2.2. Different Techniques of Digital Watermarking

Watermarks can be embedded either in the spatial or the transform domain watermarking techniques [6] as discussed below,

2.2.1. Spatial Domain Watermarking Technique

The spatial-domain techniques directly modify the intensity values of some selected pixels in an image to hide the watermark image. Liu Jun et al. [7] presented an improved watermarking detected algorithm for colour image based on a block probability in spatial domain. Each bit of the binary encoded watermark is embedded by modifying the intensities of a nonoverlapping block of 8*8 of the blue component of the host image. Experimental results show that their algorithm is robust against various kinds of attacks such as Affine, Rotating, Cropping, Scaling, JPEG compression and Mean filtering. The spatial domain methods are discussed below

2.2.1.1. Least Significant Bits (LSB)

The least significant bit (LSB) is the bit position in a binary integer giving the units value, that is, determining whether the number is even or odd. The least significant bit is sometimes referred to as the right-most bit, due to the convention in positional notation of writing less significant digit further to the right. Least significant bits are frequently employed in pseudorandom number generators, hash functions and checksums.

Deepshikha Chopra et al. [8] presented the general overview of image watermarking and different security issues. Various attacks are also performed on watermarked images and their impact on quality of images is also studied. Image Watermarking using Least Significant Bit (LSB) algorithm has been used for embedding the message/logo into the image. Chan and Cheng [9] proposed to embed data by simple LSB substitution with an optimal pixel adjustment process.

2.2.2. Spread Spectrum Modulation

Spread spectrum technique is based on spreading the message energy over a bandwidth much larger than the minimum bandwidth required. If find a way of encoding the data into a large signal bandwidth, then to get error free transmission under conditions where the noise is much more powerful than the signal are using. This very simple idea is the secret behind spread spectrum techniques. For example; 3 kHz voices signal to send through a channel with a noise level 100 times as powerful as the signal. Manipulating the preceding equation, find that require a bandwidth of 208 kHz, which is about 70 times greater than the voice signal. Readers with knowledge of radio will note here that this idea of spreading is a central part of FM radio and the reason why it produces good sound quality compared to the simpler AM scheme. These techniques are used for a variety of reasons, including the establishment of secure communications, increasing resistance to natural interference, noise and jamming, to prevent detection, and to limit power flux density. Spread-spectrum telecommunications is a signal structuring technique that employs direct sequence, frequency hopping, or a hybrid of these, which can be used for multiple access and/or multiple functions.

Spread Spectrum (SS) modulation principle has been widely used in digital watermarking due to its distinguishing characteristics viz. excellent security and robustness in performance. Das et al. [10] analysed the usage of M-ary modulation principle in SS watermarking scheme. Their method is found that, the robustness performance of wavelet transform is better over spatial domain as wavelet transform models the host data towards Gaussian independent & identically distributed nature. Maity et al. [11] proposed fast walsh transform based Spread Spectrum (SS) image watermarking scheme that serves the dual purposes of authentication in data transmission as well as quality of services assessment for digital media through dynamic estimation of the wireless channel condition. Spread spectrum methodology is used as their method has proven to be efficient, robust and cryptographically secured.

2.2.3. Frequency Domain Watermarking Technique

The watermarking systems modify the frequency transforms of data elements to hide the watermark data and finally the inverse transform is applied to obtain the marked image. The frequency domain based watermarking techniques are more robust as compared to simple spatial domain watermarking techniques. To demonstrated that the much improved performance of the frequency domain in terms of imperceptibility and robustness as compared to the spatial domain domain [12]. Gunjal et al. [13] provided complete overview of Digital Image Watermarking techniques in Spatial as well as transform domain. The Transform domain watermarking techniques are recommended to achieve robustness. The watermarking scheme based on the frequency domains can be further classified into the Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) domain methods.

2.2.3.1. Discrete Fourier Transform

The discrete Fourier transform (DFT) converts a finite list of equally spaced samples of a function into the list of coefficients of a finite combination of complex sinusoids, ordered by their frequencies, that has those same sample values.

A novel design of a DFT-based digital watermarking system for images is proposed in [14]. The original images is split into the blocks and proceed DFT transform after that by using Arnold scrambling change water mark and produce pseudo-random sequence, result an image with watermark is produce. The watermark detection is achieved with image segmentation process, DFT transform process and relativity process. A watermarking algorithm based on image segmentation, is also use for improve the security of the watermark with DFT algorithm. Awanish Kr Kaushik [15] evaluated the degradation of an image due to the implementation of a watermark in the frequency domain of the image. As a result, their watermarking method, which minimizes the impact of the watermark implementation on the overall quality of an image, is developed. The watermark is embedded in magnitudes of the Fourier transform.

2.2.3.2. Discrete Cosine Transform

A discrete cosine transform (DCT) expresses a finite sequence of data points in terms of a sum of cosine functions oscillating at different frequencies. DCT coefficients are real-valued. DCT domain watermarking can be classified into Global DCT watermarking and Block based DCT watermarking. The block based DCT, the image is first partitioned into a number of blocks and DCT transform is applied on each block before watermark embedding.

Wen-Nung Lie et al. [16] proposed two simple DCT-domain-based schemes to embed single or multiple watermarks into an image for copyright protection and data monitoring and tracking. The watermark data are essentially embedded in the middle band of the DCT domain to make a trade-off between visual degradation and robustness. A set of systematic experiments, including Gaussian smoothing, JPEG compression and image cropping are performed to prove the robustness of their algorithms. Hernandez et al. [17] analysed a spread-spectrum-like discrete cosine transform domain watermarking technique for copyright protection of still digital images. The DCT is applied in blocks of 8×8 pixels as in the JPEG algorithm. As a result of their work, analytical expressions for performance measures such as the probability of error in watermark decoding, probabilities of false alarm and detection in watermark are derived and contrasted with experimental results.

2.2.3.3. Discrete Wavelet Transform

The transformation product is set of coefficients organized in the way that enables not only spectrum analyses of the signal, but also spectral behaviour of the signal in time. This is achieved by decomposing signal, breaking it into two components, each caring information about source signal. Filters from the filter bank used for decomposition pairs are low pass and high pass filter. The filtering is succeeded by down sampling. Low pass filtered signal contains information about slow changing component of the signal, looking very similar to the original signal, only two times shorter in term of number of samples. High pass filtered signal contains information about fast changing component of the signal. Filters from the filter bank are called "wavelets".

