Literature Review of Wavelet Based Digital Image Watermarking Techniques

Vaishali S. Jabade
Assistant Professor
Vishwakarma Institute of Technology, Pune, India

Dr. Sachin R. Gengaje
Professor
Walchand Institute of Technology, Solapur, India

ABSTRACT
In image watermarking, information is embedded into cover media to prove ownership. Various watermarking techniques have been proposed by many authors in the last several years which include spatial domain and transform domain watermarking. Wavelet based image watermarking is gaining more popularity because of its resemblance with the human visual system. This paper elaborates suitability of wavelet transform for image watermarking, wavelet transform based image watermarking process, classification and analysis of wavelet based watermarking techniques. The purpose of this paper is to provide a comprehensive review of the existing literature available on wavelet based image watermarking methods. It will be useful for researchers to implement effective image watermarking method.

Keywords
Digital Image Watermarking, Discrete Wavelet Transform

1. INTRODUCTION
The digital revolution has resulted in explosion of knowledge in today's technology-driven economy. It has resulted in encouragement and motivation for digitization of the intellectual artefact. Since the digital data has no difference in quality between an original and its copy, it is impossible to distinguish original from the copy [1]. Digital media causes extensive opportunities for piracy of copyrighted material. The ways and means are required to detect copyright violations and control access to these digital media. This stimulated development of digital watermarking. While the Internet has created opportunities for authors, musicians, photographers, artists and software engineers to market their works, it has also made copyright infringement easier than ever before. Due to lack of security, images can be easily duplicated and distributed without owner's consent. Digital image watermarking is modification of the original image data by embedding a watermark containing key information such as authentication or copyright codes [2]. Watermark is perceptible or imperceptible identification code which uniquely identifies ownership of an image. It is permanently embedded into the host image. The embedded watermark may be pseudo-random binary sequence, chaotic sequence, spread spectrum sequence or binary/gray scale image. Such watermarks are used for objective detection using correlation measures. Binary or gray image is meaningful and is used for subjective detection. The examples of this type of watermark include date, serial number, logo or any other kind of identification mark [3].

1.1 Applications of Digital Image Watermarking
There are diverse applications of image watermarking. These are listed as follows [4].

1.1.1. Copyright Protection
When a new work is produced, copyright information can be inserted as a watermark. In case of dispute of ownership, this watermark can provide evidence.

1.1.2 Broadcast Monitoring
This application is used to monitor unauthorized broadcast station. It can verify whether the content is really broadcasted or not.

1.1.3 Tamper Detection
Fragile watermarks are used for tamper detection. If the watermark is destroyed or degraded, it indicates presence of tampering and hence digital content cannot be trusted.

1.1.4 Authentication and Integrity Verification
Content authentication is able to detect any change in digital content. This can be achieved through the use of fragile or semi-fragile watermark which has low robustness to modification in an image.

1.1.5 Fingerprinting
Fingerprints are unique to the owner of digital content and used to tell when an illegal copy appeared.

1.1.6 Content Description
This watermark can contain some detailed information of the host image such as labelling and captioning. For this kind of application, capacity of watermark should be relatively large and there is no strict requirement of robustness.

1.1.7 Covert Communication
It includes exchange of messages secretly embedded within images. In this case, the main requirement is that hidden data should not raise any suspicion that a secret message is being communicated.

1.2 Attacks on Watermarked Image
Attacks on watermarked image are distortions in watermarked image. These attacks may be intentional or un-intentional. An image watermarking method can be judged against such relevant attacks. The attacks are broadly classified as signal processing attacks and geometric attacks.

1.2.1 Signal Processing Attacks

Signal processing attacks are also called as image processing attacks or non geometric attacks. These common signal processing attacks may include compression of image, addition of noise like Gaussian or salt and pepper noise, gamma correction, filtering, brightness, sharpening, histogram equalization, averaging, collusion, printing, scanning etc.

1.2.2 Geometric Attacks

Geometric attacks include basic geometric transformations in an image. These include geometrical distortions like rotation, scaling, translation, cropping, row-column blanking, warping etc. Geometric attacks attempt to destroy synchronization of detection thus making the detection process difficult and even impossible.

2. ATTRIBUTES OF DIGITAL IMAGE WATERMARKING

The requirements for image watermarking can be treated as characteristics, properties or attributes of image watermarking. Different applications demand different properties of watermarking. Requirements of image watermarking vary and result in various design issues depending on image watermarking applications and purpose. These requirements need to be taken into consideration while designing watermarking system. There are basic five requirements as follows [5].

2.1 Fidelity

Fidelity can be considered as a measure of perceptual transparency or imperceptibility of watermark. It refers to the similarity of un-watermarked and watermarked images. This perspective of watermarking exploits limitation of human vision. Watermarking should not introduce visible distortions as it reduces commercial value of the watermarked image.

