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Vector Quantization based Multiple Watermarking using Spread Transform

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Abstract—Multiple watermarking is used for embedding multiple watermarks into the host single multimedia object (image) to provide authentication without bearing on the optical quality of the image. It is an embranchment of digital watermarking, which gives some particular applications, such as transaction tracking. Some digital watermarking techniques ensure the host-signal noise while associating the watermark in chronological sequence on experienced image data. The cover work is projected to multiple orthogonal projection vectors to be sure that different watermark signals do not mutually interfere in which they are embedded. Many multiple watermarking techniques suffer from host-signal interference when correlating the watermark sequence with received image data. To avoid the interference of one watermark from other watermark, N orthogonal projection vectors are chosen corresponding to N different watermarks having same dimension as the cover image. The cover work is projected to these orthogonal projection vectors to get the different orientations in which the different watermark signals are embedded. Experimental results demonstrate how the spread spectrum method enables the embedding of multiple watermarks into host image and reports its robustness to realistic attacks such as cropping, filtering, lossy compression, scaling, rotation and analog-digital and digital analog conversion.

Keywords—Digital Watermarking, Spread transform, Dither modulation.

I. INTRODUCTION

Digital watermarking is now one of the active research topics in the multimedia area. It is the process of embedding information into a digital signal. The signal may be image, audio, pictures or video etc. The goal is to conceal auxiliary information within a host digital signal so that no user could detect it and also at the same time it should not degrade the quality of the image [2].Commonly, a digital watermark is a code that is embedded within an image. It plays the role of a digital signature, providing the image with a sense of ownership or authenticity [3].A digital watermark is a complement of cryptographic process carrying identification information about the copyright owner or creator. Watermarks added to digital content serve a variety of purposes. The most common among them are ownership assertion, fingerprinting, authentication and integrity verification, content labeling, usage control, control protection, etc. Unfortunately, there is no universal watermarking technique to satisfy all of these purposes. The content (like cover image, watermark, etc) in the environment determines the digital watermarking technique [4]. The most important properties of any digital watermarking techniques are robustness, security, imperceptibility, complexity and capacity. The robustness of digital watermarking algorithms to common lossy compression algorithms such as JPEG is of considerable interest. From the image watermarking point of view, geometric attacks mainly introduce synchronization errors between the encoder and decoder. The watermark is still present, but the detector is no longer able to extract it. Different from geometric attacks, the content-preserving image processing operations (such as addition of noises, common compression and filtering operations) do not introduce synchronization problems, but will reduce watermark energy [5]. To achieve the robustness in large range of images one might embed multiple watermarks into same image for example, one can embed first watermark to convey ownership information, second watermark to verify content integrity and third watermark to convey a caption that might describe the content of image [7]. The embedding must be done such that the embedded signal causes no serious degradation to its host. Multiple watermarking algorithms can be classified into three classes: re-watermarking, segmented watermarking and composite watermarking [8].

Re-watermarking is a straight forward method of embedding. It places one watermark on the top of another and the watermark signal is detected by using former watermarked signal as the original image. Segmented watermarking partition the space available for watermarking into blocks and allocate each block to a different watermark. Composite watermark builds a single composite watermark from a collection of watermarks. Composite watermark will be separable if the watermarking patterns are orthogonal. To achieve this property of embedding cover vectors are extracted from the original cover image by using DCT. Presently, the quantization-based watermarking has received attention and the most important method proposed so far is quantization index modulation (QIM) [6]. An efficient implementation and low complexity realization of QIM is called dither modulation (DM), where the embedded information modulates the dither signal of a dithered quantizer. The proposed method can also be used for embedding robust and fragile watermark simultaneously into host signal for copyright protection and authentication.

The remainder of this paper is structured as follows: Section 2 presents the terminology of spread spectrum and dither modulation. Section 3 discusses the proposed methodology. Section 4 presents experimental results. Finally section 5 presents conclusion.

II. TERMINOLOGY

Current techniques for watermarking can be classified into two groups. The first group is based on spatial domain techniques, which embed the watermark by directly modifying the pixel values in the image. The second group comprises of transform domain methods, which embed the watermark by modulating the transform domain coefficients of the data. Spread transform dither modulation method is a transform domain method. The transform methods are more complex, but more robust than the spatial methods. The watermark is inserted into the cover image in a spread-spectrum fashion in the spectral domain, thereby making it robust against signal processing operations. In this case, the feature vector extraction process can be seen as an extension of the spread–transform technique (a more general method of spreading watermark information over a host signal than spread–spectrum) that is frequently employed on multimedia [10].To this feature vector a quantization based watermarking algorithm is used. Quantization index modulation (QIM) methods are a class of watermarking methods that achieve provably good rate-distortion-robustness performance.

