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Review on Watermarking Techniques: A Unique Approach for Digital Image Protection

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Abstract— Digital watermarking has become a promising research area to address the challenges faced by the rapid distribution of digital content over the internet. Secret message, logo or label is embedded into multimedia data such as text, image, audio, and video some imperceptibly for various applications like copyright protection, authentication, and tamper detection etc., known as watermarks. Based on the requirement of the application the watermark is extracted or detected by detection device. Digital watermarking gives a seamless interface to the users so that they may be capable of transparently utilizing protected multimedia as compared to traditional methods of security. In this paper, an outline of digital image watermarking and extensive/exhaustive survey of the various techniques used in the area of image watermarking is presented.

Keywords— Digital Watermarking, Spatial domain, DCT, DWT, Arnold Transform, Contuorlet Transform, SVD.

I. INTRODUCTION

The internet has revolutionized many aspects of our lives. The use of information and communication technology (ICT) in day to day processes is continuously rising around the world. Therefore, it seems intuitive that applying internet use to provide real time coverage of stories, publishing newspapers, magazines, music, still images and enhanced video sequences would yield commercial benefits by providing a fast and inexpensive way to distribute their work. It becomes very easy to search and develop any digital content on the internet. But there is a serious problem faced about unauthorized and illegal access and manipulation of multimedia files over internet. Everybody can obtain copies of copyrighted multimedia openly at low cost and with no loss of information, for the commercial profit. That is so called intelligent property piracy. Digital watermarking has come to the attentions of many researchers to protect the Intellectual property rights of publishers, artists, distributers and photographers. Digital watermarking can be defined as to insert a secret message or logo into the original media source by using signal processing method. It provides a high level of security; as the location of embedded information is secret, and the watermark algorithm is also not public.

Digital watermarking consists of watermarking structure, an embedding algorithm and extraction or detection algorithm. Generally, the effective and efficient watermarking scheme should satisfy certain properties to be reliable, such as imperceptibility, invisibility, unambiguity, low complexity, and either fragility or robustness, based on the watermarking application [2]. Also, digital watermarks should be difficult to remove or change without damaging the host signal. Watermarking is used for various applications viz. copyright protection, broadcast monitoring, authentication, fingerprinting. Watermarking techniques can be classified in various ways. Whether there is the need of the original image for watermark extraction or detection, watermarking is classified to blind, semi-blind and non-blind watermarking techniques. It can be classified on the basis of visibility of watermark, whether visible or invisible. On the basis of how the watermark be embedded in the image; either by changing the pixels i.e. spatial or by transformation domain.

This paper is organized into six sections. The subsequent section briefly explains the watermarking system. Section III discuss about watermarking requirements and its applications. Section IV talk about the theoretical foundations of watermarking algorithms. Section V gives the comprehensive study of existing algorithms. And we conclude this paper in Section VI.

II. WATERMARKING SYSTEM

The general framework of watermarking contains three components; embedder, attacker, and detector or extractor of the watermark.

Embedder contains the embedding algorithm that accepts the multimedia signal S, and the watermark, and generates a watermarked signal S_{wm}. The watermarked signal is then communicated to another person via the communication channel. If third person or the communicated one, makes any changes whether malicious or not, then it is termed as an attack. But the term is mainly used when intruder attempts to remove the watermark by changing the contents of multimedia by using common signal processing operations or some intentional attacks like adding noise to the multimedia content. Detecting/extracting algorithm is used by detector/extractor which is then applied over the attacked signal S'_{wm} to detect the presence or extract the watermark from it. If the signal does not undergo any change during transmission, then the watermark will be present and can be extracted easily. The extracted signal is represented as S'.