Ramana Reddy et al. [18] emphasized on the digital watermarking provides a comprehensive evaluation algorithm that embeds and extracts the watermark information effectively. Embedding the watermark at high level decomposition (II Level Decomposition) improves both the quality of watermarked image and the robustness of watermark. The extraction is done without using original image hence it is a blind watermarking scheme. The experimental results show that their scheme is highly robust against several of image processing operations such as, filtering, cropping, compression, Gaussian noise and salt and pepper noise. Yamuna and Sivakumar [19] proposed a novel watermarking scheme for copyright protection in digital images. The watermarking is performed in wavelet domain using bi-orthogonal wavelet transform. As their proposed approach is non-blind, it requires original image for extracting the watermark. The watermark image is a binary image. The watermark image is embedded in the HH sub-band of the wavelet transformed original image. A Good quality of watermarked image is assured through their proposed scheme from the higher PSNR values which is evident from experimental result.

2.3. Requirements of Watermarking

2.3.1. Data Payload

Payload is an important property of any watermarking algorithm. It determines whether a technique can be profitably used in a given context or not. Data payload refers to the number of bits a watermark encodes within a unit of time or within a Work. For a photograph, the data payload would refer to the number of bits encoded within the image. A watermark that encodes N bits is referred to as an N-bit watermark. Such a system can be used to embed any one of 2N different messages. Different applications may require very different data payloads.

2.3.2. Imperceptibility

The main requirement for watermarking technique is the perceptual transparency. In the most applications of watermarking algorithm, the watermark is to be embedded in original data, such that this does not affect the quality of the original data. A digital watermark is called imperceptible if the original cover signal and the marked signal are perceptually indistinguishable.

2.3.3. Robustness

Robustness of watermarking algorithm depends upon the capability of the hidden data to survive host signal manipulations. Robustness refers to the ability to detect the watermark after common signal processing operations. Not all watermarking applications require robustness to all possible signal processing operations. Rather, a watermark need only survive the common signal processing operations likely to occur between the time of embedding and the time of detection.

2.3.4. Security

A watermark should be secret and must be undetectable by unauthorized parties. The security of watermarking technique can be interpreted in the same way as the security of encryption technique. Watermarks should survive deliberate attempts to remove them. Ideally, a watermark should remain readable up to the point where the content becomes modified enough to be of low value.

2.3.5. Effectiveness

When input to a detector results in a positive detection. With this definition of watermarked works, the effectiveness of a watermarking system is the probability that the output of the embedded will be watermarked. In other words, the effectiveness is the probability of detection immediately after embedding.

2.4. Applications of Watermarking

2.4.1. Copyright Protection

Copyright protection objective is to embed information about the source and thus typically the copyright owner of the data in order to prevent other parties for claiming the copyright on the data. The application requires a very high level of robustness and the watermarks are used to resolve rightful ownership.

2.4.2. Copy Protection

Copy protection mechanism disallows unauthorized copying of the media. Copy protection is very difficult to achieve in open systems, it is feasible to achieve closed or proprietary systems.

2.4.3. Fingerprinting

An impression on a surface is formed by the ridges on a fingertip, especially such an impression made in ink and used for identification. The recovery of fingerprints from a crime scene is an important method of forensic science. Fingerprints are easily deposited on suitable surfaces (such as glass or metal or polished stone).

2.4.4. Authentication

With the advance of computer tools available for digital signal processing, modifying a digital document is becoming easier while detecting that the content is modified becomes harder. The authorized source knows the valid key for encryption, an adversary who tries to change the message cannot create a corresponding valid signature for the modified message.

2.4.5. Data Hiding

Data hiding is a method of hiding the existence of a message and this allows communication using often enciphered messages without attracting the attention of a third party.

2.4.6. Broadcast Monitoring

Broadcast monitoring is the process of receiving and reviewing media that is transmitted on a broadcast channel to determine if a particular media item has or has not been broadcasted. Broadcast monitoring may be performed to ensure an advertisement has been inserted on a broadcast television system as defined in an advertising agreement or broadcast monitoring may be used to ensure some media is not broadcast (e.g. licensed content).

III. ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks are a large number of highly interconnected processing elements called neurons. Each neuron is connected to other neurons by a connected link, each with an associated weight which contains information being used by the neural net to solve a particular problem. ANNs is characterized by their ability to learn, recall and generalize form similar to that of a human brain. Each neuron has an internal state of its own, called its activation or activity level of neuron, which is a function of the inputs the neuron receives. A neuron sends its activation of a one signal which can be transmitted to several other neurons.

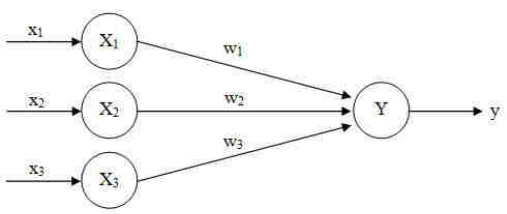

Fig. 3: Architecture of a simple Artificial Neural Network

From Fig 3 the net input has to be calculated as follows

$$y_{in} = w_1 x_1 + w_2 x_2 + w_3 x_3$$

where, x_1, x_2, x_3 are the activations of the input neurons X_1, X_2 and X_3. The weights on the connection from X_1, X_2 and X_3 to neuron y are w_1, w_2 and w_3 respectively. The output y of the output neuron Y is given by some function of its net input.

$$y=f\,(y_{in})$$

The function to be applied over the net input is called activation function.

Review of image watermarking by using artificial neural network is presented below.

Table 1 shows the different frequency domain methods and various years on Artificial Neural Network for image watermarking. An artificial neural network based scheme for fragile watermarking has been developed in [20]. They used the artificial neural network model to analyse the degree of changes and any tampered image what kind of alteration has occurred.