2.2 Robustness

Watermarks should not be removed intentionally or unintentionally by simple image processing operations Hence watermarks should be robust against variety of such attacks. Robust watermarks are designed to resist normal processing. On the other hand, fragile watermarks are designed to convey any attempt to change digital content.

2.3 Data Payload

Data payload is also known as capacity of watermarking. It is the maximum amount of information that can be hidden without degrading image quality. It can be evaluated by the amount of hidden data. This property describes how much data should be embedded as a watermark so that it can be successfully detected during extraction.

2.4 Security

Secret key has to be used for embedding and detection process in case security is a major concern. There are three types of keys used in watermark systems: private-key, detection-key and public-key. Hackers should not be able to remove watermark with anti-reverse engineering research algorithm.

2.5 Computational Complexity

Computational complexity indicates the amount of time watermarking algorithm takes to encode and decode. To ensure security and validity of watermark, more computational complexity is needed. Conversely, real-time applications necessitate both speed and efficiency.

3. DISCRETE WAVELET TRANSFORM

Discrete Wavelet transform (DWT) is a mathematical tool for hierarchically decomposing an image. It is useful for processing of non-stationary signals. The transform is based on small waves, called wavelets, of varying frequency and limited duration. Wavelet transform provides both frequency and spatial description of an image. Unlike conventional Fourier transform, temporal information is retained in this transformation process. Wavelets are created by translations and dilations of a fixed function called mother wavelet. This section analyses suitability of DWT for image watermarking and gives advantages of using DWT as against other transforms.

3.1 Characteristics of DWT

The wavelet transform decomposes the image into three spatial directions, i.e. horizontal, vertical and diagonal. Hence wavelets reflect the anisotropic properties of HVS more precisely. Fig. 1 shows DWT decomposition of an image using three level pyramid.

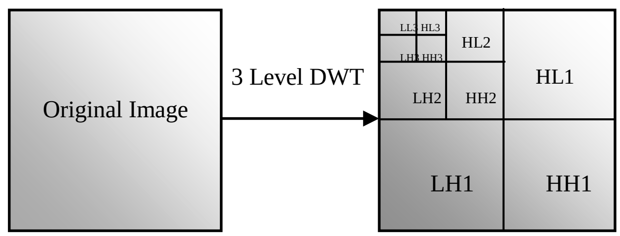

Fig.1 DWT Decomposition of an Image using 3-Level Pyramid

1. Wavelet Transform is computationally efficient and can be implemented by using simple filter convolution.
2. With multi-resolution analysis, image can be represented at more than one resolution level. Wavelets allow image to be described in terms of coarse overall shape and details ranging from broad to narrow.
3. Magnitude of DWT coefficients is larger in the lowest bands (LL) at each level of decomposition and is smaller for other bands (HH, LH, HL).
4. The larger the magnitude of wavelet coefficient, the more significant it is.
5. Watermark detection at lower resolutions is computationally effective because at every successive resolution level, less no. of frequency bands are involved.
6. High resolution sub bands help to easily locate edge and textures patterns in an image.

3.2 Advantages of DWT

The suitability of wavelet transform for image watermarking can be considered because of following reasons.

1. Wavelet transform can accurately model HVS than other transforms like Discrete Fourier Transform (DFT) [6] or Discrete Cosine Transform (DCT) [7, 8]. This allows higher energy watermarks in regions where HVS is less sensitive. Embedding watermark in these regions allow us to increase

robustness of watermark, with no much degradation of image quality.

2. Wavelet coded image is a multi-resolution description of image. Hence an image can be shown at different levels of resolution and can be sequentially processed from low resolution to high resolution. The advantage of such approach is that the features of an image that might go undetected at one resolution may be easy to spot at another.

3. Visual artefacts introduced by wavelet coded images are less evident compared to DCT because wavelet transform doesn't decompose image into blocks for processing. At high compression ratios, blocking artefacts are noticeable in DCT as against wavelet transformed images.

4. DFT and DCT are full frame transform. Hence, any change in the transform coefficients affects entire image except if DCT is implemented using a block based approach. However DWT has spatial frequency locality. It means it will affect the image locally, if watermark is embedded.

5. Another advantage is that current image compression standard JPEG 2000 is based on wavelet transform.

3.3 Image Watermarking Process in Wavelet Domain

The image watermarking process in wavelet domain includes embedding of watermark by modifying wavelet coefficients of original image, extraction and detection of watermark from watermarked image [9].

3.3.1 Embedding Watermark

To embed watermark, the original image will be decomposed into N different levels. The watermark is then embedded in DWT coefficients. The assumption is that any modification to an image leads to changes in wavelet coefficients and embedded watermark. Inverse discrete wavelet transform is taken to get watermarked image. Fig. 2 shows embedding watermark in wavelet domain.