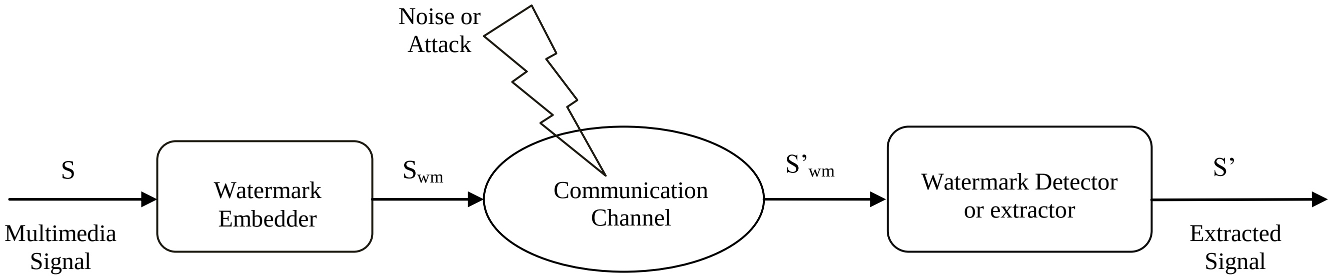


Figure1. General Framework of watermarking system

Classification of watermarks and watermarking techniques can be done in various ways as shown in the table1. Here our survey is limited to digital image watermarking techniques only.

Table1. Watermarking Classifications

Classification	Contents
Multimedia Type	Text, image, audio, video, graphics
Human perceptibility to Watermark	Visible, invisible, dual
Watermark Type	Noise, image
Robustness level	Robust, semi-fragile, fragile
Watermark Embedding Domain	Spatial Domain, Transform Domain, Feature Domain
Use of Keys	Asymmetric, symmetric
Watermark Extraction	Informed, semi-blind, blind
Recovery of the Original Image	Invertible, non-invertible, quasi-invertible, non-quasi invertible
Use at	Source based, destination based
Purpose	Copyright protection, tamper resistance, authentication, annotation, broadcast monitoring, integrity checking

III. WATERMARKING REQUIREMENTS AND APPLICATIONS

For a watermarking system to be effective and reliable it should satisfy some requirements but the relative importance of these requirements depends upon the intended application [3].

A. Transparency

Cox et al. [3] define transparency or fidelity as "perceptual similarity between the original and the watermarked versions of the cover work". Introduction of visible distortions should not be there in watermarked image because if such distortions exist it reduces the commercial value of the image.

B. Robustness

Cox et al. [3] define robustness as the "ability to detect the watermark after common signal processing operations". In other words, embedded watermark should be hard to detect, remove, or replace by illegal sources without degrading the quality of the content to very low such that it becomes unusable.

C. Capacity/Payload

Cox et al. [3] define capacity or data payload as "the number of bits a watermark encodes within a unit of time or work". To represent the uniqueness, the watermark should be able to carry that much information that gives some meaningful message.

D. Detection Error

Detection error can be measured in two ways; false negatives and false positives. False negative is when there is a watermark present; the detector algorithm detects no watermark. False positive is when there is no watermark present; the detector algorithm detects a watermark. The extraction/detection algorithm should be capable enough to prevent such types of errors [103].

Instead of above, there are other properties which are application specific. Practically, it is impossible for any watermarking system to satisfy all the properties, but instead, it is necessary to make trade-offs between them based on the underlying application. Watermarking is applied to various applications, some of them are:

A. Owner identification and proof of ownership

Digital watermark can be used to offer copyright marking functionality. User can be intimated of copyrighted material by extracted watermark, and can easily track illicit copies of the material. In case of a legal dispute, these watermarks can also be used to prove ownership [4].

B. Access Control

Different users have different privileges (play/copy control) on the object based on the payment they made [16]. The terms and conditions for using the digital content can be protected by watermarking technique. Illegal copying of data or recording is prevented by the recording device if it detects the watermark indicating prohibition [4].

C. Transaction tracking (Fingerprinting)

In this application, in order to identify the illegal distributor of the copy, every copy is embedded by a unique watermark. This unique information can then be used for identification of persons who are involved in illegal distribution of the digital item or did not adopt required measures for copying [16].

D. Tamper Proofing

This is the most common application of digital watermarking. Whenever any kind of changes is done to the digital content the watermark gets destroyed such a watermark is called fragile watermark. This kind of watermark is used in tamper detection. If the extracted watermark is incorrect, it can be said that the original content is tampered. Importance of this application is by the involvement of highly sensitive data like medical imaging or satellite imaging [4].

E. Authentication

It is required when evidences are to be presented to an authority. The aim is to detect some alterations done to the content. The embedded watermark should be unique and hard to detect or remove by the attacker. Some watermarking techniques use tampered region localization to detect the tempered regions of the altered content [16].