Table 1: Different frequency domain methods on Artificial Neural Network for image watermarking

Name of the Authors	Year	Transform	Achievements
Yu-Cheng Fan et al. [20]	2003	Discrete Wavelet Transform	Robustness
Jun Sang et al. [21]	2005	Spatial domain	Imperceptibility and robustness
Sameh Oueslati et al. [22]	2011	Discrete Cosine Transform	Invisibility and robustness
Bibi Isac et al. [23]	2011	Discrete Wavelet Transform	Robustness
Jose Aguilar et al. [24]	2011	Spatial domain	Imperceptibility
Mohamad Vafaei et al. [25]	2013	Discrete Wavelet Transform	Imperceptibility and robustness
Vafaei et al. [26]	2013	Discrete Wavelet Transform	Imperceptibility and robustness
Pallavi Agrawal [27]	-	Discrete Cosine Transform/ Discrete Wavelet Transform	Robustness an Adaptability

Jun Sang et al. [21] proposed the coupling of a watermarking technique for images, called least significant bit, in the multiple classes random neural network. Their method obtained very good performances in terms of Imperceptibility and robustness. A new method to obtain the invisibility and the robustness in DCT domain watermarking has been described in [22]. HVS characteristics are taken into consideration so as to make the watermark invisible during the process of watermark embedding and artificial neural network is applied and for enhancing the performance of conventional watermarking techniques. Bibi Isac et al. [23] described a method to embed watermark in region of non-interest (RONI) and also a method for adaptive calculation of strength factor using neural network. The embedding and extraction processes are carried out in the transform domain by using Discrete Wavelet Transform (DWT). Their algorithm robustness is tested against noise addition attacks and geometric distortion attacks. A lossless digital image watermarking algorithm based on neural network is proposed in [24]. Their proposed algorithm does not degrade the visual quality of the cover image.

A novel watermarking method based on wavelet coefficient quantization using artificial neural networks is proposed in [25]. In their proposed method, better compromises are achieved applying neural networks to adjust the watermark strength. The Experimental results demonstrate simultaneous good imperceptibility and high robustness of their method against several types of attacks, such as Gaussian and salt and pepper noise addition, median filtering, and JPEG compression. A blind digital watermarking algorithm based on feed-forward neural networks was presented in [26]. The host image was decomposed into wavelet domain and watermark bits embedded in the appropriately selected sub-band coefficients. It is shown that the neural networks can satisfactorily maximize the watermark strength using proper trainings; in addition to being adaptive based on the knowledge of the block features. The simulation results illustrate that their proposed method has good imperceptibility and high robustness. The different categories of Artificial Neural Networks are illustrated in Fig 4.

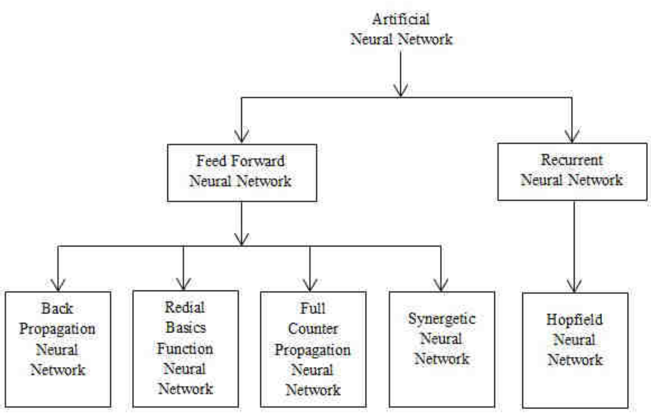

Fig. 4: The categories of Artificial Neural Networks

A novel image watermarking approach based on the human visual system (HVS) model and neural network technique is proposed in [27]. The watermark was inserted into the middle frequency coefficients of the cover image's blocked DCT/DWT based transform domain. In order to make the watermark stronger and less susceptible to different types of attacks, it is essential to find the maximum amount of interested watermark before the watermark becomes visible. Here neural networks are used to implement an automated system of creating maximum strength watermarks. The experimental results show that their method can survive of common image processing operations and has good adaptability for automated watermark embedding.

3.1. Layers of Neural Network

The neural network is formed by the interconnection of several layers such as, input, hidden and output layers [28]. The input is processed and relayed from one layer to the other, until the final result has been computed. The general structure of layered architecture is shown in Fig 5.

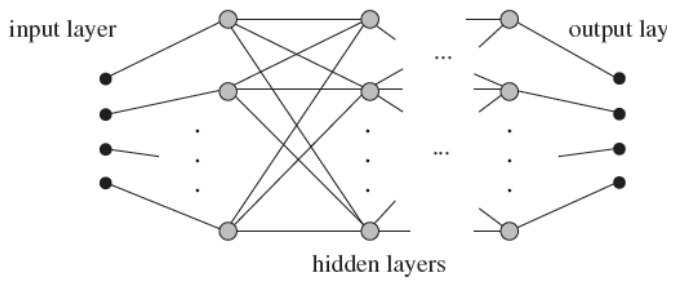

Fig. 5: General Structure of a Layered Architecture

3.1.1. Input Layer

The input layer is that which receives the input variables. This layer has no function, but simply passes the values to the processing layer.

3.1.2. Hidden Layer

The hidden layer is any layer that is formed between the input and output layers. This hidden layer is internal to the network and they are not connected directly to the external environment. It should be noted that there may be zero to several hidden layers in an artificial neural network. More the number of the hidden layer more is the complexity of the network.

3.1.3. Output Layer

The output layer generates the output of the network.

3.2. Types of Neural Network

The two major types of neural networks are feed forward and recurrent neural networks [29] as discussed below.

3.2.1. Feed Forward Neural Network

The Feed Forward Neural network (FFNN) is the first and simplest type of artificial neural network. It consists of a number of layers, which are arranged into a layered configuration as shown in Fig 6. In this network, the information moves only in forward direction, from the input layer, through the hidden layer and to the output layer. There are no loops or cycles in the feed forward neural network, that is it never goes backwards. Feed forward neural networks represent a well-established computational model, which can be used for solving complex tasks requiring large data sets [30]. Their method provided a survey of some existing techniques that optimize architecture of BP-networks.

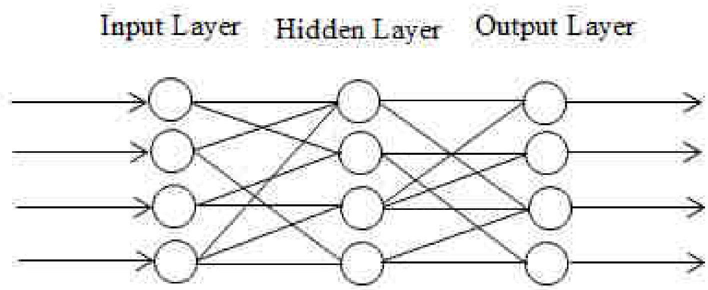

Fig. 6: The Architecture of Feed Forward Neural Network

3.2.2. Recurrent Neural Network

A recurrent neural network (RNN) is a class of artificial neural network where connections between units form a directed cycle. This creates an internal state of the network which allows it to exhibit dynamic temporal behaviour. Unlike feed forward neural networks, RNNs can use their internal memory to process arbitrary sequences of inputs. In the Recurrent Neural Network the output can be directed back to the nodes in a preceding layer. The architecture of recurrent neural network is shown in Fig 7. Ilya Sutskever et al. [31] demonstrated the power of RNNs trained with the new Hessian-Free optimizer (HF) by applying them to character-level language modelling tasks. Their standard RNN architecture is effective.

