A Survey Paper on Digital Watermarking Techniques

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Abstract---Watermarking, which belong to the information/data hiding field, has seen a lot of research interest recently. There is a lot of work begin conducted in different branches in this field. Watermarking is a technology being developed to ensure and facilitate data authentication, security and copyright protection of digital media. In this paper we present a detailed survey of existing and newly proposed watermarking techniques. We classify the techniques based on different domains in which data is embedded.
Key words: Watermarking, DCT, DWT, DFT.

I. INTRODUCTION

Watermarking is the process of embedding secret information (i.e. watermark) into digital multimedia data such as texts, audio, images and video by taking into account the limitations of the human perception system such as Human Auditory System (HAS) and Human Visual System (HVS). These techniques can be used on any type of digital data including still images, movies and music. [1] The ease with which digital content can be exchanged over the Internet has created copyright infringement issues. Copyrighted material can be easily exchanged over peer-to-peer networks and this has caused major concerns to those content providers who produce these digital contents. In order to protect the interest of the content providers, the digital contents can be watermarked. Later the embedded information is detected and extracted out to reveal the real owner/identity of the digital media. The term 'digital watermarking' was first appeared in 1994, when Tirkel presented two watermarking techniques to hide the watermark data in the images. [2]

Watermarking is used for following reasons, Proof of Ownership (copyrights and IP protection), Copying Prevention, Broadcast Monitoring, Authentication, Data Hiding. Watermarking consists of two modules watermark embedding module and watermark detection and extraction module. Digital watermarking technology has many applications in protection, certification, and distribution, anti-counterfeit of digital media and label of the user information. It has become a very important study area in information hiding. This paper analyzes the key technologies of digital watermarking. The paper is organized in the following sections:

Section 2 describes requirements of digital watermarking.
Section 3 describes the digital watermarking techniques.
Section 4 describes the watermarking algorithms.
Section 5 describes the Challenges and Limitations of Digital Watermarking
Conclusion of this paper stated in section 6.

II. REQUIREMENTS OF DIGITAL WATERMARKING

There are three main requirements of digital watermarking. They are transparency, robustness and capacity.

A. Transparency or Fidelity

The digital watermark should not affect the quality of the original image after it is watermarked. Cox et al. (2002) define transparency or fidelity as "perceptual similarity between the original and the watermarked versions of the cover work". Watermarking should not introduce visible distortions because if such distortions are introduced it reduces the commercial value of the image.

B. Robustness

Cox et al. (2002) defines robustness as the "ability to detect the watermark after common signal processing operations". Watermarks could be removed intentionally or unintentionally by simple image processing operations like contrast or brightness enhancement, gamma correction etc. Hence watermarks should be robust against variety of such attacks. Stirmark2 classifies attacks into four basic categories, attacks that try to remove watermarks totally, attacks that try to remove the synchronization between the embedder and the detector, cryptographic attacks and protocol attacks.

C. Capacity or Data Payload

Cox et al. (2002) define capacity or data payload as "the number of bits a watermark encodes within a unit of time or work". This property describes how much data should be embedded as a watermark to successfully detect during extraction. Watermark should be able to carry enough information to represent the uniqueness of the image. Different application has different payload requirements [26].

III. DIGITAL WATERMARKING TECHNIQUES

Watermarking is the method to hide the secret information into the digital media using some strong and appropriate algorithm. Algorithm plays a vital role in watermarking as, if the used watermarking technique is efficient and strong then the watermark being embedded using that technique cannot be easily detected. The attacker can only destroy or detect the secret information if he know the algorithm otherwise it is critical to know the watermark. These are various algorithms present in the today scenario that are used to hide the information. Those algorithms come into two domains, Spatial and frequency domain.

A. Spatial Domain:

Spatial domain digital watermarking algorithms directly load raw data into the original image. Spatial watermarking can also be applied using color separation. In this way, the watermark appears in only one of the color bands. This renders the watermark visibly subtle such that is it difficult to detect under regular viewing. Spatial domain is manipulating or changing an image representing an object in space to enhance the image for a given application. Techniques are based on direct manipulation of pixels in an image. One of the main algorithm is Least Significant Bit

(LSB). In LSB old popular technique embeds the watermark in the LSB of pixels. This method is easy to implement and does not generate serious distortion to the image; however, it is not very robust against attacks.

The embedding of the watermark is performed choosing a subset of image pixels and substituting the least significant bit of each of the chosen pixels with watermark bits. The watermark may be spread throughout the image or may be in the select locations of the image.