F. Broadcast Monitoring

Itis the technique for cross-verification whether the content has really been broadcasted or not on the timed schedule. To check when and where each clip shows there are automated monitoring stations for receiving broadcasts and look out for the embedded watermarks [4]. As no malicious attacks are used, the content has just to pass by common signal processing so there is no need of sophisticated watermarking techniques [16].

G. Covert Communication

It is one of the earliest applications of watermarking, or we can say data hiding for sending secret messages [4]. A robust watermarking technique is required so that the message cannot be read by the intruder.

IV. BASIC FUNDAMENTALS OF TRANSFORMS

Various transforms are used for embedding watermark. Some basic transforms which are used from the past becomes fundamental transforms are described below:

A. Discrete Cosine Transform

It is an orthogonal transform used for image and signal processing because of its energy compaction property, hence useful for image compression applications with benefits such as good information integration ability, high compression ratio, small bit error rate, and good synthetic effect of calculation complexity [5]. The DCT has special property that it has the tendency to concentrate most of the visually significant information of the image in low frequency coefficient of the DCT.

The general equation for a 2D (*N* by *N* image) DCT is defined by the following equation:-

$$F(u,v) = \frac{2}{N} C(u)C(v) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} f(x,y) cos\frac{(2x+1)u\pi}{2N} cos\frac{(2y+1)v\pi}{2N} \quad (1)$$

$$f(x,y) = \frac{2}{N} \sum_{u=0}^{N-1} \sum_{v=0}^{N-1} C(u)C(v)F(u,v) cos\frac{(2x+1)u\pi}{N} cos\frac{(2y+1)v\pi}{N} \quad (2)$$

Where, C (u) and C (v) are $1/\sqrt{2}$for u, v=0 and 1 otherwise.

DCT allows breaking an image into different frequency bands the high frequency F_H, middle frequency F_M and low F_L frequency bands. F_M is chosen as the main embedding region as it provides more resistance against lossy compression techniques, while avoiding important modification of the cover image.

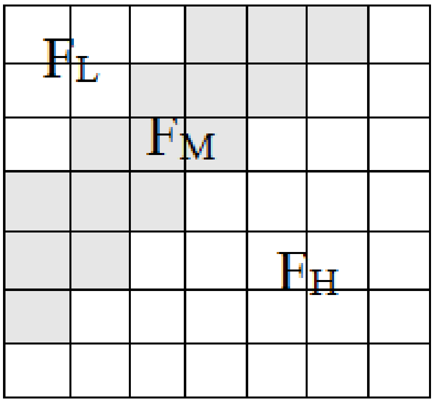


Figure2. DCT Regions

B. Discrete Fourier Transform

The Fourier transform is a most popular technique for signal study, analysis and synthesis. The transform is reversible and maintains the same energy. For robustness against geometric attacks like rotation, scaling, cropping, translation etc., the researchers have explored the DFT domain watermarking. Let n be a discrete time-domain variables, and k is a discrete frequency domain variables, then the Fourier transform can be defined-

$$F(k) = \sum_{n=0}^{N-1} f(n) e^{-j2\pi kn/N} \qquad k=0, 1, 2 \ldots\ldots N-1 \quad (3)$$

$$f(n) = \frac{1}{N}\sum_{k=0}^{N-1} F(k)e^{j2\pi kn/N} \qquad n=0, 1, 2\ldots\ldots N-1 \qquad (4)$$

Here the f (n) is a real function and F (k) is a complex function. The watermark can be embedded in amplitude function F (k) [6].

C. Discrete Wavelet Transform

It is useful for non-stationary signals processing. It is based on small waves, called wavelets, having varying frequency and limited duration. It provides both spatial and frequency description of an image. It retains the temporal information during the transformation process, unlike conventional Fourier transform [9].