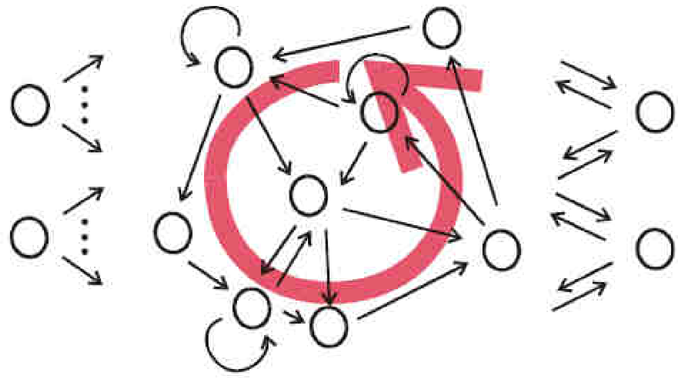

Fig. 7: Architecture of Recurrent Neural Network

3.3. Training Process in Neural Network

The learning or training process of an artificial neural network can be generally classified into supervised and unsupervised learning as follows,

3.3.1. Supervised Learning

In the supervised learning each input requires a corresponding target output, which represents the desired output. The block diagram of supervised learning network is shown in Fig 8. During the training process the actual output is compared with the desired output. If their exits a difference between the two output then an error signal is generated by the network. This error signal is used for adjustment of weights until the actual output matches the desired output. Sathya et al. [32] presented a comparative account of unsupervised and supervised learning models and their pattern classification evaluations as applied to the higher education. Their method found that, though the error back-propagation learning algorithm as provided by supervised learning model is very efficient for a number of non-linear real-time problems, KSOM of unsupervised learning model, offers efficient solution and classification.

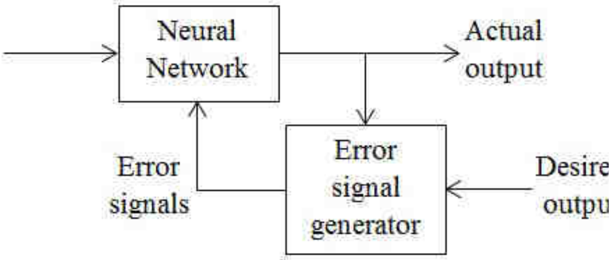

Fig. 8: Block diagram of supervised learning network

3.3.2. Unsupervised Learning

In unsupervised learning when a new input pattern is applied, the neural network gives an output response indicating the class to which the input pattern belongs. The block diagram of unsupervised learning is shown in Fig 9. Here there is no feedback from the environment to inform whether the outputs are correct. In this case the network relations for the input data over the output undergoes change its parameters. This process is also called self-organizing. Roland Memisevic et al. [33] described a probabilistic model for learning rich, distributed representations of image transformations. Experimental results demonstrated that their method is applicability to a variety of tasks.

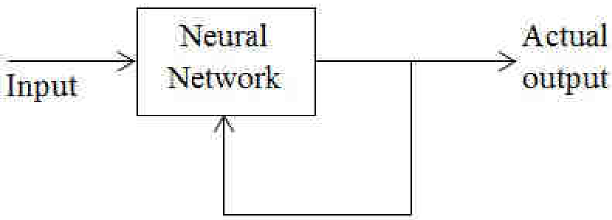

Fig. 9: Block diagram of supervised learning network

IV. IMAGE WATERMARKING USING NEURAL NETWORKS

A review of different types of watermarking techniques has been proposed for embedding and extracting a watermark in a digital image using neural networks.

4.1. Back Propagation Neural Network (BPN)

The back propagation algorithm is one of the must important developments in neural networks. The back propagation neural network (BPNN) is a very popular modal and most frequently used learning techniques in neural networks.

A BPNN is a multilayer and feed-forward neural network, order to obtain minimum mean squared error between expected outputs and actual outputs, BP neural network can fix the network weights by using mean squared error and gradient descent methods. A typical BP network architecture is shown in Fig 10, which consists of an input layer, hidden layer, and output layer. Each layer has one or more neurons and each neuron is fully connected to its adjacent layers. Two neurons of each adjacent layer are directly connected to one another, which is called a link. Each link has a weighted value, representing the relational degree between two neurons. The numbers of input nodes and output neurons of neural network can be easily determined according to the practical problem. Table 2 shows the different frequency domain methods and various years on Back Propagation Neural Network for image watermarking.

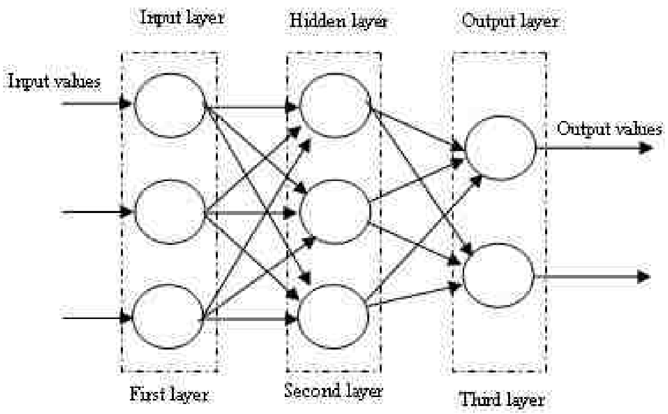

Fig. 10: Architecture of a Back Propagation Neural Network

There has been many works in the literature related to image watermarking by using back propagation neural network and some of them are discussed below.

