Different Watermarking Techniques & its Applications: A Review

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Abstract— It is the expansion of internet that has increased the availability & uses of digital data like video, audio, image to the world. Therefore copyright protection of digital data is an important research issue of information security. This paper presents a review of some influential work in the area of digital watermarking technique and main contribution in this field such as categories of digital watermarking process by which one can understand easily that which watermarking method can be used.

Index Terms— Watermarking, Spatial domain, Image Transforms, Discrete Wavelet Transform, Discrete Cosine Transform, Discrete Fourier Transform

1 INTRODUCTION

To hide multimedia information, watermarking is a relative new technique. Its application is broad, including data authentication, ownership protection, side information conveyance, broadcast monitoring etc.Basically digital watermarking is that technique in which we embed the signal or any proprietary information i.e. watermark, into the digital media like image, audio, video.Afterthat the embedded signal is detected and extracted out to reveal the real identity of digital media.The very basic idea of digital watermarking system is shown in figure 1. This technique has many applications in the field of certification, distribution, anti-counterfiet of any type of digital media. For the purpose of ownership protection, robustness is one of the important factors of concern. To solve the problem of content authentication; fragile watermark is used so that the modification in the digital media will be reflected in hidden watermark [4]. Captioning watermark is a type of watermark in which less redundancy & more information can be employed, as there are multiple watermarks. Different sorts of watermarks does the different tasks, so there should be a particular order of hiding. As Mintzer and Braudaway noted, ownership watermarks should be embedded first, then captioning watermarks and at the last fragile watermark should be done.

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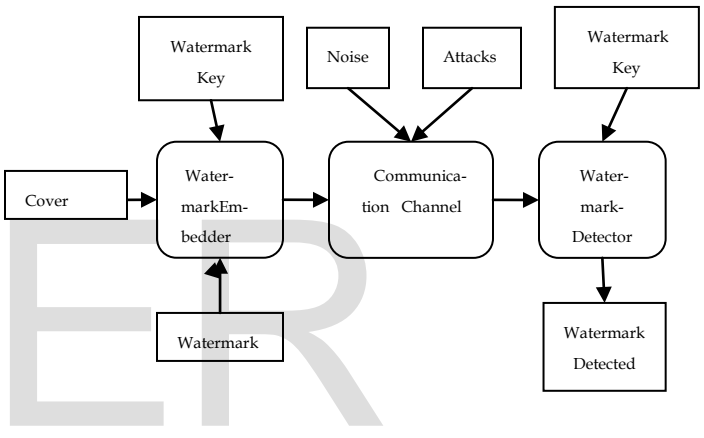

Fig. 1 Basic Digital Watermarking system

The watermark technique can be divided into two sections, visible watermarking and invisible watermarking. The main advantage of the visible watermark is that the watermark can be seen by eyes without extracting but its shortcoming is that watermark would destroy the presentation of media. That is why it is not so much appropriate for today's modern digital application. In contrast, the invisible watermark is extracted by particular method but it may reserve the original presentation of cover image

2 Classification of Digital watermarking

Here we will discuss different categories of watermark, characteristics, techniques and their applications.

2.1 According to robustness

- **Fragile watermarking:**

It is used for integrity protection, which must be very sensitive to change of signal. According to state of fragile watermark, one can predict whether the original data has been tampered or not.

- **Semi Fragile watermarking:**

It is capable of tolerating some degree of change to watermarked image like addition of noise attacks [6].

- **Robust watermarking:**

It is mainly used to prevent various noisy attacks, geometrical or non-geometrical attacks without tampering embedded watermark. So the watermark is not destroyed after some attacks and can easily detected to provide certification.

2.2 According to perceptivity

- **Visible watermarking:**

It is visible in digital data e.g. HBO, where logo is visibly superimposed on the corner of TV picture [5].

- **Invisible watermarking:**

By this technology, we can insert the secret information into digital media like image which cannot be seen. It must be extracted by specific process.