DWT uses filters with different cut-off frequencies to analyses an image at different resolutions. The filter decomposes the image into several frequencies [7]. The image is passed through a number of high-pass filters, also known as wavelet functions, to analyses the high frequencies and to analyses the low frequencies image is passed through a number of low-pass filters, also known as scaling functions. Half of the samples can be eliminated after filtering, according to the Ny Quist criteria. For a 2-D image, a wavelet Ψ and a scaling function Φ are chosen such that the scaling function Φ_{LL}(x, y) of low-low sub band in a 2-D wavelet transform can be written as

$$\Phi_{LL}(x, y) = \Phi(x)\ \Phi(y). \qquad (5)$$

Three other 2-dimensional wavelets can also be obtained by using the wavelet associated function Ψ(x) as follows:

$$\Psi_{LH}(x, y) = \Phi(x)\ \Psi(y);\ \text{horizontal} \qquad (6)$$
$$\Psi_{HL}(x, y) = \Psi(x)\ \Phi(y);\ \text{vertical} \qquad (7)$$
$$\Psi_{HH}(x, y) = \Psi(x)\ \Psi(y);\ \text{diagonal} \qquad (8)$$

Where, H is a high-pass filter and L is a low-pass filter [8].

This constitutes one level of decomposition, also known as the sub-band coding. This decomposition halves the time resolution (half the number of samples) and doubles the frequency resolution (half the span in the frequency band). To make a multi-resolution analysis the above procedure is repeated for further decomposition.

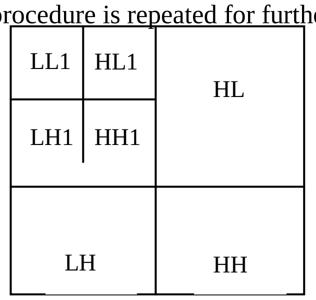


Figure3. DWT Decomposition (2 Level)

D. Singular Value Decomposition

It is a popular numerical technique in linear algebra and it has applications for data compression and data denoising, matrix inversion, to obtain low dimensional representation for high dimensional data, to diagonalize matrices in numerical analysis. From the perspective of image processing, the SVD of an image A with size N × N denoted as A∈**F** ^{NxN}, where **F** represents either the real number domain **R** or the complex number domain **C;** is given by

$$A=USV^{T} =\sum_{i=1}^{r} \lambda_i u_i v_i^{T} \qquad (9)$$

Where, U∈**F** ^{NxN} and V∈**F** ^{NxN} are unitary orthogonal matrices, S∈**F** *N*x*N* is a diagonal matrix. The columns of U are the left singular vectors denoted as u_i, whereas the columns of V are the right singular vectors of the image A, denoted as v_i, and r is the rank of A. The diagonal elements of matrix S= diag (λ_i), are nonnegative values representing singular values of A satisfy the order: $\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_N$.

This process is known as the Singular Value Decomposition (SVD) of image A. Each singular value specifies the luminance of the image, whereas the respective pair of singular vectors specifies the intrinsic geometry properties of images [11]. Watermarking can be done by using SVD because slight variations of Singular values do not affect the visual perception of the cover image.

E. Arnold Transform

Arnold transformation is proposed in the research of Arnold theory [13]. The Arnold transformation can be applied to the image of size NxN can be shown as:

$$\binom{x'}{y'} = \left[\begin{pmatrix}1 & 1\\ 1 & 2\end{pmatrix}\binom{x}{y} modN\right] (x,y)\epsilon\, 0,1.\ldots,N-1 \qquad (10)$$

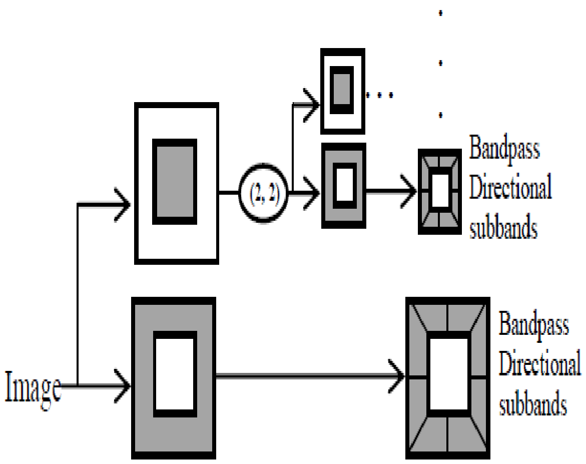
Where, (x, y) are the coordinates of image and the transformed pixels are denote as (x', y').

Scrambled image is produced by applying the equation (9) on each and every pixel of the image. Same process is repeated for a number of times to get the image we want for embedding to the original image. It is used in watermarking to scramble the watermark image to make it unreadable. After watermarking extraction, the watermark can become readable due to the periodicity process of the Arnold transform, which is based on the permutation concept [13].

