An Implementation of Informed Watermarking technique using Hidden Markov Model

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Abstract-- In Digital watermarking, message is embedded into original copy to prove ownership. Different watermarking schemes have been proposed by many authors in the last several years which include spatial domain and transform domain watermarking. Discrete Wavelet Transform (DWT) based watermarking is more prominent because of its similarity with the human visual system. This paper deals with the Hidden Markov Model (HMM) based informed watermarking in wavelet domain. The proposed method uses biorthogonal wavelets to decompose the image. From the coefficients of the image, vector nodes are formed in which watermark bits are embedded. Viterbi algorithm is used for finding the place of embedding later the data is embedded in the image making it informed watermarking. Tradeoff between robustness, invisibility and capacity is achieved using HMM based watermarking method.

Keywords-- Digital Image Watermarking, Hidden Markov Model (HMM), Informed Watermarking, Discrete Wavelet Transform and Viterbi Algorithm

I. INTRODUCTION

The issue of protecting multimedia data becomes more important and a lot of copyright owners are concerned about protecting any illegal duplication of their data or work. Some serious work needs to be done in order to maintain the availability of multimedia information but, in the meantime, the industry must come up with ways to protect intellectual property of creators, distributors or simple owners of such data. Digital image watermarking provides copyright protection, by hiding appropriate ownership data (information) in digital images. This data may be in the form of logo called 'watermark'. The image formed after hiding 'watermark' in original image is called 'watermarked image'. There are four important parameters, which are commonly used to find quality of watermarking scheme. They are payload, security, robustness and imperceptibility. Payload is the amount of bits to be embedded into cover image i.e. ‘watermark capacity’. Robustness means watermark should be difficult to remove or destroy. Robustness is a measure of resistance of watermark, against attempts like image manipulation and modification like cropping, scaling, compression, rotation, filtering, resizing, etc. Imperceptibility is the quality of original image should not be destroyed after embedding of watermark.

A digital watermark can be expressed as a visible or invisible recognition code that is embedded in the data. A general definition is "Hiding of a secret message or information within a normal message and the extraction of it at its destination.” The aim is to embed some information in the image without changing its visual content. Figure.1 shows a general watermarking technique in order to give an idea of the different operations involved in the process.

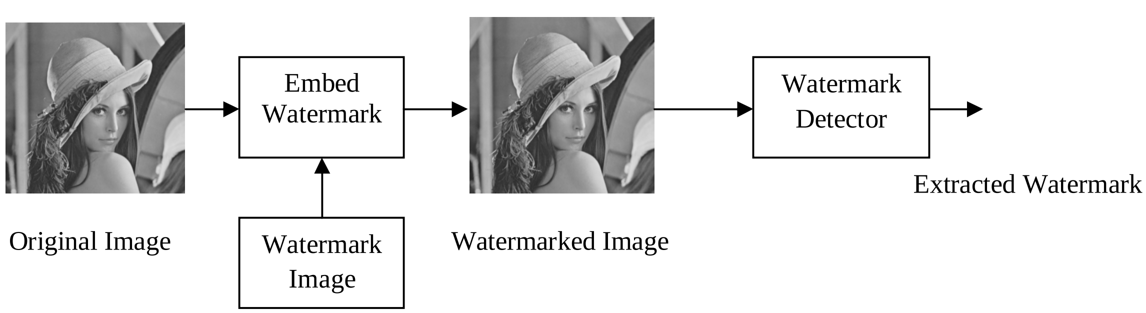

Fig.1 General watermarking scheme

II. FEATURES OF DIGITAL WATERMARKING SYSTEM

The importance of a watermarking property in any application depends upon the requirements of that specific application. Some of the watermarking system properties are highlighted in this section.

A. Embedding Efficiency

Efficiency of watermarking system is the probability of detecting watermark, especially at the receiver point. The desired efficiency is 100% but it is often not possible because of the requirement of perceptual similarity clash. Thus, it's application dependent to yield efficiency for better performance with respect to other features.

B. Perceptual comparison

Perceptual sameness is a measure that finds the similarity match between the original and watermarked image, particularly at the receiving end. Sometimes the fidelity of the system can be abandoned for the better performance with respect to other features like robustness and capacity. The most regularly used image similarity index measure is PSNR (Peak Signal to Noise Ratio) for two X Y images, O and W where one is original and the other is watermarked image that can be calculated as,

PSNR is given as,

$$PSNR = 20 \log \left(\frac{\max^2}{\mathrm{MSE}} \right)$$

Where MSE is given as,

$$MSE = \frac{1}{XY} \sum_{i=0}^{1-X} \sum_{j=1}^{1-Y} [O(i,j) - W(i,j)]^2$$

Where max is the possible maximum value of the image i.e. max = 255 for 8-bit gray scale image.