A robust watermarking system and several wavelet-based watermarking methods were introduced in [34]. Their algorithms robustness against different attacks is increased as the power of the added watermark increases. A novel public watermarking method has been proposed in [35]. The logo watermark is embedded into a multiwavelet transform domain after that the BPN model is used to improve imperceptibility and robustness. Jun Zhang et al. [36] proposed a novel watermarking scheme for an image, in which a logo watermark is embedded into the multiwavelet domain of the image using neural networks. According to these characteristics of the multiwavelet domain, embed a bit of the watermark by adjusting the polarity between the coefficient in one sub block and the mean value of the corresponding coefficients in other three sub blocks. The learning and adaptive capabilities of the BPN, the false recovery of the watermark can be greatly reduced by the trained BPN. Experimental results show that their proposed method has good imperceptibility and high robustness to common image processing operators.

Zhenfei Wang et al. [37] proposed a novel digital watermarking technique based on neural networks in wavelet domain. Watermark bits are added to the significant coefficients of wavelet selected by considering the human visual system (HVS) characteristics, because of the learning and adaptive capabilities of neural networks, the trained neural networks can exactly recover the watermark from the watermarked image. Extensive experiments show that their technique possesses significant robustness to be against the various attacks. Cheng-Ri Piao et al. [38] proposed a new watermarking scheme in which a logo watermark is embedded into the discrete wavelet transform (DWT) domain of the color image using Back-Propagation Neural networks (BPN). In order to strengthen the imperceptibility and robustness, the original image is transformed from RGB color space to brightness and chroma space (YCrCb). BPN will learn the characteristics of the color image, and then watermark is embedded and extracted by using the trained neural network.

An effective blind digital watermarking algorithm based on neural networks in the wavelet domain is presented in [39]. The significant coefficients of wavelet are selected according to the human visual system (HVS) characteristics. The neural networks to learn the characteristics of the embedded watermark related to them, because of the learning and adaptive capabilities of neural networks, the trained neural networks almost exactly recover the watermark from the watermarked image. Their proposed digital watermarking technique can be robust against many different types of attacks. A new digital watermarking algorithm based on BPN neural network is proposed in [40]. Watermark bits are added to the selected coefficients blocks, because of the learning and adaptive capabilities of neural networks, the trained neural networks can recover the watermark from the watermarked images. The experimental results show that their watermarking algorithm has a good preferment.

A novel blind watermarking technique based on back propagation neural networks is proposed in [41]. The watermarking technique hides a scrambled watermark into an image, and takes HVS characteristics into consideration during the watermark embedding process, then uses a back propagation neural network to learn the characteristics of the embedded watermark related to the watermarked image. Extensive experiments show that their proposed watermarking algorithm has a good imperceptibility and high robustness to various common image processing attacks. Ashish Bansal et al. [42] described the algorithm to use a Back propagation Neural Network with an additional advantage of hiding the trained network weights within the original cover image. The watermarked image has a good robustness and the imperceptibility of the cover image is also highly preserved. For the extraction, only cover image is required and no external weights files need to be supplied with the watermarked image.

Qianhui Yi et al. [43] proposed a improved Back-Propagation neural network for color image. The watermark is embedded into the discrete wavelet domain of the original image and extracted by training BPN, which can learn the characteristic of the image. Experimental results show that their proposed method has good imperceptibility and high robustness to common image processing such as JPEG compression, noise adding, chopping, and rotation. A novel watermarking technique based on image features and neural network is proposed in [44]. The watermark is the fusion of a binary copyright symbol and image feature label which is gotten by analyzing the image fractal dimension. Then the watermark is pre-treated by Arnold transform in order to increase the security, and embedded into the multiwavelet transform domain. Experimental results demonstrate that their proposed algorithm can achieve good perceptual invisibility and security, and it is also robust against various common image processing attacks. A color image oblivious watermarking scheme based on neural network and discrete wavelet transform (DWT) is proposed

Table 2: Different frequency domain methods on Back-Propagation Neural Network for image watermarking

Name of the Authors	Year	Transform	Achievements
Davis et al. [34]	2001	Discrete Wavelet Transform	Robustness
Zhang et al. [35]	2002	Multiwavelet Transform	Imperceptibility and robustness
Jun Zhang et al. [36]	2002	Multiwavelet Transform	Imperceptibility and robustness
Zhenfei Wang et al. [37]	2006	Discrete Wavelet Transform	Robustness
Cheng-Ri Piao et al. [38]	2006	Discrete Wavelet Transform	Imperceptibility and robustness
WANG Zhenfei et al. [39]	2006	Discrete Wavelet Transform	Robustness
Xue-Quan Xu et al. [40]	2007	Discrete Wavelet	Robustness

		Transform	
Song Huang et al. [41]	2008	Discrete Wavelet Transform	Imperceptibility and robustness
Ashish Bansal et al. [42]	2008	---	Imperceptibility and robustness
Qianhui Yi et al. [43]	2009	Discrete Wavelet Transform	Imperceptibility and robustness
Song HUANG et al. [43]	2009	Arnold Transform	Invisibility, security and robustness
Qun-ting Yang et al. [45]	2010	Discrete Wavelet Transform	Robustness
Yonghong Chen et al. [46]	2010	Discrete Wavelet Transform	Robustness
Fenglian Liu et al. [47]	2010	Dual-Tree Wavelet Transform	Robustness
Olanrewaju et al. [48]	2011	Fourier Transform	Fidelity
Mohananthini et al. [49]	2012	Discrete Wavelet Transform	Imperceptibility
Nallagarla Ramamurthy et al. [50]	2012	Discrete Wavelet Transform	Imperceptibility and robustness
Nallagarla Ramamurthy et al. [51]	2012	Discrete Wavelet Transform	Imperceptibility and robustness
Mya Thidar Kyaw et al. [52]	2013	Discrete Cosine Transform	Robustness
Saini [53]	2014	Discrete Wavelet Transform	Robustness

in [45]. Three identical watermarks and some different expanded bit streams are adaptively embedded into the low frequency sub-bands generated from three channels for a color image. Extensive experiments illustrate that their new scheme possesses good robustness against different attacks including noise addition, shearing, scaling, luminance and distortion.

A novel blind watermarking scheme based on the back-propagation neural networks (BPNN) for image is presented in [46]. The convolutional codes encoding is used to refine the watermark for increasing robustness of the scheme. BPNN is developed to memorize the relationships between the wavelet selected samples and a processed chaotic sequence. With wavelet domain of original image being divided into watermarking blocks, then several different BPNN models of selected watermarking blocks are trained simultaneously to form certain relationships, which are employed for embedding the coded watermark bit stream. Experimental results demonstrate the high robustness of their proposed scheme against common signal processing.