F. Contourlet Transform

The Discrete Contourlet Transform was proposed by Do et al., [14]. It is a multi-directional and multi-resolution transform used in image analysis for capturing contours and fine details in images [10]. It has the potential to handle 2-D singularities efficiently, i.e. edges, so it is the advantage over wavelets which can work on point singularities exclusively. This difference is caused by two main properties of the CT: 1) the directionality property 2) the anisotropy property.

Many image processing operations performed on wavelets can be easily adapted by contourlets due to its structural resemblance with the wavelet transform [10].



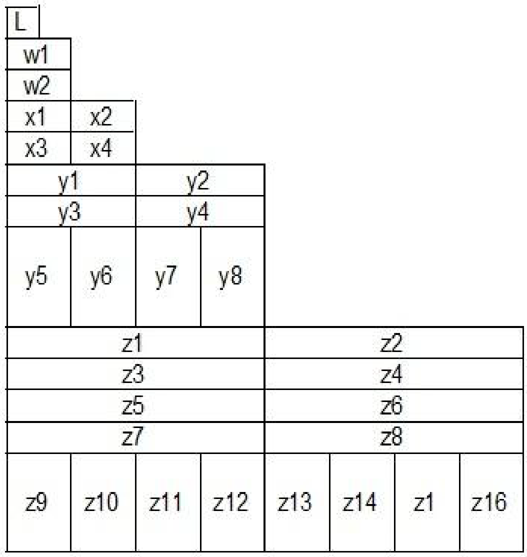


Figure4. (a) Contourlet Filter Bank (b) Contourlet transforms decomposition

It uses two filter-banks, a Laplacian Pyramid (LP) and the Directional Filter Bank (DFB) shown in Figure4 (a). The LP The decomposition of the image into octave radial-like frequency bands to capture the point discontinuities is done by LP first, then each LP detail band is decomposed by DFB into many directions (a power of 2) to connect the point discontinuities into linear structures. The result is that the image gets expanded by using basic elements like contour segments, and thus it is known as contourlet transform [10].

Figure 4(b) shows the directional decomposition using CT. To make the transform unique, different number of directional decompositions can be chosen. Here L is the low pass version of the image and W, X, Y and Z is the directional detail bands at different levels. Directional bands in four levels of multi resolutions are divided into 2, 4, 8 and 16 directional sub bands from coarse to fine scales respectively [15].

V. PREVIOUS WORKS ON DIGITAL IMAGE WATERMARKING ALGORITHM

Image can be represented either by pixel intensity matrix or by the frequency components. Watermark can be added to the image by modifying these values. Image watermarking algorithms are broadly classified into two domains; spatial domain and the transform domain. Early works were based on the spatial domain watermarking. Schyndel et al. [19] proposed watermarking technique by changing the LSB of some pixels in an image. Another, well-known spatial domain scheme is patchwork watermarking. It works on the statistical property of an image given by Bender et al.[20]. Cox et al. [1] who is considered as one of the founders, proposed a method using spread-spectrum multimedia, in which the watermark was embedded into DCT coefficients. After this watermarking becomes one of the most important fields of the research. The straight-forward approach used for watermarking was proposed by the Ling Na Hu et al.[21] who embed the watermark into the LSB of the original content. A small watermark iterates multiple times for covering the entire content capacity [22]. Kutter et al. [23] extended the work of Cox, and gave the idea of second generation watermarking. They suggested the watermark embedding area in the original image; by identifying the important part of the media for robustness and imperceptibility. Piva et al. [24] introduced another watermarking algorithm for color image. It is based on the cross-correlation of RGB-color space by taking DCT for each channel. The change became adaptive by using different watermark strengths to fine-tune the different channel sensitivity; and to verify the existence of the watermark, correlation coefficients of RGB channels was computed. In [34] the author used direct saturation adjustment and proposed robust spatial domain watermarking for color images. Wu et al. [25] considered human visual effects for adaptive adjustment of the embedded watermark bits. How many bits of watermark are used for embedding was obtained by determining the visual effect of the pixels in the original image.