2.3 According to attached digital signal

- **Image watermarking:**

It is used to embed particular original data into digital image

- **Video watermarking:**

It embeds the original data in the video stream. It requires real time extraction [2].

- **Audio watermarking:**

Here we use the audio system for watermark like MP3.

2.4 According to task performed

- **Data authentication and integrity watermarking:**

It keeps the contents of image same as it was at initial stage. It prevents the lossy compression

- **Copyright protection watermarking:**

It means if the owner want others to see the mark of the image watermark, then the watermark can be seen after adding the watermark to the image and the watermark still exist even it is attacked.

- **Anti-Counterfeiting watermarking:**

It is used in building process of paper notes and can be detected after printing, scanning etc [10].

2.5 According to domain type

- **Spatial watermarking:**

This domain emphasis on modifying the one or two randomly choosed subsets of image for directly loading the raw data into the pixels. Some of algorithms used in this domain are LSB, SSM modulation based techniques. Computational complexity in spatial domain is low and it is mainly used in authentication.

- **Transform watermarking:**

It is also called frequency domain. In this domain value of certain frequencies are changed from their initial values.DCT, DWT, DFT are few commonly used frequency domain method. Computational complexity in this method is high. It is used in copyright application

2.6 According to extraction process

- **Visual watermarking:**

It has stronger robustness but its application is limited

- **Semi-blind watermarking:**

There is no need of original media for detection and extraction.

- **Blind watermarking:**

It requires a higher watermark technology and does not need original data.

2.7 According to secret keys

- **Asymmetric watermarking:**

For embedding and detecting the watermark, different keys are used.

- **Symmetric watermarking:**

Here we use the same keys for both embedding and detecting the watermark.

3 Analysis of digital watermarking

Digital watermarking can be analyzed in different categories;

3.1 Robustness:

It means that the watermark embedded in data has the capability of surviving after the different processing operations and noisy attacks.

3.2 Copyright Protection:

The purpose of copyright protection can be achieved if the watermark cab be detected, extracted and even modified by authorized party only, not by others. Then only the watermark system is said to be secure, that means watermark cannot be removed without the complete knowledge of composition of watermark and its embedding algorithm

3.3 Embedding capacity:

Watermark embedding capacity can be defined as number of watermark bits in a message in data pay load and maximum repetition of data payload within an image. A watermark can have high data capacity but low data payload.

3.4 Reliability of watermark detection:

To achieve the copyright protection, we will use a Watermark consisting Pseudo-random binary sequence to represent the identity of a copyright holder. In case of both exactly detected and randomly chosen watermark, the correlation values graph plotted against watermarks has a significant peak at the correctly detected watermark which implies the copyright holder‘s identity. This is watermark detection outcome.

For a given image with watermark embedded, there are 2 possible results of its watermark detection:

a) The successful detection of the watermark is called a true positive.
b) The unsuccessful detection of the watermark is called a false negative.

In the same way, there are 2 possibilities for a given unwatermarked test image:

a) The absence of watermark corresponds to a true negative[13].
b) An incorrectly detected watermark corresponds to a false positive.

4. Requirement of Digital Watermarking

The most important properties of digital watermarking techniques are fidelity, robustness, security, integrity, capacity, imperceptibility. Transparency relates to the properties of the human sensory. A transparent watermark causes no artifacts or quality loss.

4.1 Fidelity:

Fidelity or transparency cab be defined as "perceptual similarity between the original and watermarked versions of cover work ".That means watermarking should not generate the visible distortion because these distortions reduces the quality of original image[15].

4.2 Robustness:

It is basically defined as the ability to detect the watermark after common signal processing operations. Watermarks may be removed during the signal processing operations like gamma correction, brightness enhancement. Watermarks should be robust against such attacks.

4.3 Integrity of information:

It represents that the embedded watermarking information cannot be altered or removed beyond reliable detection by targeted attacks based on a complete knowledge of the embedding algorithm and the detector[26]. This implies that the watermark should be difficult to alter or remove without distorting the host signal[28].