But these primitive techniques are vulnerable to attacks and the watermark can be easily destroyed.

Such an approach is very sensitive to noise and common signal processing and cannot be used in practical applications.

B. *Frequency Domain:*

Compared to spatial-domain methods, frequency-domain methods are more widely applied. The aim is to embed the watermarks in spectral coefficients of the image. The most commonly used transforms are the Discrete Cosine Transform (DCT), Discrete Fourier Transform (DFT), Discrete Wavelet Transform (DWT), the reason for watermarking in frequency domain is that the characteristics of the human visual system are better captured by the spectral coefficients.

IV. WATERMARKING ALGORITHMS

A. *Discrete Cosine Transforms (DCT):*

DCT like a Fourier Transform, it represents data in terms of frequency space rather than an amplitude space. This is useful because that corresponds more to the way humans perceive light, so that the part that are not perceived can be identified and thrown away. DCT based watermarking techniques are robust compared to spatial domain techniques. Such algorithms are robust against simple image processing operations like low pass filtering, brightness and contrast adjustment, blurring etc. However, they are difficult to implement and are computationally more expensive. At the same time they are weak against geometric attacks like rotation, scaling, cropping etc. DCT domain watermarking can be classified into Global DCT watermarking and Block based DCT watermarking. Embedding in the perceptually significant portion of the image has its own advantages because most compression schemes remove the perceptually insignificant portion of the image. Steps in DCT Block Based Watermarking Algorithm [25].

1) Segment the image into non-overlapping blocks of 8x8
2) Apply forward DCT to each of these 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 block.

Most algorithms discussed in this section are classified based on step 3 and 4 i.e. the main difference between most algorithms is that they differ either in the block selection criteria or coefficient selection criteria.

B. *Discrete Wavelet Transforms (DWT):*

Wavelet Transform is a modern technique frequently used in digital image processing, compression, watermarking etc. In some applications wavelet based watermarking schemes outperforms DCT based approaches. The transforms are based on small waves, called wavelet, of varying frequency and limited duration. 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. 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). The Discrete Wavelet Transform (DWT) is currently used in a wide variety of signal processing applications, such as in audio and video compression, removal of noise in audio, and the simulation of wireless antenna distribution. Wavelets have their energy concentrated in time and are well suited for the analysis of transient, time-varying signals. Since most of the real life signals encountered are time varying in nature, the Wavelet Transform suits many applications very well [27]. One of the main challenges of the watermarking problem is to achieve a better tradeoff between robustness and perceptivity. Robustness can be achieved by increasing the strength of the embedded watermark, but the visible distortion would be increased as well [27]. However, DWT is much preferred because it provides both a simultaneous spatial localization and a frequency spread of the watermark within the host image [28]. The basic idea of discrete wavelet transform in image process is to multi-differentiated decompose the image into sub-image of different spatial domain and independent frequencies [26].

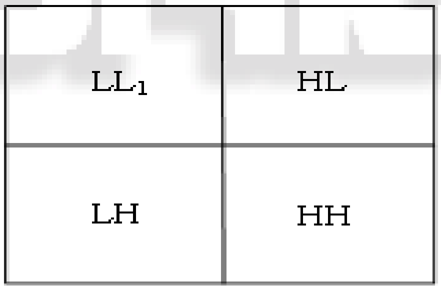

Fig. 1: Single level Decomposition using DWT

1) *Advantages of DWT over DCT:*

Wavelet transform understands the HVS more closely than the DCT. 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. Visual artifacts introduced by wavelet coded images are less evident compared to DCT because wavelet transform doesn't decompose the image into blocks for processing. At high compression ratios blocking artifacts are noticeable in DCT; however, in wavelet coded images it is much clearer.

2) *Disadvantages of DWT over DCT:*

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

C. Discrete Fourier Transform (DFT):

Transforms a continuous function into its frequency components. It has robustness against geometric attacks like rotation, scaling, cropping, translation etc. DFT of a real image is generally complex valued, which results in the phase and magnitude representation of an image. DFT shows translation invariance. Spatial shifts in the image affects the phase representation of the image but not the magnitude representation, or circular shifts in the spatial domain don't affect the magnitude of the Fourier transform. The strongest components of the DFT are the central components which contain the low frequencies. Rotation of image results in cyclic shifts of extracted signal and can be detected by exhaustive search. Scaling in the spatial domain causes inverse scaling in the frequency domain. Rotation in the spatial domain causes the same rotation in the frequency domain. There are several coefficient selection criteria for the DFT like; Modification to the low frequency coefficients can cause visible artifacts in the spatial domain. Hence, low frequency coefficients should be avoided. High frequency coefficients are not suitable because they are removed during JPEG compression. The best location to embed the watermark is the mid frequency.