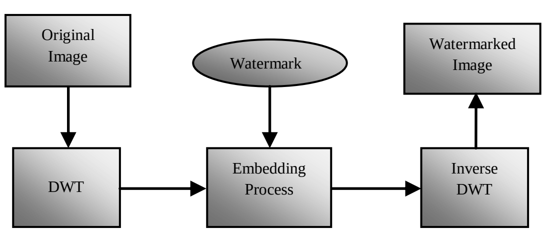

Fig. 2 Embedding Watermark in Wavelet domain

3.3.2 Transmission

The transmission process can be seen as distribution of watermarked image through watermark channel. Possible attacks in the broadcast channel may be intentional or accidental.

3.3.3 Extraction and Detection of Watermark

Extraction of watermark from watermarked image may be blind or non-blind depending on requirement of original image for extraction. In involves comparison of both the images or comparison with the threshold. The correlation between the extracted watermark and the embedded watermark signal is then calculated. Detection process allows the owner to be identified and provides information to the intended recipient depending on threshold value**.** Watermark detection at lower resolutions is computationally effective because at each successive resolution level, smaller frequency bands are involved.

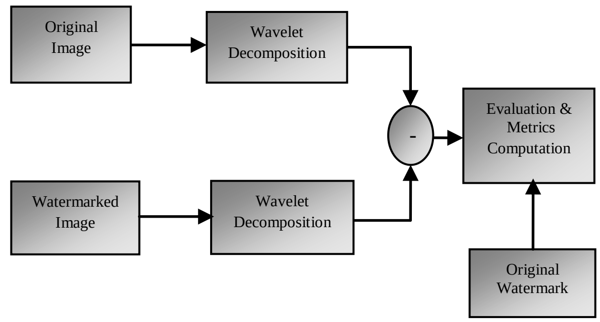

Fig. 3 Extraction and Detection of Watermark

4. PERFORMANCE ANALYSIS

The performance analysis for watermarked image and extracted watermark is done using different statistical measures. The watermark robustness depends directly on the embedding strength, which in turn influences visual degradation of the image. For benchmarking and performance evaluation, visual degradation due to embedding is important. Since there is no universal metric, we review in this section the most popular pixel based distortion criteria [10].

4.1 Watermark Imperceptibility Analysis

The imperceptibility of watermarked image is qualitatively decided by visual artefacts in watermarked image. Different literatures have reported different metrics. As a quantitative measure, following metrics are used. The notations used are listed below.

$X(i,j)$: Original image,
$X'(i,j)$: Watermarked image, and
Nt : Size of image

4.1.1 Mean Square Error (MSE)

Mean Square Error between original image and watermarked image is calculated as follows:

$$MSE = \frac{1}{Nt}\sum_{i,j}\left(X(i,j) - X'(i,j)\right)^2 \qquad (1)$$

4.1.2 Peak Signal to Noise Ratio (PSNR)

PSNR is calculated between the original and the watermarked image. Larger the PSNR value, more similar is watermarked image to the original image. This image quality metric is defined in decibels as:

$$PSNR = 10\ log_{10}\frac{(255\ \times 255)}{MSE} \qquad (2)$$

If the PSNR value is greater than 30dB then the perceptual quality is acceptable.

4.1.3 Image Fidelity (IF)

Image fidelity is a measure of imperceptibility or transparency of watermarked image and is calculated as follows:

$$IF = 1 - \frac{\sum_{i,j}(X(i,j) - X'(i,j))^2}{\sum_{i,j}(X(i,j))^2} \qquad (3)$$

High value of image fidelity is desirable.

4.2 Watermark Robustness Analysis

The robustness of watermarked image is qualitatively analysed by visual artefacts in extracted watermark in case of visually meaningful logo watermark. As a quantitative measure, following metrics are used in case of logo or binary sequence watermark. These indicate reliability and readability of extracted watermark. The notations used are listed below.

$W(i,j)$: Original Watermark
$W'(i,j)$: Extracted Watermark

4.2.1 Correlation Coefficient (CRC)

This metric is used to analyze compatibility of original watermark and extracted watermark. The value ranges from 0 to 1.

$$CRC = \frac{\sum_i \sum_j W(i,j)W'(i,j)}{\sqrt{\sum_i \sum_j W(i,j)^2 \times \sum_i \sum_j W(i,j)^2}} \qquad (4)$$

4.2.2 Similarity Measure (SIM)

A similarity measure also called as similarity coefficient (SC) between extracted watermark and embedded watermark is used for objective judgment of the extraction fidelity.

$$SIM(W,W') = \frac{\sum_i \sum_j W(i,j)W'(i,j)}{\sum_i \sum_j W'(i,j)^2} \qquad (5)$$

4.2.3 Bit Error Rate (BER)

This performance metric is suitable for random binary sequence watermark. The parameter is defined as ratio between number of incorrectly decoded bits and length of the binary sequence. BER indicates probability of incorrectly decoded binary patterns. It is defined as follows.

$$BER = \frac{DB}{NB} \qquad (6)$$

where,
DB : No. of incorrectly decoded bits
NB : Total no. of bits

4.2.4 Accuracy Ratio (AR)

It is used to evaluate similarity between the original watermark and extracted one. It is defined as ratio of number of correct bits between original watermark and extracted watermark and number of original watermark bits. It is defined by following equation.

$$AR = \frac{CB}{NB} \qquad (7)$$

where,
CB : No. of correct bits
NB : Total no. of bits

AR value closer to 1 indicates more similarity between extracted and original watermark.