Recently, researchers put their efforts for generating the frequency-domain watermarking algorithms. An improved DCT watermarking technique was proposed by Malik et al. [47]; based on the concept of mathematical remainder, and modifies the low-frequency coefficients of DCT. It is robust against common processing operations, especially for the JPEG compression. It is a simple process and the watermark has the property of self-extraction. Ramani et al. [43] proposed a DWT domain color image watermarking in which the RGB color channels of an image are converted into YIQ color channels and the watermark was embedded in Y and Q components. It works best under JPEG compression attack. In [44], Watermarking algorithm based on wavelet and cosine transform was proposed. In this a binary watermark embedded in either G or B component of the color image. In [45], Bit plane complexity segmentation with integer wavelet transform (IWT) was used with the advantage of having more data hiding capacity. This method also uses RGB color channels for embedding. In [46], the author suggested the pyramid wavelet based watermarking algorithm for colored image so as to get better security and better correlation in noise and compression attacks. In [48] the author proposed lifting wavelet based watermarking technique which acts as a best alternative solution for DWT; as it helps in reducing information loss, and also improving the robustness and intactness of watermark. Authors of [41] proposed a watermarking technique using various transforms i.e. DWT, Arnold, and Chaos transforms are applied on the watermark and then embedded into the multimedia object. In [99] Kunder et al. used both DCT and DWT transforms. The high frequency band of DCT then undergoes wavelet transform and the technique is robust against many attacks.

Singular value decomposition has many properties which become helpful in embedding watermarks. SVD based algorithm proposed by Liu and Tan et al. [12] is most popular or considered as one of the first works in SVD domain. The authors in [51, 52, 53, and 54] reported the high false detection error rate in this approach and proved that SVD does not uphold the criteria for copyright protection. To overcome this problem the author in [55] suggested a scheme. In the paper [56], the authors gave a blind watermarking and check out the results by embedding the watermark in all the SVD components (U, S and V) or watermarking only S component, with sufficiently large (close to 1) linear interpolation parameter. Qu et al. [62] suggested a DWT-SVD based robust watermarking technique and embedding the watermark in G-channel of color image gave PSNR up to 42-82.

In paper [32], the author used the combination of the space and spatial/ frequency domains by generating algorithm in fractional Fourier transformation (FRFT) domain. The advantage of this scheme is that it has more probability to generate more watermarks than the DFT and DCT domains. This watermarking is robust against many attacks. Joshi and Darji et al. [57] also used both the spatial and frequency domain. The fact behind this is that computational cost is less in the spatial domain and frequency domain has the benefits of more robustness. Authors of [58] used gray level images for watermarking, which was based on DCT and spread spectrum communications. It used the low frequency components. This method has high robustness and imperceptibility.

Another watermarking domain based on features of the image, called feature domain watermarking. For extracting the feature of the image the authors in [59] used the Harris detector and the Achard–Rouquet detector. This scheme had the limitation that it is less effective for texture images. In [60] feature points are retrieved by using the Mexican Hat wavelet scale interaction method by the authors and then they link them to form Voronoi diagrams in order to embed the watermark. The method has robustness against many attacks. Pitas et al. [61] suggested a technique which gains the advantages of both feature extraction and image normalization. A DFT based robust watermarking technique was then obtained; which has resistance against geometric distortions and also helps in reducing the watermark synchronization problem simultaneously. For authentication purposes [63] generated a digital signature by encrypting the feature points' positions in the original content. It is robust against many attacks and especially lossy compression because the feature points are liable to be shifted.

Many authors [72, 73, and 75] used a new theory of compressive sensing for embedding the watermark, called sparse domain watermarking. This theory is mainly used for increasing payload capacity and tamper detection applications. Confidential watermark was embedded by [76] was based on compressive sensing and used the transform domain watermarking for this. Candes, et al. [77] suggested that this setup is perfect for L1 decoding in order to determine the sparse coefficients accurately. In [78] the author proposed another robust watermarking algorithm, MSE value is used for the distortion estimation.