Fenglian Liu et al. [47] proposed a novel digital watermarking technique based on BP neural networks in wavelet domain. The original image is decomposed by DTCWT, and then the watermark bits are added to the selected coefficients blocks, because of the learning and adaptive capabilities of neural networks, the trained neural networks can recover the watermark from the watermarked images. Experimental results show that their proposed scheme has good performance against several attacks. Olanrewaju et al. [48] suggested an efficient and distortion free digital watermarking algorithm using complex neural network and fast Fourier transform. The performance of their proposed technique has been evaluated image fidelity.

A digital image watermarking technique based on Back-Propagation neural networks (BPNN) is proposed in [49]. Using improved BPNN, the watermark can be embed into Discrete Wavelet Transform(DWT), which can reduce the error and improve the rate of the learning, the trained neural networks can recover the watermark from the watermarked images. Their proposed method has good imperceptibility on the watermarked image and superior in terms of Peak Signal to Noise Ratio (PSNR).

A novel image watermarking approach based on quantization and back propagation neural network is proposed in [50]. The cover image is decomposed up to 3-levels using quantization and DWT. The back propagation neural network is implemented while embedding and extracting the watermark. Their proposed watermarking algorithm is imperceptible and robust to some normal attacks such as JPEG compression, salt and pepper noise, median filtering, rotation, and cropping. Nallagarla Ramamurthy et al. [51] presented a blind robust digital image watermarking approach based on back propagation neural network in DWT domain. In BPNN the errors will be back propagated to the input layer, so that the weights and learning rate parameters may be changed to get the output. The BPNN is trained in such a way that it converges fast and reaches high accuracy. Their proposed watermarking algorithm is imperceptible and robust to some normal attacks such as JPEG compression, salt and pepper noise, rotation, median filtering and cropping.

An image authentication by combination of online signature and watermarking techniques is proposed in [52]. The image authentication of two watermarking techniques such as partially blind watermarking technique with Neural Network, and efficient blind watermarking technique with Neural Network based on

Discrete Cosine Transform (DCT). The performance analysis such as robustness of their secret information against various attacks will be presented. Their proposed system can be applied for copyright protection for authorized user using handwritten online signature. Saini [53] proposed a hybrid watermark embedding and extracting technique. SVD and DWT methods are used for watermark embedding because DWT method is more flexible and provides a wide range of functionalities for still image processing. Their result shows that after a numerous image attacks like paper and salts, mean, median, shear, noise, crop and rotation the watermark is identifiable.

4.2. Radial Basis Function Neural Network (RBF)

The Radial Basis Function is a classification and functional approximation neural network. RBF is a multi-layered feed forward networks. The radial basis function network has universal approximation capability and has been successfully applied to many signal and image processing problems. The RBF network used the most common nonlinearities such as sigmoidal and Gaussian function. This is resembles a BPN network, but the activation function used a Gaussian function.

The Radial basis function Network architecture is shown in Fig 11, consists of a set of inputs, a hidden layer for the processing elements and an output layer. The output layer is a linear combination of the Gaussian functions computed by means of the RBF notes or hidden layer nodes. The Gaussian function in the hidden layer produces a significant nonzero response to the input stimulus it has received only when the input of it falls with in a small localized region of the input space. Table 3 shows the different frequency domain methods and various years on Radial basis function Network for image watermarking.

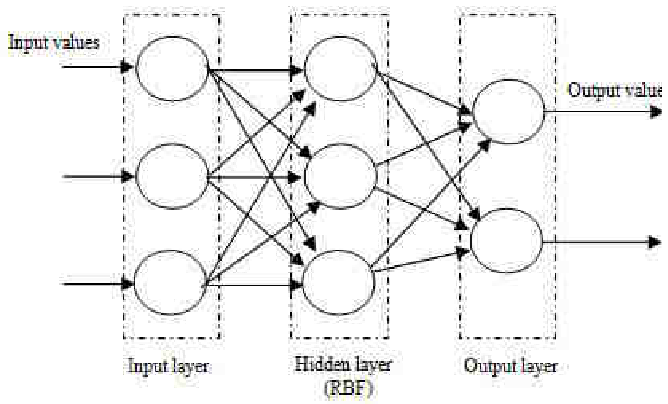

Fig. 11: Architecture of a Radial Basis Function Network

Review of image watermarking by using radial basis function network is presented below.

A meaningful digital image watermarking algorithm based on RBF (radial basis function neural network) neural network is proposed in [54]. RBF neural network is used to simulate human visual speciality to determine the watermark embedding intensity endured by DCT coefficients and the watermarking is a meaningful two value image. The experiments of results show that their algorithm has good robustness against all kinds of attacks. Cheng-Ri Piao et al. [55] proposed a new blind watermarking scheme in which a watermark is embedded into the discrete wavelet transform (DWT) domain. Radial basis function neural networks (RBF) will be implemented while embedding and extracting watermark and human visual system (HVS) model is used to determine the watermark insertion strength. Experimental results show that their proposed method has good imperceptibility and high robustness to common image processing attacks.

Table 3: Different frequency domain methods on Radial Basis Function Neural Network for image watermarking

Name of the Authors	Year	Transform	Achievements
Quan Liu et al. [54]	2005	Discrete Cosine Transform	Robustness
Cheng-Ri Piao et al. [55]	2006	Discrete Wavelet Transform	Imperceptibility and robustness
Hitesh et al. [56]	2007	Discrete Cosine Transform	Robustness
Rakhi Motwani et al. [57]	2009	-	Embedding capacity and robustness
Yanhong Zhang et al. [58]	2009	Discrete Wavelet Transform	Invisible and robust
Nallagarla.Ramamurthy et al. [59]	2012	Discrete Wavelet Transform	Robustness

Hitesh et al. [56] presented investigates the copyright protection by utilizing the digital watermarking of images. The earlier used Back Propagation Network (BPN) is replaced by Radial Basis Function Neural Network (RBFNN) in their proposed scheme to improve the robustness and overall computation requirements. Since RBFNN requires less number of weights during training, the memory requirement is also less as compared to BPN. In [57] the ability of a supervised learning RBF neural network is investigated for watermarking of 3D models. The neural network is trained for various types of 3D surfaces (planar, cylindrical, minimal, curved, uneven) that characterize different geometries. Their algorithm achieves minimal perceptual distortion and accomplishes high watermark embedding capacity. Experimental results prove that their algorithm is robust against a variety of attacks as well.