5. REVIEW OF WAVELET BASED IMAGE WATERMARKING

Review of image watermarking based on DWT is carried out and presented below.

M. Barni et al. [11] have developed an improved wavelet-based watermarking through pixel-wise masking. It is based on masking watermark according to characteristics of HVS. The watermark is adaptively added to the largest detail bands. The watermark weighing function is calculated as a simple product of data extracted from HVS model. The watermark is detected by correlation. Victor et al. [12] have developed an algorithm that relies upon adaptive image watermarking in high resolution sub-bands of DWT. Weighting function is the product expression of data extracted from the HVS model.

N. Kaewkamnerd and K.R. Rao [13] developed a wavelet based image adaptive watermarking scheme. Embedding is performed in the higher level sub-bands of wavelet transform, even though this can clearly change the image fidelity. In order to avoid perceptual degradation of image, the watermark insertion is carefully performed while using HVS. Bo Chen and Hang Shen [14] developed a new robust fragile double image watermarking algorithm using improved pixel-wise masking model and a new bit substitution based on pseudo-random sequence. The method embeds robust and fragile watermark into the insensitive part and sensitive part of wavelet coefficients making two watermarks non-interfering.

Peng Liu and Zhizhong Ding [15] proposed a blind image watermarking scheme based on wavelet tree quantization. The largest two coefficients are selected as significant coefficients and the difference between them is taken as significant difference. A watermark bit is embedded by comparing the significant difference with an average significant difference value and maximum difference coefficients are quantized. Zhao Dawei et al. [16] suggested a chaos-based robust wavelet-domain watermarking algorithm. They apply wavelet transform locally and embed watermark based on chaotic logistic map.

5.1 Review on Types of Wavelet used for Image Watermarking

The type of wavelet to be used for image watermarking depends on the following aspects:

1. Symmetry: The wavelets used should be symmetric as human visual system is less sensitive to symmetry.
2. Perfect Reconstruction: To retain the quality of watermarked image and imperceptibility, the decomposed image should be perfectly reconstructed.

Literature has reported use of various wavelet filters. The wavelets used in image watermarking by researchers are summarized below:

5.1.1 Haar Wavelet

Ester Yen and Kai-Shiang Tsai [17] developed Haar DWT based gray scale watermark for copyright protection. They have proposed visual cryptographic approach to generate two random parts of watermark. One is embedded in cover image and other one is kept as a secret key for watermark extraction. The watermark survives in watermarked even after several attacks.

5.1.2. Daubechies Wavelet

Kundur et al. [18] decomposed binary logo through DWT. The watermark is scaled by a sailence factor, computed on a block by block basis, depending on local image noise sensitivity. It is then repeatedly added to the subbands of DWT decomposition of host image. Visual masking is thus exploited upto only block resolution. D. Kundur and D. Hatzinakos developed scheme of digital watermarking using multiresolution wavelet decomposition. A binary code is embedded by suiatbly quantizing the coefficients of detail bands. For watermark recovery, the embedded binary code is estimated by anlyzing coefficients quantization. Once the code is estimated, it is correlated and result is compared to a threshold chosen on the basis of a given false positive probability.

5.1.3 Bi-orthogonal Wavelet

Bi-orthogonal wavelet uses one basis function for decomposition and the other basis function for reconstruction. They exhibit linear phase property. It satisfies both the properties required for image watermarking that is perfect reconstruction and symmetry.

5.1.4 Complex Wavelet

Complex wavelets can provide both shift invariance and good directional selectivity, as against in the traditional wavelet transform. However, it can not satisfy the condition of perfect reconstruction. Dual tree complex wavelet transform (DT-CWT) which employs a dual tree of wavelet filters to obtain the real and imaginary parts of complex wavelet coefficients, can solve this problem. The DT-CWT introduces limited redundancy (4:1 for 2-dimentional signals) and allows the transform to provide approximate shift invariance and directionally selective filters (properties lacking in the traditional wavelet transform) while preserving the usual properties of perfect reconstruction. Taking advantage of DT-CWT, Lan Hongxing et. al. improves the embedding scheme and extracting scheme, and uses the spread spectrum in embedding scheme and Error correction code [19].