In [79] M.Kankanhalli, et al. introduced a visible watermarking algorithm by using block based approach. To calculate the DCT of each block, the original cover is divided into blocks; the blocks are then classified into six different classes in the ascending order of noise sensitivity. As visible watermarks have very few applications, the researchers are more interested in invisible watermarks. I.J.Cox et al. [1, 80] argued that to make the watermark robust against attacks, it should be embedded in the perceptually significant components of the cover. Dual watermarking was firstly proposed by S.P.Mohanty, et al. [81] who combines both the visible and an invisible watermark. The invisible watermark is used for protection/back up of the visible watermark. In [18], a dual watermarking technique based on DWT was done, a secondary watermark of PN sequence was embedded in the DWT domain of a primary watermark.

The attacker may generate a 'counterfeit original' from the watermarked image. So the technique which does not use the original image for watermark extraction was proposed and is known as blind watermarking. It has wider applications; on the other side, the implementation is more challenging. Three approaches are used for this. O'Ruanaidh et al. [35] first have introduced the theory of integral transform invariants using DFT and Fourier-Mellin transform(FMT) and proved that it can be used for embedding watermarks which are then robust against rotation, scaling, and translation (RST) attacks. It has the disadvantage that it is difficult to implement. To overcome this difficulty, Lin *et al* [36] proposed the method which produces a 'termark' invariant to RST so as to embed the watermark in a 1-D signal obtained by using the FMT transformed image. This approach produces a one bit watermark which tells presence or absence of the watermark only. The second approach is based on the self-reference principle which used an auto-correlation function (ACF) or the Fourier magnitude spectrum of a periodical watermark [38], [39]. The third approach [20] used an additional template e.g. a sinusoid [40]. Pun et al. [37] also used an additional template, known as a "pilot" signal in DFT domain. This embedded template was then used to estimate the affine attacks on the image. The image was first corrected, and then the detection of watermark was done. Kang et al.[42] proposed another robust technique, resistant to affine transforms and lossy compression simultaneously. DWT-DFT composite watermarking is used for this purpose. Another type of watermarking is semi-blind watermarking which uses the watermark and/or the secret key for watermark extraction. Yogesh Kumar et al [64] proposed a semi-blind color image watermarking scheme on high frequency band using DWT-SVD. Other semi-blind techniques can be found in [65, 66, 67, 68, and 69]. The third type of watermarking which uses the original content and the secret key is called non-blind/informed watermarking [1, 70, and 71].

Sometimes, the embedding should be done in such a way that the original image can be obtained without having any data loss; such a scheme is known as reversible watermarking. In [86] the authors suggested robust lossless data hiding scheme using IWT transform. This technique is resistant to salt and pepper noise. In [87] the authors embed a PN-sequence with unit variance as watermark in the discrete multi wavelet transform by quantizing with successive sub-band and a perceptual modelling. Wang and Lin [88] formed a super tree by grouping the transformed coefficients. Quantized super tree is used for embedding and the watermark extraction is done by taking the difference between the quantized and the unquantized trees.

Problem of rightful ownership was first noticed by Craver et al. [89] and others and they considered it as a very important issue. They generated the counterfeit attack that can be performed on a watermarked image to allow multiple claims of ownership, and the attack is known as the IBM attack. Then they proposed a method for the same by designing a non-invertible technique which can be said that the advanced version of the watermarking scheme introduced by Cox et al. [90]. The limitation of this scheme is that the non-invertibility is based on an invalid assumption [91]. Another method based on time-stamping was proposed by [92] but it has the drawbacks of third party requirement for archiving the contents safely; and other drawback is manipulation of timestamps by anybody. Qiao *et al* [91] proposed a scheme to generate the randomized watermarks from the original image by combining their scheme with cryptography and using DES. The embedded watermark is then becomes a function of the original image and key. The limitation of this scheme is that it cannot insert semantically meaningful watermarks.

When we want to check what has been altered by attackers, then the techniques used are known as temper detection. Fragile watermarks are used for this application. The algorithm proposed by [93] was among the first algorithms used for image tampering detection, based on inserting check-sums into LSB of the image using a secret key and watermarking pseudo-random groups of pixels. Another approach is proposed by [94] by self-embedding an image into itself as a means of protecting the original content. The basic principle lies in embedding a compressed cover into the LSB of its pixels. It has the advantage that it partially repairs the regions of the image that have been tampered with, cropped, or replaced. A semi-fragile watermarking technique was proposed by Lin and Chang [95] that accepts lossy compression and rejects malicious attacks. They pointed out two invariance properties of DCT coefficients with respect to JPEG compression. The third method is based on feature domain [96, 97] which extracts the features of the original image, and hides them in a robust and invisible watermark. To check whether an image has been altered or not, just compare its features with those of the image recovered from the watermark. A wavelet-based telltale image authentication was introduced by Kundur et al. [98]. The watermark was localized using both spatial and the frequency domains, hence provides information how the signal was modified.