C. Robustness

Robustness is the ability to detect the embedded watermark after regular image processing operations like compression, filtering, geometric distortion etc.It is application dependent and it is not necessary that all the applications need robustness against all the manupalations. For example, in broadcast monitoring the robustness is useful only against the communication related operations. In fragile watermarking, robustness is unwanted. However, there is another type of watermarking called semi-fragile watermarking, where robustness is neded only against the unintentional manipulations.

D. Data Embedding Capacity

The number of bits, a watermarking scheme encodes within a cover work is referred to as data payload and is application dependent. For N bits watermark, the system can encode any of 2^N different messages. Increasing the watermark payload will affect the fidelity of the system and vice versa. Thus, it is very important for the researchers to make trade-off between contradicting properties of the watermarking while developing the watermarking systems. The three main contradicting parameters are robustness, imperceptibility, and payload. Increasing the watermark payload will affect the perceptual similarity (fidelity) of the image and robustness is affected by decreasing the watermark payload.

E. Informed and Blind Detection

In informed watermarking technique the detector needs the original information about the original unwatermarked image. However, in the blind watermarking systems there is no need of original or any information about the original image. Private watermarking systems may be related to informed watermarking and public watermarking is related to blind watermarking approaches. Blind detection has low PSNR value but provides very high security while informed detection provides high pay load and gives very high PSNR value. Informed watermarking systems have simple embedding and extracting algorithms.

F. Computational Complexity

It indicates the amount of time taken by the watermarking algorithm to encode and decode the images. To provide the security and potency of watermark, high computational complexity is needed. Conversly real-time applications requires both efficiency and speed.

III. DISCRETE WAVELET TRANSFORM

To decompose an image hierarchically, a special tool known as Discrete Wavelet transforms (DWT) is used [3]. Non-stationary signals are processed with the help of DWT. The wavelets are small waves used for transformation, of varying frequency and limited duration. Frequency and spatial description of an image are provided by wavelet transform. Unlike Fourier transform, temporal information is given in this transformation process. With the help of translations and dilations of a fixed function called mother wavelet, we can create wavelets.

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. 2 shows DWT decomposition of an image using three level pyramids.

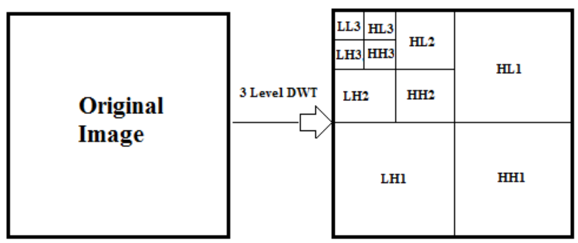

Fig.2 DWT Decomposition of an Image using 3-Level Pyramid

IV. INFORMED WATERMARKING PROCESS IN WAVELET DOMAIN

Informed watermarking is a kind of technique that adapts watermark signals to host ones, aiming at "eliminating" interferences of host signals on watermarks. This technique originates from the connection between digital watermarking and the problem of communication with side information at the encoder [2][11]. By lying on the consolidated information theories handling communication channels with side information and their adaption to the watermarking case this connection makes digital watermarking be promising to achieve a large capacity, high robustness, and good imperceptibility.

In this paper, a new informed watermarking scheme using hidden Markov model (HMM) in the wavelet domain (WDHMM) is proposed. The host image is first decomposed using the wavelet transformation (WT). The wavelet coefficients from the two coarsest scales and at a given location are grouped together to form a 15-dimensional (15-D) vector (known as vector tree). This 15-D vector tree is used as the carrier for embedding the watermark signal. In our approach, two cosets and with corresponding representative code words and are used to embed a one-bit message to each 15-D vector tree.