1) Advantages of DFT over DWT and DCT:

DFT is rotation, scaling and translation (RST) invariant. Hence it can be used to recover from geometric distortions, whereas the spatial domain, DCT and the DWT are not RST invariant and hence it is difficult to overcome from geometric distortions.

Literature shows two different kinds of DFT based watermark embedding techniques. One in which watermark is directly embedded or template based embedding.

Algorithms	**Advantages**	**Disadvantages**
LSB	1. Easy to implement and understand 2. Low degradation of image quality 3. High perceptual transparency	1. It lacks basic robustness 2. Vulnerable to noise 3. Vulnerable to cropping, Scaling
DCT	The watermark is embedded into the coefficients of the middle frequency, so the visibility of image will not get affected and the watermark will not be removed by any kind of attack.	1. Block wise DCT destroys the invariance properties of the system. 2. Certain higher frequency components tend to be suppressed during the quantization step.
DWT	1. Allows good localization both in time and spatial frequency domain. 2. Higher compression ratio which is relevant to human perception.	1. Cost of computing may be higher. 2. Longer compression time. 3. Noise near edges of images or video frames.
DFT	DFT is rotation, scaling and translation invariant. Hence it can be used to recover from geometric distortions.	1. Complex implementation 2. Cost of computing may be higher.

Table. 1: Comparisons of Different Watermarking Techniques

V. CHALLENGES AND LIMITATIONS OF DIGITAL WATERMARKING

There are various technical challenges in watermarking research. The robustness and imperceptibility trade-off makes the research quite interesting. To attain imperceptibility, the watermark should be added to the high frequency components of the original signal. On the other hand, for robustness the watermark can be added to the low frequency components only. Thus, the watermarking scheme can be successful if the low frequency components of the original signal are used as the host for watermark insertion. In this section, we discuss the various technical issues related to watermarking, such as properties of the human visual system and spread-spectrum communication, which are commonly exploited for making watermarking schemes successful [29].

A. Properties of visual signal

Since image and videos are visual signals, it is necessary to understand the behavior of visual signals in order to find ways to hide additional information in them. Visual signals are generally recognized as amplitude plots, intensity versus space displays of image information and intensity versus space and time displays of video scenes. These waveforms reveal a lot of information about the properties of the signals. Some of the properties of visual signals are listed:

1) Non-stationary:

Non stationary property is common to all signals. Image and video signals contain a wealth of segments of flat or slowly changing intensity, as well as edges and textured regions. While the edges need to be preserved to maintain perceptual quality, the textured regions need to be judiciously used to store additional information

2) Periodicity:

There exists line to line and frame to frame periodicity in image and video signals. They are not exactly periodic but there exists redundancy between frames and lines. These redundancies are exploited in any compression scheme, and need to be considered during the watermarking process.

B. Properties of Human Visual System

The success of any watermarking scheme lies in making the best use of the human visual system (HVS). In this section, we discuss the various properties of the human visual system which are exploited in designing watermarking algorithms. Texture sensitivity: The visibility of distortion depends on the background texture. The distortion visibility is low when the background has a strong texture. In a highly textured image block, energy tends to be more evenly distributed among the different DCT coefficients. In a flat-featured portion of the image the energy is concentrated in the low frequency components of the spectrum. This indicates that in strong texture regions more watermark signal can be added.

Brightness sensitivity:

The human eye is sensitive in perceiving a low intensity signal in the presence of backgrounds of different intensity. As the surrounding region intensity is increased, the relative intensity in dark areas is reduced and the sensitivity in the light areas is increased. When the mean value of the noise square is the same as that of the background, the noise square tends to be most visible against a mid-grey background. This characteristic is known as Weber‘s law. This means that the eye has high sensitivity at low intensity levels and greatly reduced sensitivity at high intensity levels.

VI. CONCLUSION

In this paper we have presented various aspects for digital watermarking like overview, requirement, techniques, challenges and limitations. Apart from it a brief and comparative analysis of watermarking techniques is presented with their advantages and disadvantages which can help the new researchers in related areas. We classified watermarking algorithms based on the spatial domain as well as in frequency domain.

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