4.4 Capacity:

It can be defined as number of information bits a watermark encodes within a unit of time or work. Watermark should be able to carry enough information that can represent the uniqueness of image. It points out the possibility of embedding many watermarks in one domain in parallel.

4.5 Imperceptibility:

It means the watermark should not be noticeable to the viewer that is unnoticeable. The term —imperceptible is mainly used for this purpose[24]. If a signal is truly imperceptible, then perceptually based lossy compression algorithms either introduce further modifications that jointly exceed the visibility threshold or remove such a signal, Gonzalez and Woods (2008). It is then important to develop techniques that can be used to add imperceptible or unnoticeable watermark signals in perceptually significant regions to resist the effects of signal processing.

5. DIGITAL WATERMARKING TECHNIQUES

Watermarking is defined as the process of embedding watermarks in digital media e.g. audio, video, image etc.using an appropriate algorithm. On the internet application, we embed some logo, trademark or an image in multimedia objects to prevent it from misuse [12]. Hence, watermarking can be used for solving many purposes like tamper detection, data authentication, security, copyright protection. Watermarking is done by using some particular, strong and appropriate algorithms which plays an important role in watermarking. This is because if the technique which is used in watermarking process is strong, efficient and effective, then the embedded watermark cannot be easily extracted. One can only extract the secret data if he knows the appropriate algorithm otherwise it is difficult to get the watermark. There are many algorithms which are being used to hide the secret information. These algorithms can be categorized into two domains called frequency domain and spatial domain.The basic idea of spatial and frequency domain is shown in figure 2 as shown below.

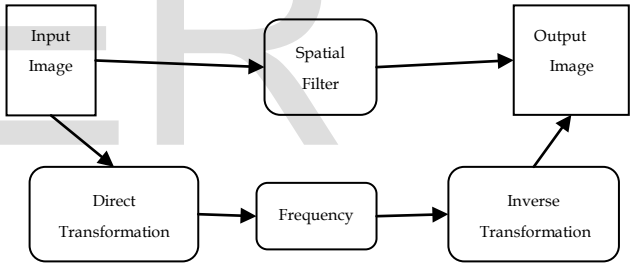

Fig 2. Brief Idea of Spatial and Frequency Domain [2]

- **Frequency domain:**

In frequency domain the watermark is embedded in the spectral coefficient of the image. The commonly used algorithms in frequency domain are the Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT), Discrete Wavelet Transform (DWT), the watermarking in frequency domain are widely applied because of the characteristics of the human visual system (HVS) are captured more efficiently by the spectral coefficients[25] . Some of its main algorithms are discussed below:

Discrete cosine transforms (DCT):

DCT represents data in terms of frequency space rather than an amplitude space. Watermarking techniques which are based on DCT are more robust compared to spatial domain techniques. These algorithms are robust against digital image processing operations like low pass filtering, brightness and contrast adjustment etc.These are computationally more ex-

pensive and are difficult to implement. At the same time they are weak against geometric attacks like rotation, scaling, cropping etc. DCT domain watermarking can be categorized into Global DCT watermarking and Block based DCT watermarking. One of the first algorithms presented by Cox et al. (1997) used global DCT watermarking to embed a robust watermark in the perceptually significant portion of the Human visual system (HVS)[27].

We use the following steps in DCT Block Based Watermarking Algorithm:

1) Segment the image into non-overlapping blocks of 8x8
2) Apply forward DCT to each of these 8x8 blocks
3) Apply some block selection criteria (e.g. HVS)
4) Apply coefficient selection criteria (e.g. highest)
5) Embed watermark by modifying the selected coefficients.
6) Apply inverse DCT transform on each 8x8 block [2].

Discrete wavelet transforms(DWT):

This is a modern technique, widely used in digital signal processing, image compression, watermarking etc. The transforms are based on small waves, called wavelet, of varying frequency and limited duration. This technique uses wavelet filters to transform the image [29]. The basic idea of DWT in image process is to multi-differentiated decompose of image into sub image of different spatial domain and independent frequencies.