To enhance the security of watermarks, visual cryptography was used by Chin-Chen Chang et al [26] suggesting the spatial-domain scheme to hide a binary watermark into two shares. The author used different gray level original images to embed these two shares, so as to balance the performance between pixel expansion and contrast. Embedded images can then be superimposed to decode the hidden message. Liguo Fang [27] proposed scheme based upon combination of pixel expansion and the threshold of visual contents. To enhance the robustness of the scheme [28] suggested VC-based repeating watermarking, in this the edge blocks of the original cover are used to embed the some parts of the watermark. The drawback of the scheme is that alterations to the original image are required to embed a watermark and this limitation is removed by Chang et al. [29]. They proposed an algorithm using torus automorphism and visual cryptography. Lou et al [30] suggested a copyright protection technique using chaos and VC techniques, but it is unable to provide the main characteristic of VC and uses the HVS to decrypt secret messages. By doing XOR on the shadowed images, only then the watermark can be retrieved. To gain robustness and security [31] Hsu and Hou proposed another copyright protection scheme based on sampling distribution of means and VC. It has the disadvantage that it can identify the secret message by the HVS directly without using the computers.

The secret key can be private or public. Public watermarking is more simple and feasible for availing the image on the internet. Podilchuk et al. [82] proposed a public watermarking system that embeds two watermarks: a delicate watermark in the spatial and a semi-delicate one in the frequency domain. AES is used for encryption and to provide high robustness against different signalling operations. In [83] Patra et al. suggested a novel watermarking technique, different watermarks can be extracted by using a single key image. In this method, they used independent component analysis technique. Mei and Li [84] proposed technique using DWT based multi resolution data fusion approach with HVS model. And watermark embedding was done into more prominent and strong components of the cover to resist against many attacks. In the paper [85], the authors introduced a public watermarking algorithm which was resistant to the print-and-scan and general scaling and cropping processes.

To find out the optimal embedding parameters, computational techniques are now being used by many researchers, they named it as intelligent watermarking (IW). The evolutionary computation optimization techniques used by the researchers in order to find out the embedding parameters which maximize the fitness for both fidelity and robustness are Genetic Algorithms (GA) [100], Particle Swarm Optimization (PSO) [101], and combinations of GA and PSO [102]. A few authors have proposed multiple objective formulations that correspond to the trade-off among different fidelity and robustness objectives. To fine-tune the watermarking system, the scheme provides multiple optimal non-dominated solutions (Pareto front) which gives a system operator the ability to choose among multiple solutions [17, 74].The [17] approach provides more operational flexibility.

Hardware implementation of adaptive encrypted watermarking based on DWT was done by Lande et al. [33] using fuzzy logic in FPGA for achieving low power usage, real-time performance, reliability. It was shown that fuzzy logic is important for calculating the gain factor with respect to texture sensitivity of the image. Another color image encrypted algorithm was proposed by Zhang et al.[49] using SIMULINK. To increase the speed close to 500% as compared to the conventional methods [50] proposed hardware implementation using DCT/IDCT in Xilinx XC3S4000 FPGA.

VI. DISCUSSION AND CONCLUSION

In this paper we have studied various research articles in the field of watermarking. In depth literature review revealed that a huge work was done by for a variety of applications, including copyright protection, content archival, authentication, integrity checking etc. but it was clear that some modifications to the image watermarking are still necessary in order to significantly improve its performance. New secure techniques can be proposed for copyright protection so that the performance of algorithms can be enhanced by combining with security techniques. Most of the work had been done for increasing the robustness of the techniques, but there are some applications like tamper proofing which require fragile watermarks; new techniques can be proposed for fragility. New schemes for medical images can be proposed for medical database. In conclusion, watermarking remains a promising and interesting domain, which would be used extensively by the researchers from different fields around the world.

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