High Capacity Wavelet Watermarking Using CDMA Multilevel Codes

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Abstract—**This paper proposes a technique based on CDMA and multilevel coding in order to achieve a high capacity watermarking scheme. The bits of watermark are grouped together and for each sequence a different modulation coefficient is used. Using the wavelet transform domain for embedding watermarks offers many advantages including robustness against intentional and unintentional attacks. The proposed algorithm results in low computational demands while maintains the same high accuracy achieved by other approaches.**

***Index Terms*—Watermarking, Digital copyright, M-ary modulation, Embedding capacity.**

I. Introduction

THE recent growth of networked multimedia systems has caused problems relative to the protection of intellectual property rights. This is particularly true for image and video data. The types of protection systems involve the use of both encryption and authentication techniques. New technology, however, provides authors with valuable new weapons in their battle to enforce the law in the on-line world. Digital watermarking [1], sometimes called "fingerprinting," allows copyright owners to incorporate into their work identifying information invisible to the human eye. When combined with new tracking services offered by some of the same companies that provide the watermarking technology, copyright owners can, in theory, find all illegal copies of their photos and music on the Internet and take appropriate legal action. For webmasters, digital watermarking can help ensure that only lawful image and audio files are used, protecting webmasters against the dangers of copyright infringement [2], [3].

II. Proposed algorithm

A. CDMA approach

A watermarking algorithm can be viewed in terms of a telecommunication system: a message (the watermark) has to be sent through a noise channel (the image) to a receiver that has to recover the original message [4]. A possible domain for watermark embedding is that of the wavelet domain [5], [6]. The DWT (Discrete Wavelet Transform) separates an image into a lower resolution approximation image (LL) as well as horizontal (HL), vertical (LH) and diagonal (HH) detail components. The process can then be repeated to computes multiple "scale" wavelet decomposition. One of the many advantages over the wavelet transform is that that it is believed to more accurately model aspects of the Human Visual System (HVS) as compared to the FFT or DCT. This allows us to use higher energy watermarks in regions that the HVS is known to be less sensitive to, such as the high resolution detail bands (LH, HL, HH). Embedding watermarks in these regions allow us to increase the robustness of our watermark, at little to no additional impact on image quality. The problem of data embedding rate can be solved using code division multiple access (CDMA) scheme [7], [8]. Different watermark messages are hidden in the same transform coefficients of the cover image using uncorrelated codes, i.e. low cross correlation value (orthogonal/near orthogonal) among codes. For each message bit, two different binary valued pseudo Noise (PN) matrices namely of size identical to the size of the wavelet coefficient matrices, are generated. Based on the value of the bit for the message vector, the respective two PN matrices are then added to the corresponding HL and LH coefficients matrices respectively according to the data embedding rule as follows:

$$X^e = \begin{cases} X + kP & if\ b = 0 \\ X - kP & if\ b = 1 \end{cases} \tag{1}$$

where X is wavelet coefficient of the cover image, X^e is the wavelet coefficient after watermark embedding, k is the modulation index, P is the PN matrix and b is the bit of watermark that has to be embedded. To detect the watermark we generate the same pseudo-random sequence used in CDMA generation and determine its correlation with the two transformed detail bands. If the correlation exceeds some threshold T, the watermark is detected. This can be easily extended to multiple bit messages by embedding multiple watermarks into the image. As in the spatial version, a separate seed is used for each PN sequence. During detection, if the correlation exceeds T for a particular sequence a "1" is recovered; otherwise a zero. The recovery process then iterates through the entire PN sequence until all the bits of the

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watermark have been recovered. Furthermore, as the embedding uses the values of the transformed value in embedded, the embedding process should be rather adaptive; storing the majority of the watermark in the larger coefficients. We will introduce a new scheme for M-ary modulation through the selection of proper indices. Respect to other approaches using CDMA and M-ary modulation [9], [10] our algorithm proposes a different scheme for watermark embedding and detection, with low computational cost and achieving great robustness against linear and nonlinear attacks.