A low-complexity realization of QIM called dither modulation has previously been proven to be better than both linear methods of spread spectrum and nonlinear methods of low-bit(s) modulation against square-error distortion constrained intentional attacks. We introduce a new form of dither modulation called spread-transform dither modulation that retains these favorable performance characteristics while achieving better performance against other attacks such as JPEG compression [8]. Dither modulation is the simplest form of quantization index modulation and is the most thoroughly analyzed by its ease of practical implementation.

Dither modulation systems embed watermark by modulating the amount of the shift, which is called the dither vector, by the embedded signal. The host signal is quantized with the resulting dithered quantizer to form the composite signal. Spread-transform dither modulation (STDM) couples the effectiveness of QIM schemes and conventional spread-spectrum systems and performs significantly better than DM. STDM has a number of advantages over earlier forms of dither modulation. One advantage is that the STDM signal constellation has fewer "nearest neighbors", which usually results in a lower probability of decoding error. Another advantage is that one can easily convert existing amplitude-modulation spread spectrum (AM-SS) systems into spread-transform dither modulation systems by replacing addition with quantization. This property is useful if one has already invested considerable effort in optimizing a spread spectrum system [8].

III. PROPOSED METHODOLOGY

The proposed method makes use of perceptually significant DCT coefficients of the image and uses them to carry the watermark information. This serves two purposes: First, these coefficients have a great perceptual capacity, in that modifying their DCT coefficients will not cause visible artefacts. Second, this serves as a security measure against tampering. Any attack on these regions will remain the image unusable. The method for watermark insertion and extraction are introduced and their performances are analysed.

3.1 Watermarking Embedding Method

The above discussion suggests the following general procedure for embedding multiple watermarks into the same image.

- Read the input image to be watermarked.
- Extract the cover vectors from the cover image by first dividing the image into blocks of 8 × 8 pixels and compute DCT for each block.
- Choose L projection vectors to hide L different watermark signals such that number of projection vectors remains orthogonal to each other.
- Embed different watermarks into corresponding projected data using dither modulation method.

Dither modulation systems embed information by modulating the amount of the shift, which is called the dither vector, by the embedded signal, *i.e.*, each possible embedded signal maps uniquely onto a different dither vector d(*m*).Watermark embedding process is shown in Fig. 1.

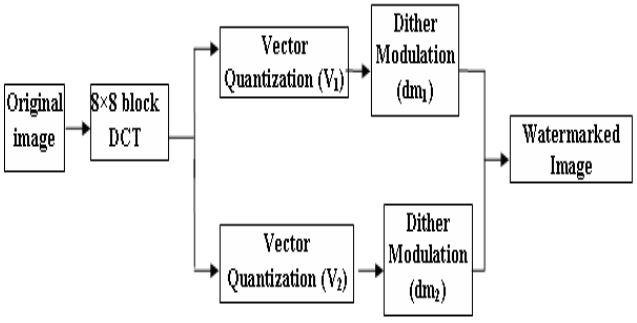

Fig. 1 Watermarking embedding scheme based on dither modulation

The host signal is quantized with the resulting dithered quantizer to form the composite signal [9]. Specifically, we start with some base quantizer q(·), and the embedding function is given by:

$s(x;m) = q(x + d(m)) - d(m)$

This equation is taken from [7]. In this paper the two watermarks embedded using DM method with uniform, scalar quantizer of step size Δ, where Δ is the quantization step used to control the embedding distortion. This method is called double spread transform dither modulation (DSTDM).

3.2 Watermark Detection Method

In watermark detection process the embedded watermark signals are extracted using corresponding extraction method and compared with the original watermarked data. Extraction method depends on the embedding method used. Minimum distance decoder is used to extract the watermark which is similar to STDM algorithm. The detailed extracting method of DSTDM is following:

- Extract the cover vectors by computing DCT in the blocks of 8 × 8 pixels of watermarked image.
- Project the cover vectors to the same projection vectors used in the embedding process.
- Apply DM with the same quantization step Δ.
- Apply minimum distance decoding rule into the corresponding dither value received by dither modulation.

The minimum distance decoding rule is
$m_i = \arg_{h \in \{0,1\}} \min |Wvi[h]-Wvi| \quad i \in \{1,2\}$
Where Wvi [0] and Wvi [1] represent dither modulation result of Yvi using d[0] and d[1] as dither value , V_i is the projection vector and e_i is the i^{th} extracted watermark signal [1].