Yanhong Zhang et al. [58] proposed a new blind watermarking scheme based on discrete wavelet transform (DWT) domain. The method uses the HVS model, and radial basis function neural networks (RBF). RBF will be implemented while embedding and extracting watermark. The human visual system (HVS) model is used to determine the watermark insertion strength. The neural networks almost exactly recover the watermarking signals from the watermarked images after training and learning. The experimental results show that their watermark is invisible (the PSNR is higher than 41) and is robust in the case of against some normal attacks such as JPEG compression, additive noise and filtering. A blind transform domain based algorithm using Radial Basis Function Neural Network is introduced in [59]. Their proposed algorithm is robust to cropping, salt & pepper noise and rotation attacks.

4.3. Hopfield Neural Network

John J. Hopfield has developed a number of Neural Networks based on fixed weights and adaptive activations. The Networks proposed by Hopfield are known as Hopfield networks and the network has found many useful applications in associative memory and various optimization problems. The architecture of Hopfield network with four nodes is shown in Fig 12 consists of a set of neuron forming a multiple loop feedback system. The number of feedback loops is equal to the number of neurons. Hopfield networks normally have units that take on values of +1 or -1. Table 4 shows the different frequency domain methods and various years on Hopfield neural network for image watermarking.

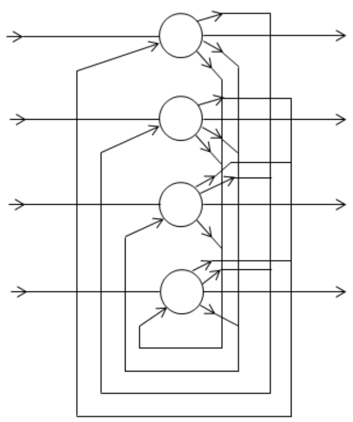

Fig. 12: Architecture of a Hopfield Network

Review of image watermarking by using Hopfield network is presented below.

Fan Zhang et al. [60] presented a blind watermarking algorithm using Hopfield neural network, and analyze watermarking capacity based on neural network. In their watermarking algorithm, watermarking capacity is decided by attraction basin of associative memory. A blind digital watermarking algorithm based on Hopfield neural network is proposed in [61]. The host image and original watermark are stored by Hopfield neural network. The noise visibility function (NVF) is used for adaptive watermark embedding. In watermark extraction, the host image and the original watermark are retrieved by neural network. The experimental results show that their watermarking algorithm has a good preferment.

Table 4: Different frequency domain methods on Hopfield Neural Network for image watermarking

Name of the Authors	Year	Transform	Achievements
Fan Zhang et al. [60]	2004	-	Capacity
Xinhong Zhang et al. [61]	2005	-	Imperceptibility
Katiyar et al. [62]	2011	-	Image quality
He Xu et al. [63]	2011	Discrete Cosine Transform	Invisible and robust

Katiyar et al. [62] proposed a digital watermarking technique with the Hopfield Neural network for the authentication and copyright protection of audio, video and still images. Different from the traditional methods, the watermark is embedded in the synapses of Hopfield Neural Network rather than the cover image. Hence the quality of the watermarked image is almost same as the original cover image. In addition, the quality of the extracted watermark image does not degrade after most attacks, because the watermark is stored in the synapses. An adaptive image watermarking algorithm based on neural network is proposed in [63]. The watermarking signal is embedded in higher frequency, which is in the lower frequency of original image by DWT joined with DCT. The ability of attracting is improved by pre treatment and re-treatment of image scrambling and Hopfield network. Experimental results show that their embedded digital watermarking is invisible and robust enough against common image processing such as JPEG compression, noises, filter and shearing.

4.4. Full Counter propagation Neural Network (FCPN)

Counter propagation networks applications are data compression, function approximation and pattern association. The Full Counter Propagation Network and Forward only Counter Propagation network are the types of counter propagation networks. The Full Counter Propagation Network is the extension of Forward only Counter Propagation network with is a supervised learning network with the capacity of bidirectional mapping.

The architecture of Full Counter Propagation Network is shown in Fig 13, constructed from an instar-outstar model such as input layer, instar, and hidden (competitive) layer and outstar. An instar responds maximally to the input vectors from a particular cluster, and then all the instars are grouped into a layer called the competitive (hidden) layer.

Every instar responds maximally to a group of input vectors in a different region of space. The input layer of instars classifies any input vector because, for a given input, the winning instar with the strongest response identifies the region of space in which the input vector lies. Hence, need the competitive layer to single out the winning instar by setting its output to a nonzero value and also suppressing the other outputs to zero. That is, it is a winner-take-all or a Maxnet-type network. An outstar model is found to have all the nodes in the output layer and a single node in the competitive layer. The outstar looks like the fan-out node. Table 5 shows the different frequency domain methods and various years on Full Counter Propagation Neural Network for image watermarking.

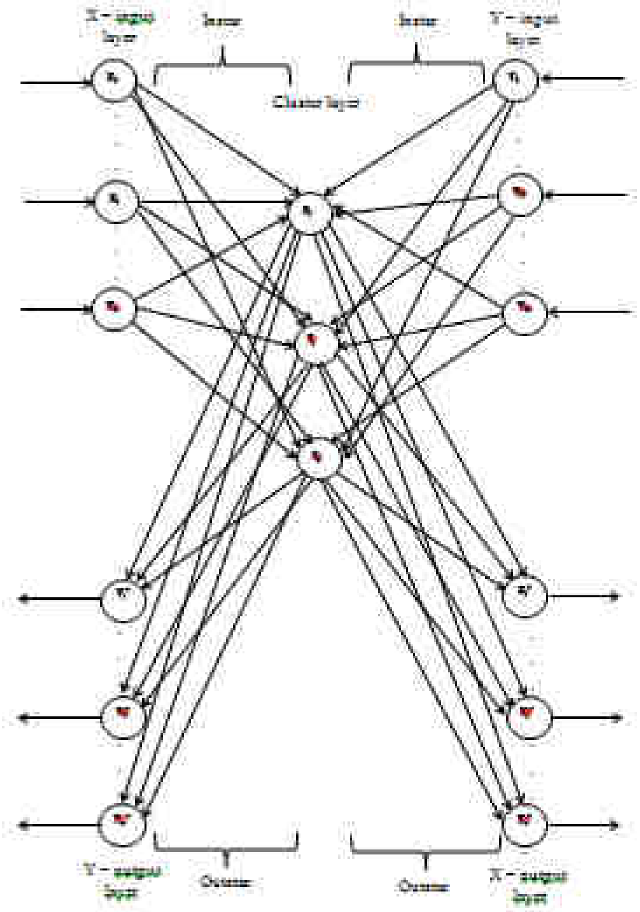

Fig. 13: Architecture of a of Full Counter Propagation Network

Review of image watermarking by using Full Counter Propagation Neural Network is presented below.