5.1.5 Wavelet Packets

Wavelet packets provide better decomposition than classical wavelet from spatial frequency aspect, the classical wavelet decomposition just decomposes low frequency band recurrently, while wavelet packets decomposition decompose low frequency band as well as three high frequency bands at the same time. This type of decomposition allows us to choose bands more widely [20]. Cong Jin [21] developed a wavelet packets-based robust blind watermark scheme using chaotic encryption. Two chaotic sequences are modulated according to characters of chaotic system, used for sub image extraction and watermark encryption. The binary watermark information is changed into one dimension sequence by module arithmetic. For embedding watermark, the original image is partitioned into 8×8 blocks, quarter sub image is extracted by another chaotic sequence and then wavelet packet decomposition is applied on it. Watermark is embedded using relationships of wavelet packet coefficients.

5.1.6. Balanced Multiwavelet

Balanced multiwavelet transform achieves simultaneous orthogonality and symmetry without requiring any input pre-filtering. This leads to considerable reduction in computational complexity making this transform a good candidate for real-time watermarking implementations. Miang Zuang Zang et al. [22] in "An Adaptive Digital Watermarking Algorithm Based On Balanced Multiwavelet" proposed visual masking model based on single wavelet transformation and Just Noticeable Differrence. The watermark algorithm is achieved by changing the mean value of high frequency area. Multiwavelet offers better smoothness, symmetry, orthogonality using coherence among neighbourhood coefficients. The strength of the embedded watermark is controlled according to local properties of the host image. This has been achieved by perceptual model, which is only dependent on the image activity and is not on the multi-filter sets used, unlike scalar wavelets. The watermark embedding scheme is based on the principles of spread-spectrum communications to achieve higher watermark robustness. The optimal bounds for the embedding capacity are derived using a statistical model for balanced multi-wavelet coefficients of the host image. The data hiding capacity or payload for balanced multi-wavelets provide higher watermarking rates.

5.1.7. Stationary Wavelet

Hey Jiang and Liu Jianjun [23] proposed an algorithm based on stationary wavelet transform to embed watermark in primitive digital terrain model images. The embedding position is selected in gentle terrains by analyzing slope of the image. The embedding intensity is optimized by an optimization model. The objective function is defined as similarity between original watermark and extracted watermark.

5.1.8 Morphological Wavelet

Lin Zhuang [24] proposes a novel multipurpose digital watermarking algorithm in morphological wavelet transform domain. Morphological wavelet differs from classical linear wavelet as mathematical morphological operators such as erosion and dilation are used in the former. It serves dual purpose of notifying copyright owner with a visible gray image watermark and protecting copyright with an invisible binary image watermark. Both the watermarks are embedded in different blocks with different methods. The morphological wavelet has state-of-the-art performance to make visible watermark hard to remove and invisible watermark robust.

5.1.9 Non-tensor Wavelet

Qingyan He [25] proposed image watermarking scheme using non-tensor Wavelets. The desirable property of this wavelet is detection of more singularities of the host image with reflecting whole orientation. Traditional DWT considers only three orientations. This facilitates more details in middle and high frequency regions optimizing imperceptibility and robustness requirements.

5.1.10 Berkeley Wavelet

Remya Ravindran and Soman K. P. [26] developed Berkeley Wavelet Transform (BWT) based image watermarking. BWT is a two dimensional triadic wavelet transform. These are localized in space, tuned in spatial frequency and orientation. Hence it forms a set which is approximately scale invariant. BWT is a complete, orthonormal basis and hence it is inexpensive to compute, manipulate, and invert. BWT consists of four pairs of mother wavelets at four orientations. In each pair, one of the wavelets has odd symmetry and the other wavelet has even symmetry. Translation and scaling of the whole set (plus a single constant term) of wavelet results in a complete, orthonormal basis in two dimensions. The BWT comprises eight mother wavelets, in four pairs. Each pair has a different orientation as 0, 45, 90, and 135 degrees. The properties of BWT make useful in the situations where computational power is limited.

6. OPTIMIMIZATION TECHNIQUES FOR DWT IMAGE WATERMARKING

In recent years, wavelet based watermarking algorithms have been improved using optimization techniques. This includes singular value decomposition, independent component analysis, support vector machine, artificial neural network, optimization algorithms such as genetic algorithm and fuzzy logic.

6.1 Singular Value Decomposition (SVD)

Singular value decomposition is one of the most powerful numerical analysis tool used to analyze matrices. In SVD transformation, a matrix can be decomposed into three matrices that are of the same size as original matrix. SVD transformation preserves both one-way and non-symmetric properties, usually not obtainable in DCT and DFT transformations. Wie Cao et.al developed SVD in DT-CWT domain [27]. Using SVD in digital image processing has advantages like the size of the matrices from SVD transformation is not fixed and can be a square or a rectangle; singular values in a digital image are less affected if general image processing is performed and singular values contain intrinsic algebraic image properties. The singular values of the host image are modified to embed the watermark image by employing multiple singular functions. Watermark is embedded and extracted by adjusting value between selected coefficients and actual output trained by support vector regression. SVD factorization is done on different non-overlapping blocks by taking wavelet transform. Watermarks are generated by singular value of different block [28 -30].