B. Watermark embedding

A multilevel code can be reached grouping n bits of original watermark and associating to each group one of $L = 2^n$ possible levels. For a 4-levels watermarking scheme ($n = 2, L = 4$) the embedding rule becomes:

$$X^e = \begin{cases} X + k_1 P & if\ b_0 = 0\ and\ b_1 = 0 \\ X + k_2 P & if\ b_0 = 0\ and\ b_1 = 1 \\ X + k_3 P & if\ b_0 = 1\ and\ b_1 = 0 \\ X + k_4 P & if\ b_0 = 1\ and\ b_1 = 1 \end{cases} \quad (2)$$

where X is wavelet coefficient of the cover image, X^e is the wavelet coefficient after watermark embedding, P is the PN matrix, k_1, k_2, k_3 and k_4 are the four modulation indices, b_0 and b_1 are two consecutive bits of watermark. Since each impulse of multilevel sequence carries a number of bits equal to $n = \log_2 L$, the correspondent hiding capacity will be increased by the same factor n. The number of levels can not be arbitrarily increased, since immunity to noise decreases with a higher number of levels.

C. Watermark decoding

In CDMA watermarking scheme the detection of binary valued watermark data depends on the decision variable obtained by evaluating the zero-lag cross-covariance function between the image coefficient blocks and each code pattern. Using a multilevel coding for modulation indices the correlation value can't be used to recover input sequence of bits since this value is equal for each coding. To solve this problem we used the simple following rule:

$$[b_1, b_2, \ldots, b_n]_i = \min_i (X - k_i P) \quad (3)$$

Where X is the wavelet coefficient matrix of watermarked image, k_i is the modulation coefficient associated to the i-th sequence, P is the PN matrix and $[b_1, b_2, \ldots, b_n]_i$ is the sequence of bits that has been decoded associated to k_i modulation index.

III. Results

In this section we present the experimental results. Using a 4-levels CDMA and a single-level discrete 2-D Haar wavelet transform, on the original gray-scale 512*512 image of Lena, using the following modulation coefficients $k_1 = 0.00$, $k_2 = 0.50$, $k_3 = 1.25$ and $k_4 = 2.00$ we obtain a SNR of 27.06 dB and a PSNR of 32.37, with no errors on recovered watermark (Fig. 2). Using a 8-levels CDMA approach and modulation coefficients equal to $k_1 = 0.00$, $k_2 = 0.50$, $k_3 = 0.92$, $k_4 = 1.33$, $k_5 = 1.75$, $k_6 = 2.17$, $k_7 = 2.58$, and $k_8 = 3.00$ we obtain a SNR of 24.13 and a PSNR of 29.44, with no errors on extracted watermark (Fig. 3). If watermarked image is compressed using JPEG algorithm, recovered watermark still remains highly visible (Fig. 4). By introducing other kind of noise such as salt and pepper noise, Gaussian white noise, multiplicative noise and Poisson noise, the quality of watermark is not significantly degraded (Fig. 5). The proposed scheme is robust also to cropping and other filtering techniques. A Matlab implementation of the proposed algorithm is available at the following URL: http://www.advancedsourcecode.com/hiddenbits.asp .

IV. Conclusion

In this paper we presented a multilevel CDMA algorithm for wavelet based watermarking. The proposed scheme is robust to most of common filtering attacks, cropping and compression. We are currently investigating on the possibility to optimize the selection of modulation indices through genetic algorithm approaches, in order to achieve the optimal compromise among visual imperceptibility, capacity and robustness.

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Fig. 1 Cover image and original 52x19 logical watermark.

Fig. 2 Watermarked image using a 4-levels CDMA algorithm and recovered watermark.

Fig. 3 Watermarked image using a 8-levels CDMA algorithm and recovered watermark.

Fig. 4 Watermarked image using a 4-levels CDMA algorithm and recovered watermark after JPEG compression with quality factor 25.

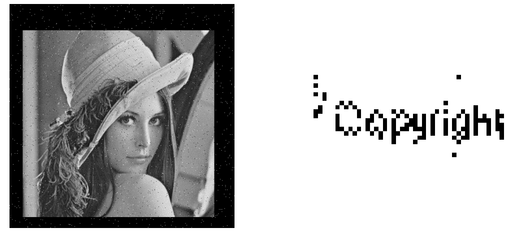

Fig. 5 Watermarked image using a 4-levels CDMA algorithm and recovered watermark after cropping and salt and pepper noise.