Characteristics of DWT:

1) The wavelet transform decomposes the image into three spatial directions, i.e. horizontal, vertical and diagonal.
2) Magnitude of DWT coefficients is larger in the lowest bands (LL) at each level of decomposition and is smaller for other bands (HH, LH, and HL).
3) Watermark detection at lower resolution is more effective because there are few frequency bands involved at every successive resolution level.
4) The wavelet coefficient will be more efficient if its magnitude is larger[1].

➢ Advantages of DWT over DCT:

Wavelet transform understands the HVS more closely than the DCT. DWT provides both a simultaneous spatial localization and a frequency spread of watermark within the host image[21]. Wavelet coded image can be shown at different levels of resolution and can be sequentially processed from low resolution to high resolution. The visual artifacts introduced by wavelet coded images are less evident compared to DCT.The comparison between advantages and disadvantages of DWT and DCT is given table1.

➢ Disadvantages of DWT over DCT:

Computational complexity of DWT is more compared to DCT. As Feig (1990) pointed out it only takes 54 multiplications to compute DCT for a block of 8x8, unlike wavelet calculation depends upon the length of the filter used, which is at least 1 multiplication per coefficient.[20].

Discrete Fourier transforms(DFT):

DFT has robustness against geometric attacks like scaling, rotation, cropping, translation etc. It transforms a continuous function into its frequency components[22]

Characteristics of DFT:

1) DFT shows translation invariance. Spatial shifts in the image affects the phase representation of the image but not the magnitude representation
2) DFT of a real image is usually complex valued which results in magnitude and phase representation of an image.
3) Central component of DFT is the strongest component which contains low frequencies[23].
4) Scaling in image results in amplification of extracted signal and detected by correlation coefficient.
5) Rotation of image results in cyclic shift of extracted signal and it can be detected by exhaustive search. Translation of image has no result on extracted signal.

➢ Advantages of DFT over DWT and DCT:

DFT is rotation, scaling and translation (RST) invariant. So, it can be used to recover from geometric attacks like cropping, whereas the spatial domain, DCT and the DWT are not RST invariant and hence it is difficult to overcome from geometric distortions[3] .The comparison between advantages and disadvantages of DWT,DFT and DCT is given table1.

Table 1 Comparative Analysis of Different Frequency Domain Watermarking Techniques

Algorithm	Advantages	Disadvantages
DCT	1.More robust against digital processing operations. 2.Watermark cannot be removed by any attacks because of embedding. Watermark into middle frequency coefficient.	1.Certain higher frequency components tend to be suppressed during the quantization process. 2.Block wise DCT destroys the invariance properties of the system. 3. Vulnerable to cropping, scaling.
DWT	1.Higher compression ratio which is relevant to human perception. 2.Allows good localization both in time and spatial frequency domain. 3. Vulnerable to cropping, scaling.	1.Cost of computing may be higher. 2.Computational complexity is more. 3.Compression time may be longer. 4.Noise may appear near the edges of image.
DFT	1.DFT is rotation, scaling and translation (RST).So, it is used to recover from geometric distortions.	1.Complex implementations. 2.Computing cost may be higher.

➢ Spatial Domain

Spatial domain digital watermarking algorithms directly load the raw data into the original image. It can also be applied using color separation. Spatial domain is manipulating an image representing an object in space to enhance the image for a given application[30]. These algorithms are based on direct embedding of watermark into the image pixels. Some of its main are as discussed below:

Additive watermarking

It is the direct method used in spatial domain for embedding the watermark. It is done by adding pseudo random noise pattern to the intensity of image pixels. The noise signal may be integers like (-1, 0, 1) or floating point numbers. To ensure that the watermark can be detected, the noise is generated by a key, such that the correlation between the numbers of different keys will be very low[18].

Least Significant bit

In this technique we embed the watermark in the LSB of pixels. This method is easy to implement but it is not very robust against attacks[16]. That means, the watermark may be destroyed. The watermarking is done by choosing a subset of image pixels and substituting the LSB of each of the chosen pixels with watermark bits. This approach is very sensitive to noise and common signal processing and cannot be used in practical applications [28]..