6.2 Independent Component Analysis (ICA)

Independent component analysis is recently developed technique for image watermarking. ICA is applied to compute statistically independent transform coefficients where watermark is embedded. The main advantage of this approach is that on one hand, each user can define its own ICA-based transformation. These transformations behave as private-key. An orthogonal watermark is developed to blindly detect it with a simple matched filter. ICA consists of projecting a set of components onto another statistically independent set. This approach assumes multiple-input multiple- output model and has been successfully applied to image watermarking. ICA presumes watermarked image as a mixture of original image and watermark. The mixture image can be separated to estimate this watermark. Although ICA is utilized to detect and extract the watermark, they are still vulnerable to geometric distortion attack. Thai Duy Hiena [31] developed "Robust multi-logo watermarking by Redundant DWT and ICA". To embed logo watermarks, the original image is decomposed by Redundant DWT and watermarks are embedded into middle frequency at LH and HL sub-bands. An intelligent ICA-based detection is proposed which directly extracts watermarks in spatial domain. A novel characteristic of this detection is that it does not require the transformation process to extract the watermarks.

6.3 Artificial Neural Network (ANN)

An artificial neural network (ANN) is a mathematical model or computational model that is inspired by the structure and/or functional aspects of biological neural networks. A neural network consists of an interconnected group of artificial neurons, and it processes information using a connectionist approach to computation. They are usually used to model complex relationships between inputs and outputs Chuan-Yu Chang et. al. [32] introduced copyright authentication for images with a full counter-propagation neural network (FCNN). Most attacks do not degrade the quality of detected watermark image as FCNN has storage and fault tolerance. Chen Yong Qiang devised an optimal image watermark algorithm using synergetic neural network. Quan Liu et. al. [33] designed and realized meaningful digital watermarking algorithm based on Radial Basis Function (RBF) neural network. RBF Neural network is used to simulate human visual system to determine watermark embedding intensity.

6.4 Support Vector Machine (SVM)

SVM is a novel machine learning method introduced by Vapnik. SVM has been successfully applied to numerous classification and pattern recognition problems. SVM is claimed to lead enhanced generalization properties. In recent years, SVM has been used for digital watermarking. SVMs are easier and better to use than traditional neural network models. The idea of SVM is to construct a mapping model from input data to output data which are also defined as features for input data and targets for output data. There are two data sets in classification, i.e., training data and testing data. Each training data contains several features and one target. After SVM learns using the training data, SVM can produce a model to predict the corresponding target of the test data. Yuanhai Shao developed multiwavelet based digital watermarking with support vector machine technique [34].

6.5 Genetic Algorithm (GA)

Chin-Shiuh Shieha et. al. [35] developed genetic watermarking based on transform-domain techniques. A genetic algorithm is a search heuristic used for optimization. It generates solutions using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover. The evolution usually starts from a population of randomly generated individuals and happens in generations. In each generation, the fitness of every individual in the population is evaluated, multiple individuals are stochastically selected from the current population (based on their fitness), and modified (recombined and possibly randomly mutated) to form a new population. The new population is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population. In case of watermarking, the singular values (SVs) of the host image are modified by multiple scaling factors to embed the watermark image. Modifications are optimized using GA to obtain the highest possible robustness without losing the transparency.

6.6 Fuzzy Logic

Fuzzy logic is a multi-valued logic with un-sharp boundaries in which membership is a matter of degree. Fuzzy set theory has been introduced by Lotfi A. Zadeh as an extension of the classical crisp set theory. The basic concept underlying fuzzy logic is that variable values are words or linguistic variables, rather than numbers. Although words are inherently less precise than numbers, their use is closer to human intuition. Furthermore, computing with words exploits the tolerance for imprecision and thereby lowers the cost of solution. Watermarking based on fuzzy logic is developed to extract human eye sensitivity knowledge. FIS is used to adjust the watermark strength and to insert maximum possible watermark length that can be embedded without degrading the quality of image. Nizar Sakr et. al. [36] used a dynamic fuzzy logic approach to adaptive HVS based watermarking. The watermark is adaptively embedded in significant DWT coefficients that are selected in higher level sub bands. In order to determine texture activity, only sub band in which watermarking will be performed is considered rather than considering the sub bands with all three orientations. Santi P. Maity and Seba Maity [37] developed a multistage spread spectrum watermark detection technique using fuzzy logic. There are other methods suggested based on fuzzy c-means clustering, adaptive fuzzy clustering, elastic fuzzy approach, fuzzy inference filter and fuzzy inference system.