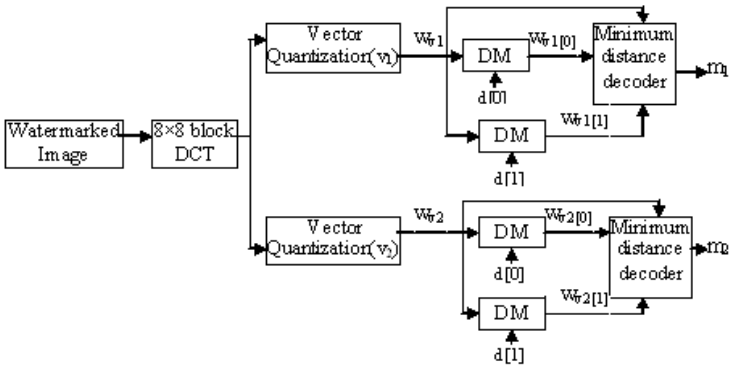

Fig. 2 Watermark detection scheme based on dither modulation

During watermark extraction phase, the elements of the signal received at the decoder are quantized using each dither quantizer [8]. The received message is reconstructed from the indices of the sequence of quantizers which contain the reconstruction points closest to the elements. The decoder extracts the embedded information m_i based on dither modulation result Wvi. It is well known that due to insertion of watermark, there will be degradation in visual quality of the host image (cover image). The degree of deterioration depends on the size of watermark embedded as well as step size used for DM. To achieve that goal, watermark bits are detected using minimum distance decoder and the remaining self-noise due to watermark embedding is suppressed to provide better quality of image. The experimental results are shown that validate this claim.

IV. EXPERIMENTAL ANALYSIS

In our experiments DM is used as the embedding method. The two watermarks namely watermark 1 and watermark 2 are used as it is multiple watermarking. Both the watermarks are the binary images of size 32×32. The cover work is the grey scale image. For simplicity, we had used the size of the cover work as 256 × 256.
Many experiments are carried out under the different cover images and different watermarks. Due to limited space, we only give the experimental results when using Lena image as cover work.

(a) cover image

(B) WATERMARK 1

(C) WATERMARK 2

Fig. 3 Cover Image and watermarks

Under the experimental condition described above, the watermarked image obtained is shown in fig 4(a). Similarly the extracted watermarks are shown in fig 4(b) and 4(c).

(a) Watermarked image

(b) extracted watermark 1

(c) extracted watermark 2

Fig 4 Watermarked image and extracted watermarks

We had used the two quantization step size of DM as 34 and 40. To check the robustness of the algorithm different attacks are carried out. The bit error ratio at various JPEG quality factor (Q) is given in the following table:

TABLE 1 ROBUSTNESS TEST AGAINST JPEG

JPEG quality factor (Q)	Quantization step size	PSNR	Bit error ratio (watermark-1)	Bit error ratio (watermark-2)
50	34	43.2723	0.6836	0.9072
	40	41.9346	0.6836	0.9063
75	34	43.34	0.6836	0.9036
	40	41.9346	0.6836	0.9063

From the experimental results obtained in table1, we can conclude that the proposed algorithm is robust against the JPEG attack. The perceptiblity of the cover work is intact after applying the watermarks and JPEG compression. Also, the method can embed and detect the multiple watermark signals synchronously and the different watermarks do not have any interference among them because of the orthogonal projection vectors.

A measure of robustness is done for a given bit-error rate at a given distortion level and embedding rate. We experimentally determined achievable better rate-distortion-robustness by implementing STDM. As the embedding strength of watermarking algorithm is increased, there will be a corresponding decrease in the BER when the watermark is extracted as shown in Fig.5.

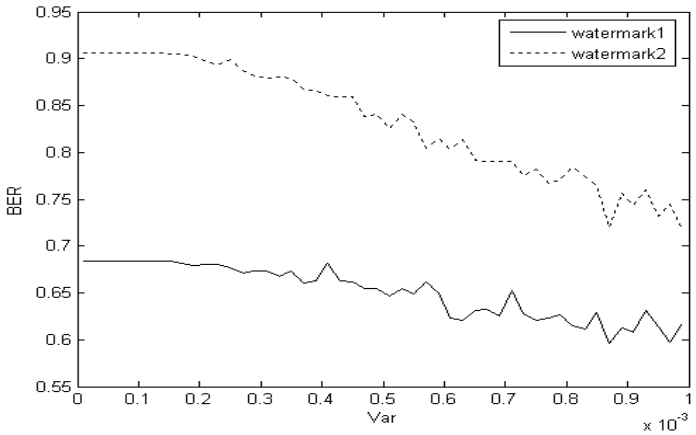

Fig 5 Bit Error Ratio of both Watermarks against Quality factor

V. CONCLUSIONS

In this paper we have described a new form of multiple watermarking which is unique both in terms of the feature vector used to carry the watermark, and in its application of STDM principles. We have presented new and promising experimental results on random projection for hiding the different watermark signal information in cover image. When comparing different methods for hiding the watermark information, the criteria depends on the number of projection vectors. Our results indicate that random projection preserves the similarities of the data vectors well even when the data is projected to moderate numbers of dimensions; the projection is yet fast to compute. Future work must focus on expansion of attacks, and more complete evaluation of watermark robustness.

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