ROBUST IMAGE WATERMARKING USING FULL-FRAME DISCRETE COSINE TRANSFORM

Punya Thitimajshima

Department of Telecommunications Engineering, Faculty of Engineering
King Mongkut's Institute of Technology Ladkrabang
Bangkok 10520, THAILAND
Tel: (66 2)326-4242, Fax: (66 2)326-4554, Email: ktpunya@kmitl.ac.th

Abstract. In this paper a new watermarking algorithm for digital images operating in the frequency domain is presented: a sequence of pseudo-random real numbers is embedded in a selected set of DCT coefficients. After embedding, the watermark is adapted to the image to be signed by exploiting the masking characteristics of the Human Visual System in order to achieve watermark invisibility without diminishing its robustness. Experimental results demonstrate that the watermark is robust to several signal processing techniques and geometric distortions.

INTRODUCTION

The recent development of network multimedia systems has been damped by the reluctance of authors and publishers of multimedia to grant the distribution of their documents in a network environment because the availability of duplication means encourages copyright violation. Digital watermarking represents a viable solution to the above problem, since it makes possible to identify the author, owner, distributor or authorized consumer of a document. Image watermarking techniques proposed so far can be divided into two groups, according to the type of feature set the watermark is embedded in: the intensity value of the luminance in the spatial domain, or the image coefficients in a transformed domain. [1]

In this paper, a new technique to add a watermark to digital images is presented. The proposed algorithm operates in the frequency domain, and watermark casting is performed by exploiting the masking characteristics of the Human Visual System. [2] Watermark extraction is performed without resorting to the original, uncorrupted image. Though at the expense of a slight loss of robustness, the proposed technique represents a major improvement to methods relying on the comparison between the watermarked and original images. [3, 4]

The proposed Technique

The watermark $X = \{x_1, x_2, \ldots, x_M\}$ consists of a pseudo-random sequence of length M; each value x_i is a random real number with a normal distribution having zero mean and unity variance. The watermarking process can be viewed as a communication task, consisting of two main steps: *watermark casting*, in which the signal, represented by the watermark, is transmitted over the channel, which the original image acts the part of; intentional attacks and distortions to the image represent channel noises the signal must be immune to; *watermark detection*, in which the signal is received and extracted from the corrupted image. Furthermore, such sequences could be easily reproduced by providing to the generating algorithm the correct key.

Watermark casting

In *watermark casting* the $N \times N$ DCT of an $N \times N$ image I is computed; the DCT coefficients are reordered into a zig-zag scan, such as in the JPEG compression algorithm, and the first $L+M$ coefficients are selected to generate a vector $T = \{t_1, t_2, \ldots, t_L, t_{L+1}, \ldots, t_{L+M}\}$. Then, in order to obtain a tradeoff between perceptual invisibility and robustness to image processing techniques, the lowest L coefficients are skipped and a watermark $X = \{x_1, x_2, \ldots, x_M\}$ (chosen among 1000 pseudo-random sequences) is embedded in the last M numbers, to obtain a new vector $T' = \{t_1, t_2, \ldots, t_L, t'_{L+1}, \ldots, t'_{L+M}\}$ according to the following rule:

$$t'_{L+i} = t_{L+i} + \alpha \left| t_{L+i} \right| x_i \tag{1}$$

where $i = 1, \ldots, M$. The vector T' is then reinserted in the zig-zag scan and the inverse DCT algorithm is performed, obtaining the watermarked image I'.

Visual masking

In order to enhance the robustness of the watermark, the characteristics of the Human Visual System can be exploited to adapt the watermark to the image being signed: the original image I and the watermarked image I' are added pixel by pixel according to a local weighting factor $\beta_{i,j}$, obtaining a new watermarked image I'', i.e.:

$$I''_{i,j} = i_{i,j}\left(1 - \beta_{i,j}\right) + \beta_{i,j} I'_{i,j} = I_{i,j} + \beta_{i,j}\left(I'_{i,j} - I_{i,j}\right) \tag{2}$$

In this way it is possible to increase the marking level α without compromising mark invisibility, and make more difficult for an attacker to erase the mark. The weighting factor $\beta_{i,j}$ takes into account the characteristics of the HVS, so that in regions characterized by low noise sensitivity $\beta_{i,j} \approx 1$, and $I''_{i,j} \approx I'_{i,j}$, whereas in regions more sensitive to variations, $\beta_{i,j} \approx 0$ and $I''_{i,j} \approx I_{i,j}$.

Watermark detection

In *watermark detection*, given a possibly corrupted image *I**, the *N x N* DCT is applied to *I**; the DCT coefficients are reordered into a zig-zag scan, and the coefficients from the *(L + 1)th* to the *(L + M)th* are selected to generate a vector The correlation between the marked and possibly corrupted coefficients *T**, and the mark itself is taken as a measure of the mark presence. More specifically, the correlation *z* between the DCT coefficients marked with a codemark *X* and a possibly different mark *Y* is defined as:

$$z = \frac{Y \cdot T^*}{M} = \frac{1}{M}\sum_{i=1}^{M} y_i t^*_{L+i} \tag{3}$$

By comparing the correlation *z* to a predefined threshold S_z, it is possible determine whether a given mark is present or not. In practical applications, the threshold S_z is evaluated directly on the marked image, e.g.:

$$S_z = \frac{\overline{\alpha}}{3M}\sum_{i=1}^{M}\left|t^{*\,\prime}_{L+i}\right| \tag{4}$$

Experimental Results

In order to test the watermarking algorithm, some gray scale standard images were labeled, and several common signal processing techniques and geometric distortions were applied to these images to evaluate the robustness of the algorithm. The original "Lenna" image was signed with a key value of 100, α = 0.2, *L* = 10% and *M* = 6%. The PSNR of the watermarked copy without visual masking equal to 38.82 dB, and after visual masking is 39.77 dB.

The robustness of the algorithm against several signal processing techniques and geometric distortions will be presented, including JPEG compression, addition of Gaussian noise, and cropping.

CONCLUSION

In this paper a new watermarking algorithm for digital images operating in the frequency domain is presented. After embedding, the watermark is adapted to the image to be signed by exploiting the masking characteristics of the Human Visual System in order to achieve watermark invisibility without diminishing its robustness. Experimental results demonstrate that the watermark is robust to several signal processing techniques.

REFERENCES

[0][1] C.I. Podilchuk and E.J. Delp, "Digital Watermarking: Algorithms and Applications", *IEEE Signal Processing Magazine*, Vol. 18, pp. 33-46, 2001.

[1][2] H.A. Peterson, A.J. Ahumada, Jr., and A.B.Watson, "Improved Detection Model for DCT Coefficient Quantization", *SPIE Conf. Human Vision, Visual Processing, and Digital Display IV*, Vol. 1913, pp. 191-201, 1993.

[2][3] I.J. Cox, J. Kilian, T. Leighton, and T. Shamoon, "Secure Spread Spectrum Watermarking for Images, Audio and Video", *IEEE Intl. Conf. Image Processing*, pp. 243-246, 1996.

[3][4] M.D. Swanson, B. Zhu, and A.H. Tewfik, "Transparent Robust Image Watermarking", *Intl. Conf. Image Processing*, pp. 211-214, 1996.