7. CONCLUSION

The watermarking research is progressing very fast and various researchers from various fields are focusing to develop robust watermarking schemes. Despite of the efforts taken during last few years towards developing effective watermarking scheme, none of the techniques is robust to all possible attacks and image processing operations. This paper emphasizes wavelet based watermarking which is widely used today and analyses various methods and approaches to wavelet based image watermarking in detail. Also, it reviews the applications and attributes of image watermarking. Many new research directions arise in image watermarking for developing a technique to satisfy two conflicting requirements. First, the watermark needs to be resistant against intentional and unintentional removal. Second, watermarked image needs to sustain a good fidelity i.e. watermark needs to be perceptually transparent. Wavelet based image watermarking provides a good platform for such requirement.

8. REFERENCES

[1] Thi Hoang Ngan Le, Kim Hung Nguyen, Hoai Bac Le, "Literature Survey on Image Watermarking Tools, Watermark Attacks, and Benchmarking Tools", *Second IEEE International Conferences on Advances in Multimedia, 2010,* pp.67-73.

[2] Mr. Manjunatha Prasad. R, Dr.Shivaprakash Koliwad "A Comprehensive Survey of Contemporary Researches in Watermarking for Copyright Protection of Digital Images", *International Journal of Computer Science and Network Security (IJCSNS), Vol.9 No.4, April 2009,* pp.91-102.

[3] Wan Adnan, W.A.; Hitam, S.; Abdul-Karim, S., Tamjis, M.R., "A review of image watermarking", *Research and Development, SCORED, 2003,* pp. 381-384.

[4] Vidyasagar M. Potdar, Song Han, Elizabeth Chang, "A Survey of Digital Image Watermarking Techniques", *3rd IEEE International Conference on Industrial Informatics (INDIN),* 2005, pp.709-713.

[5] Santa Agreste, Guido Andaloro, Daniela Prestipino, Luigia Puccio, "An Image Adaptive Wavelet Based Watermarking of Digital Images", Science Direct *Journal of Computational and Applied Mathematics*, 2006, pp. 1-9.

[6] Xiao Jun Kang Li Jun Dong, "Study of the Robustness of Watermarking Based on Image Segmentation and DFT", *IEEE International Conference on Information Engineering and Computer Science, ICIECS,* 2009, pp1-4.

[7] Chien Chang Chen and De-Sheng Kao, "DCT Based Reversible Image Watermarking Approach", *Third IEEE International Conference on Intelligent Information Hiding and Multimedia Signal Processing,* 2007, pp 1-5.

[8] Said E. El-Khamy, Fellow IEEE, Mona I. Lotfy and Rowayda A. Sadek, "A Block Based Wavelet Watermarking Technique for Copyright Protection and Authentication", *IEEE Transactions, Vol.1,* 2003, pp. 90-93.

[9] B.N. Chatterji, Manesh Kokare, A. Adhipathi Reddy, Rajib Kumar Jha., "Wavelets for Content Based Image Retrieval and Digital Watermarking for Multimedia Applications", *IEEE Transactions, Vol.2*, 2003, pp.812-816.

[10] F. Kumgollu, A Bouridane, M A Roula and S Boussaktd, "Comparison of Different Wavelet Transforms for Fusion Based Watermarking Applications", *IEEE Transactions, Vol.3, 2003,* pp. 1188-1191.

[11] Barni M, Bartolini F, Piva, "An Improved Wavelet Based Watermarking Through Pixelwise Masking", *IEEE transactions on image processing, Vol. 10,* 2001 pp.783-791.

[12] Victor V., Guzman, Meana, "Analysis of a Wavelet-based Watermarking Algorithm", *IEEE Proceedings of the International Conference on Electronics, Communications and Computer,* 2004, pp. 283-287.

[13] N. Kaewkamnerd and K.R. Rao, "Wavelet Based Image Adaptive Watermarking Scheme", *IEEE Electronic Letters, Vol. 36,*Feb. 2000, pp.312-313.

[14] Bo Chen, Hong Shen, "A New Robust-Fragile Double Image Watermarking Algorithm", *Third IEEE International Conference on Multimedia and Ubiquitous Engineering,*2009, pp. 153-157

[15] Peng Liu, Zhizhong Ding, "A Blind Image Watermarking Scheme Based on Wavelet tree Quantization", *Second IEEE International Symposium on Electronic Commerce and Security,* 2009, pp. 218-222.

[16] Zhao Dawei, Chen Guanrong, Liu Wenbo, "A Chaos-based Robust Wavelet-domain Watermarking Algorithm", *IEEE International Conference on Multimedia and Expo (ICME),* 2004.

[17] Ester Yen, Kai-Shiang Tsai, "HDWT-based Grayscale Watermark For Copyright Protection", Expert Systems with Applications 35, Elsevier,2008, pp. 301–306.