In [14], Malvar *et al.* proposed an improved spread spectrum watermarking scheme (ISS). By adapting to the host, as the source of interference, ISS achieves significant improvement in terms of robustness performance. Two related schemes were proposed in [12] and [13], which use informed coding and informed embedding. In informed coding, the message is firstly associated with a coset containing more than one code words, and the optimal codeword is then chosen from the associated coset to represent the message, where the correlation detector is usually adopted. In informed embedding, the chosen codeword is tailored, according to both the host signal and the constraints of robustness and distortion, so as to put the watermarked signal into the detection region of the chosen codeword. By utilizing spherical codes lying on the surface of sphere with radius one, both [12] and [13] have good performances against scaling attack. The scheme in [13] was evaluated through Monte Carlo simulation, while a practical informed watermarking scheme with superior robustness performance was demonstrated in [12]. The computational complexity of the latter algorithm, however, is relatively high, which partially comes from the fact that the scheme uses the trellis code with a long codeword length to achieve a high robustness.

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V.HIDDEN MARKOV MODEL (HMM)

A *hidden Markov model (HMM)* is a statistical Markov model in which the system being modeled is assumed to be a Markov process with unobserved (*hidden*) states. An HMM can be presented as the simplest dynamic Bayesian network. The mathematics behind the HMM was developed by L. E. Baum and coworkers. The Hidden Markov Model (HMM) is a power statistical tool for modeling a wide range of time series data. Markov models (like a Markov chain), the state is directly visible to the observer, and therefore the state transition probabilities are the only parameters. HMMs have found application in many areas interested in signal processing, and in particular speech processing, in a hidden Markov model, the state is not directly visible, but output, dependent on the state, is visible. Each state has a probability distribution over the possible output tokens. Therefore the sequence of tokens generated by an HMM gives some information about the sequence of states. The essential difference between a Markov chain and a hidden Markov model is that for a hidden Markov model there is not a one-to-one correspondence between the states and the symbols.

HMM IN WAVELET DOMAIN

In [3], Crouse *et al.* proposed the hidden Markov model in the wavelet domain (WD-HMM) to characterize the behavior of wavelet coefficients.

The hidden markov chain model connects the state variables horizontally within each scale the hidden markov tree model connects the state variables vertically across scale then refer to these models collectively as wavelet domain HMMs. Wavelet transforms are used to obtain only a robust image watermark, but in case of WD-HMM is used to attain robustness, invisibility and capacity at once.

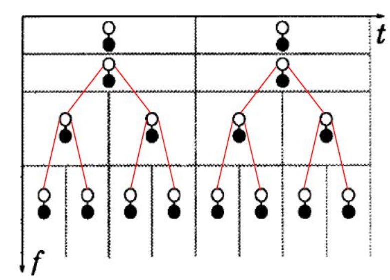

Fig.3.Hidden Markov tree for wavelet coefficients.

The WD-HMM model efficiently describes the non-Gaussian behavior of wavelet coefficients and captures the statistical dependency of wavelet coefficients across scale. This model, however, ignores the existing cross-correlation among the subband coefficients in different orientations at the same scale. To further enhance the accuracy of WD-HMM in capturing the dependency of wavelet coefficients, Ni *et al.* proposed a vector WD-HMM (VWD-HMM) and applied it to design a new watermarking scheme [15].

Any input image is decomposed via orthogonal or biorthogonal wavelets into a ***J***-level (***J>1***) pyramid. The input image is first decomposed into four subbands of LH_1, HL_1, HH_1, and LL_1. The LL_1 subband is further used to generate another four subbands of LH_2, HL_2, HH_2, and LL_2 at the next scale. Such decomposition is repeated until a predefined scale, ***J***, is achieved or the subband size does not allow further decomposition, as illustrated in Figure 4.

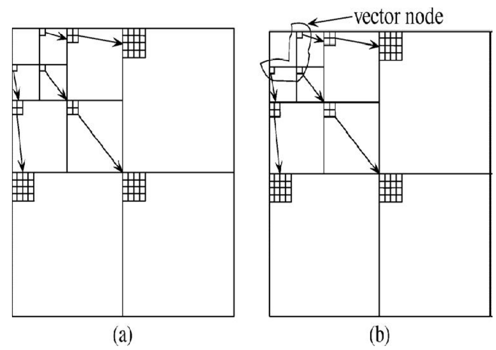

Fig.4. WD-HMM and quad tree of wavelet Coefficients (three levels). (a) Scalar. (b) Vector.