Correlation-Based technique:

In this method, a pseudorandom noise (PN) pattern says W(x, y) is added to cover image I(x, y).

$$Iw(x, y) = I(x, y) + k*W(x, y)$$

Where K represent the gain factor, Iw represent watermarked image at position x, y and I represent cover image [2]. The quality of watermarked image may be decreased by increasing the gain factor.The difference between LSB and Correlation is shown in table 2 as shown below.

Table 2 Comparative Analysis of Different Spatial Domain Watermarking Techniques

Algorithm	Advantages	Disadvantages
LSB	1.Low degradation of image quality. 2.Easy to implement and understand. 3. High perceptual transparency.	1.Very sensitive to noise. 2.Vulnerable to cropping, scaling attacks. 3.Very less robust against attacks.
Correlation	1.Increases the robustness of watermark by increasing the gain factor.	1.Due to very high increment in gain factor, image quality may decrease.
Patchwork	1.High level of robustness against many types of attacks.	1.Very small amount of information can be hidden.

Texture mapping coding technique:

This technique is used in only those images which have some texture part in it. It hides the watermark in the texture part of the image. The disadvantage of this technique is that, it is only preferred for the areas with large number of arbitrary texture images

Patchwork technique:

It is a data hiding technique developed by Bender et alii and published on IBM Systems Journal, 1996. It inserts a watermark with a particular statistic using a Gaussian distribution. A pseudo randomly selection of two patches is carried out where the first one is A and the second is B. Patch A image data is brightened where as that of patch B is darkened.[1]

6. DIGITAL WATERMARKING APPLICATIONS

Copyright protection:

Digital watermarking can be used to identify and protect copyright ownership. Digital content can be embedded with watermarks depicting metadata identifying the copyright owners [2].

Content archiving:

Watermarking can be used to insert digital object identifier or serial number to help archive digital contents like audio, image, video.Basically digital contents are recognized by their file names; however this is a very fragile technique as file name can be easily changed.So, by embedding the object identifier within the object itself, we can reduce the possibility of tampering and hence can be effectively used in archiving systems [1].

Image and content authentication:

With the help of image authentication application, we can solve the purpose of detecting modification to the data. The characteristic of an image such as its edges are embedded and compared with the current images for differences [29]. This problem can also be solved by cryptography, where digital signature has been studied as a message authentication method. One example of such technology being used for image authentication is the trustworthy digital camera.

Medical application:

We can use digital watermarking for printing name of patient on X-ray reports and MRI scans. This plays an important role in treatment offered to the patient because if there is a mix up in the reports of two patients, this could lead to a disaster[27].

Tamper detection

By embedding fragile watermarking, digital data can be detected for tampering. If the fragile watermarking got degraded, it indicates the presence of tampering and hence the digital content can not be trusted[30]. Such type of watermarking can be used to authenticate the content. It is also useful in court of law where digital images could be used as a forensic tool to prove whether the image is tampered or not.

Digital finger printing:

Fingerprints are unique to the owner of digital content. It is the characteristic of an object that tend to distinguish it from other small objects.Hence; a single digital object can have different fingerprints because they belong to different users. As in the applications of copyright protection, the watermark for finger printing is used to trace authorized users who violate the license agreement and distribute the copyrighted material illegally.

Broadcast monitoring:

Number of television and radio channel has notably expanded for broadcasting the contents. And the amount of content carried by these media vehicles continues to grow rapidally.Watermarking is used for broadcast monitoring. It has a major application in commercial advertisement broadcasting where the one who is advertising wants to know whether the advertisement was actually broadcasted on right time and for right duration[17].

7. CONCLUSION

In this paper, we surveyed the various aspects for digital watermarking techniques and its applications. A brief and comparative analysis of watermarking techniques is also presented which can help in the new researches in related areas.We also classified the watermarking algorithms based on spatial and transform domain.Due to space limitation we couldn't cover enough technical details but we have tried to be as clearer as possible.

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