[18] D. Kundur and D. Hatzinakos, "Digital Watermarking using Multiresolution Wavelet Decomposition",

*Proceedings, IEEE International Conference Acoustic, Speech, Signal Processing,Vol. 5,*1998, pp. 2969-2972

[19] Lan Hongxing, Chen Songqiao, Li Taoshen, Hu Aina, "A Digital Watermarking Algorithm Based on Dual-tree Complex Wavelet Transform", 9th *International Conference for Young Computer Scientists,* IEEE Computer Society, 2008, pp. 1488-1492.

[20] Alexandre H. Paqueta, Rabab K. Wardb, Ioannis Pitasc, "Wavelet Packets-Based Digital Watermarking For Image Verification And Authentication", Signal Processing, 83, Elsevier, 2003, pp. 2117 – 2132.

[21] Cong Jin, Shu-Wei Jin, "Wavelet Packets-Based Robust Blind Digital Watermark Scheme", IEEE International Conference on Wavelet Analysis and Pattern Recognition, Aug. 2008, pp. 724-728.

[22] Ming Ziang Zang, Na Zang, Jian Guo Jiang, "An Adaptive Digital Watermarking Algorithm based on Balanced Multi-Wavelet", Fifth IEEE International Conference on Information Assurance and Security, 2009, pp.243-246.

[23] Hey Jiang and Liu Jianjun, "A Digital Watermarking Algorithm for DEM Image Based on Stationary Wavelet Transform", *Fifth IEEE International Conference on Information Assurance and Security,* 2009, pp. 221-224.

[24] Lin Zhuang, "Multipurpose Digital Watermarking Algorithm Based on Morphological Wavelet Transform", IEEE International Conference on Communications and Mobile Computing, 2009, pp. 396-400.

[25] Qingyan He, Xinge You, Patrick S. Wang, Yuanyuan Tang, "An Image Watermarking Scheme using Non-tensor Wavelets", IEEE International Conference on Wavelet Analysis and Pattern Recognition, 2007, pp. 350-356.

[26] Remya Ravindran.P., Soman K. P., "Berkeley Wavelet Transform Based Image Watermarking", IEEE International Conference on Advances in Recent Technologies in Communication and Computing, 2009, pp. 357-359.

[27] Wei Cao, Yixin Yan, Shengming Li, "Robust Image Watermarking Based on Singular Value Decomposition in DT-CWT Domain", *IEEE International Workshop on Imaging Systems and Techniques, IST,* 2009.

[28] Feng Wen-ge, Liu Lei, "SVD and DWT Zero-bit Watermarking Algorithm", *2nd IEEE International Asia Conference on Informatics in Control, Automation and Robotics*, 2010, pp. 361-364.

[29] Vijay R Ayangar, S. N. Talbar, "A Novel DWT-SVD Based Watermarking Scheme", MCIT, 2010, pp. 105-108.

[30] Ben Wang, Jinkou Ding, Qiaoyan Wen, Xin Liao, Cuixiang Liu, "An Image Watermarking Algorithm Based on DWT, DCT and SVD", *Proceedings of IC-NIDC,*2009, 1034-1038.

[31] Thai Duy Hiena, Zensho Nakaoa, Yen-Wei Chenb, "Robust multi-logo watermarking by RDWT and ICA", Signal Processing 86, Elsevier, 2006, pp. 2981–2993.

[32] Chuan-Yu Chang, Hung-Jen Wang, Sheng-Jyun Su, "Copyright Authentication For Images With A Full Counter-Propagation Neural Network" Science Direct, Expert Systems with Applications 37,2010,pp. 7639–7647

[33] Quan Liu, Xuemei Jiang, "Design and Realization of a Meaningful Digital Watermarking Algorithm Based on RBF Neural Network" *IEEE, 2005* pp. 214-218.

[34] Yuanhai Shao, Wei Chen, Chan Liu, "Multiwavelet based Digital Watermarking with Support Vector Machine Technique", *IEEE, 2008,* pp. 4557-4561.

[35] Chin-Shiuh Shieha, Hsiang-Cheh Huangb, Feng-Hsing Wangc, Jeng-Shyang Pana, "Genetic watermarking based on transform-domain techniques", *Science Direct Pattern Recognition 37, 2004,*pp. 555–565.

[36] Nizar Sakr, Jiying Zhao, and Voicu Groza , "A Dynamic Fuzzy Logic Approach to Adaptive HVS-based Watermarking", *IEEE international workshop on Haptic Audio Visual Environments and their Applications,* 2005, pp. 121-126.

[37] Santi P. Maity and Seba Maity, "Multistage Spread Spectrum Watermark Detection Technique using Fuzzy Logic", *IEEE Signal Processing Letters, Vol.16, No.4,* 2009, pp. 245-248.