VI. VITERBI ALGORITHM

The Viterbi algorithm is a standard component of tens of millions of high-speed modems. It is a key building block of modern information infrastructure. Essentially the Viterbi Algorithm finds a path through any Markov graph, which is a sequence of states governed by Markov chain. Viterbi Algorithm is a dynamic programming algorithm for finding the most likely sequence of hidden states – called Viterbi Path – that results in a sequence of observed events, especially in the context of Markov information sources and hidden Markov models.

The Viterbi algorithm is named after Andrew Viterbi, who proposed it in 1967 as a decoding algorithm for convolutional codes over noisy digital communication links. Viterbi Algorithm is a dynamic programming algorithm for finding the most likely sequence of hidden states-called Viterbi path [14].

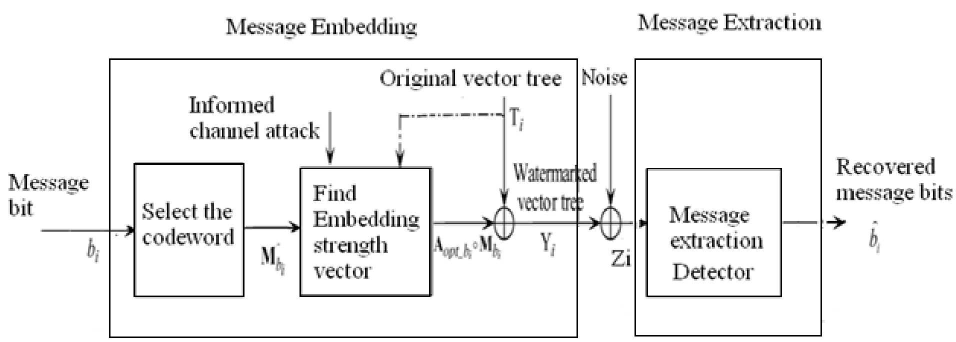

Fig.5. Block diagram of watermark embedding and extraction processes

A. Message Embedding

The embedding process of the proposed HMM-based informed watermarking can be described as follows.

1. Decompose image **I(x.y)** using bi-orthogonal Wavelet into a three-level wavelet pyramid, and use the Coarsest two levels to construct vector trees as shown in Fig. 2.
2. To achieve good robustness, one bit is inserted into one vector tree, which in turn requires generating the message of random bits.
3. Associate the given message (information) bit to its representative codeword.
4. Determine the optimal strength vector for through Informed embedding, and embed into via the rule.

$$Y_{i=} T_{i\,+} A_{opt\_bi} \bigcirc M_{bi}.$$

5. After finishing, embedding all message bits into their corresponding vector trees via Steps 3) to 4), perform the inverse wavelet transformation to obtain the watermarked image

B. Message Extraction Process

1. First decompose the watermarked image into a Three-level wavelet pyramid and then construct the vector trees using the coarsest two levels.
2. To every vector tree employ the TLOT detector to find a codeword with the maximum TLOT value.
3. Take the corresponding coset index (0, 1) of $M_{b\,i}$ as the extracted message bit ($b_{i\,\varepsilon}$ 0, 1).
4. After processing all vector trees reorder the extracted bits to recover the message sequence.

C. Result

Fig.6. a) Original Lena image b) Watermarked Lena image

Fig.7. a) Watermark Image b) Extracted watermark Image

The above result shows the better performance in watermarked image and watermark extraction. Watermarked Lena image has more quality than original Lena image. Original watermark is extracted with negligible noise. With the help of informed watermarking using hidden Markov model in DWT we obtained the tradeoff between capacity, robustness and imperceptibility.

D. Performance Evaluation

TABLE 1

Quality parameters	Watermarked Image	Recovered Watermark
PSNR	56.84	58.74
Correlation coefficient	0.67	0.78

VII. CONCLUSION

The research on watermarking is increasing very fast and various researchers from various fields are focusing to enhance robust watermarking schemes. Different efforts taken during last few years for developing effective watermarking scheme, to satisfy the robustness to all possible attacks and image processing operations. Some of the scientists were worked on watermarking schemes to satisfy the robustness, imperceptibility and capacity but still there is a tradeoff between them.

This paper emphasizes informed watermarking using Hidden Markov Model (HMM) which is one of latest methods and analyses various methods and approaches to wavelet based informed image watermarking in detail. Many new research directions arise in image watermarking for developing a technique to satisfy three conflicting requirements. First, the watermark needs to be robust against intentional and unintentional removal, second imperceptibility and third capacity. HMM based informed watermarking provides a good platform for such requirements.

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