A specific designed full counter- propagation neural network for digital image watermarking has been presented in [64]. The watermark is embedded in the synapses of FCNN instead of the cover image. The result shows that their proposed FCNN could resist various attacks. Chuan-Yu Chang et al. [65] proposed a novel method called Full Counter-propagation Neural Network (FCNN) for digital image watermarking, in which the watermark is embedded and extracted through specific FCNN. The experimental results show that their proposed method is able to achieve robustness, imperceptibility and authenticity in watermarking.

Naghsh Nilchi et al. [66] presented a new robust digital image watermarking technique based on discrete cosine transform (DCT) and neural network. FCNN has been used to simulate the perceptual and visual characteristics of the original image. The implementation results have shown that their watermarking algorithm has an acceptable robustness versus different kinds of watermarking attacks.

Summrina Kanwal Wajid et al. [67] proposed a method based on Full Counter Propagation Neural Network (FCPN) to train multiple grey or color cover images to produce a desired watermark image. The specialty of their technique is its lesser complexity and easy apprehension.

Table 5: Different frequency domain methods on Full Counter Propagation Neural Network for image watermarking

Name of the Authors	Year	Transform	Achievements
Chuan-Yu Chang et al. [64]	2005	-	Robustness
Chuan-Yu Chang et al. [65]	2005	-	Robustness, imperceptibility and authenticity
A.R. Naghsh Nilchi et al. [66]	2008	Discrete Cosine Transform	Robustness
Summrina Kanwal Wajid et al. [67]	2009	-	Lesser complexity
Ashish Bansal et al. [68]	2010	Discrete Cosine Transform	Complexity, capacity and PSNR
Amarjeet Kaur et al. [69]	2013	Discrete Cosine Transform	Robustness
Amarjeet Kaur et al. [70]	2013	-	Imperceptibility

Ashish Bansal et al. [68] proposed a novel approach using Full Counter propagation Neural Network for Watermarking. Chun –Yu-Chang et al. [64] proposed a wonderful technique of embedding the watermarks into synapses of FCNN rather than cover image. This helped to increase robustness and reduce imperceptibility problems to a great extent. However, with their modification, FCNN can be practically employed to obtain a successful watermarking scheme with better time complexity, higher capacity and higher PSNR. Amarjeet Kaur et al. [69] proposed Hopfield model and full counter propagation neural network (FCNN) techniques to overcome the remedies such as peak signal to noise ratio (PSNR) and to maintain the quality of the image. Their result shows that Hopfield model can resist various attack better than FCNN. Amarjeet Kaur et al. [70] proposed Hopfield model and full counter propagation neural network (FCNN) techniques for two images as a cover image and one image in the form of text as watermark image to overcome the remedies such as peak signal to noise ratio (PSNR) of watermarked image and to check the quality of the image normal correlation is also calculated by using six parameters.

4.5. Synergetic Neural Network

Synergetic neural network (SNN) associates synergetic with artificial neural network, it can carefully deal with the behaviour of network in the mathematical theory, and have the advantage of fast learning, short pattern recalling time. Synergetic neural network (SNN) developed by Haken [71] describes the pattern recognition process in the human brain which tries to achieve the learned model with fast learning and no false state. Table 6 shows the different frequency domain methods and various years on Synergetic Neural Network for image watermarking.

Table.6: Different frequency domain methods on Synergetic Neural Network for image watermarking

Name of the Authors	Year	Transform	Achievements
Chen Yongqiang et al. [72]	2009	Discrete Wavelet Transform	Imperceptibility and robust
Chen Yongqiang et al. [73]	2009	Discrete Cosine Transform	Imperceptibility and robustness
Chen Yongqiang et al. [74]	2009	Discrete Wavelet Transform	Security, imperceptibility and robustness

Review of image watermarking by using Synergetic Neural Network is presented below.

A novel optimal color image watermarking scheme in DWT domain is proposed in [72]. In the procedure of watermark embedding, the watermark is embedded into host color image through selecting and modifying the wavelet coefficients using Genetic Algorithm (GA) to improve the imperceptibility of watermarked image. In order to identify the owner of extracted watermark, Synergetic Neural Network (SNN) is used in the watermarking identification to overcome the limitation of correlation analysis or the human sense organ after some attacks. The results of their scheme realization and robust experiments show that this novel scheme has preferable performance.

To prove the validity of the optimal image watermark is proposed in [73]. Genetic algorithm is a kind of evolutionary optimization technique that can improve watermark imperceptibility and robustness. Through well-connected fitness function with peak signal-to-noise ratio and normalized cross-correlation coefficient, the watermark sequence encrypted by two-dimensional chaotic stream encryption from a meaningful image is embedded into the DCT coefficients of host image through getting an optimal intensity by genetic algorithm. Synergetic neural network, offering a new and different approach to the construction of highly parallel structures for pattern recognition, is used in watermark identification to identify the extracted watermark and has the ability to recognize the original watermark quickly and accurately after attacks. In [74] their scheme they used the two-dimensional chaotic stream encryption, GA and SNN to meet these watermarking properties. In their scheme realization and robust experiments, the results prove the feasibility and validity of their proposed scheme.

V. CONCLUSION

This paper has studied a several important issues and recent developments of neural networks for image watermarking. A few papers are found using spatial domain, while many papers are carried out in frequency domain by using the different types of neural networks such as, Artificial Neural Network (ANN), Back propagation Neural Network (BPNN), Radial Basis Function Neural Network (RBF), Hopfield Neural Network, Full Counter Propagation Network (FCPN), Synergetic Neural Network (SNN). In this study, the BPNN is found to be better for the image watermarking process. There are many other research topics have been studied the most important aspects of neural networks in solving image watermarking problems.

In future work, a new algorithm can be designed to embed and extract the watermark using BPNN. The error will be minimized to a minimum value using the back propagation neural network which has to be trained for performing the testing phase. In the testing process, the trained neural network is to check whether the testing data will predict the maximum watermarking strength.

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