Digital Image Watermarking by Spread Spectrum

ANDREJA SAMCOVIC[1], JAN TURAN[2]
[1]Faculty of Traffic and Transport Engineering, [2]Faculty of Electrical Engineering and Informatics
[1]University of Belgrade, [2]University of Kosice
[1]Vojvode Stepe 305, 11040 Belgrade, [2]Park Komenskeho 13, 04120 Kosice
[1]SERBIA, [2]SLOVAKIA

Abstract: - One digital watermarking method, based on the spread spectrum technique, is described in this paper. This method uses the frequency hopping spread spectrum in order to determine positions for watermark embedding in an original image, while the direct spread spectrum technique is used to provide robustness to the watermark signal. To embed the watermark signal, the selected bits are used to carry the watermark signal. The performance of the watermarking scheme can be evaluated by the Peak Signal-to-Noise Ratio (PSNR). Some simulation results indicate that the proposed method gained higher PSNR, and more watermark bits could be embedded into an original image.

Key-Words: - watermarking, image, data hiding, spread spectrum, bits, PSNR, embedding

1 Introduction

The rapid development of new Information-Communication Technologies (ICT) has improved the ease of access to digital information. Since digital data can be reproduced infinitely without any loss of quality, it is therefore difficult to differentiate the illegal copies from the original one. The copyright protection for multimedia data is then needed to counteract the piracy. Several techniques in digital signal processing have been studied and emerged to provide copyright owners with the desired degree of protection and to act as a disincentive to data piracy, for example digital signature, digital fingerprint and digital watermarking [1].

Digital watermarking is a method for embedding hidden data that contain copyright related information into a digital object. This provides an ownership identification of the object, and possibly other information that conveys conditions of use. Therefore, watermarking enables identification and tracing of different copies of distributed data. Watermark embedding can generally take place either in the spatial or in the transform domain. In the spatial domain, the watermark signal is directly embedded into the value of each pixel in an image, while in the frequency domain the watermark signal is embedded into the coefficients of the transformed image. Empirically, the transform domain approaches are more robust against noise or attack [2]. Digital watermarks can be either a visible or an invisible “seal” placed over an image to identify the copyright owner.

Digital watermarking has many applications. The requirements on digital watermarking are number of desirable characteristics that a watermark should exhibit. Since different applications have different requirements, there is no unique set of requirements that all watermarking techniques must satisfy. Some of the desirable properties are:

- Imperceptibility: the watermark should not be noticeable to the viewer nor should it degrade the quality of the content.
- Robustness: the watermark should not be removed or destroyed without degrading the quality of an image. It should be robust to common attack methods (filtering, compression, additive noise…). Thus, the major challenge in watermarking is to ensure both imperceptibility and robustness.
- Unambiguousness: retrieval of the watermark should unambiguously identify the owner of the content.
- Universality: the same digital algorithm should be appropriated for all media under consideration. This allows to image watermarking to be processed on common hardware.

This paper is organized as follows. After an introduction, the fundamentals of spread spectrum techniques are given in the second part. The process of watermark embedding is described in the third part of the paper. After presenting some results concerning this topic, the conclusion finishes this paper.

2 Spread Spectrum Techniques

The watermark should not be placed in perceptually insignificant regions of an image (or its spectrum), since many common signal and geometric processes could affect these components.

The problem then becomes how to insert a watermark into the most perceptually significant regions of the spectrum in a fidelity preserving fashion. Clearly, any spectral coefficient may be altered, provided such modification is small. However, very small changes are very susceptible to noise. To solve this problem, the frequency domain of an image at hand can be viewed as a communication channel, and correspondingly, the watermark is viewed as a signal that is transmitted through it. Attacks and unintentional signal distortions are thus treated as noise that the immersed signal must be immune to.

In spread spectrum communications, one transmits a narrowband signal over a much larger bandwidth such that the signal energy present in any single frequency is undetectable. Similarly, the watermark is spread over many frequency bins so that the energy in any one bin is very small and certainly undetectable.

The mostly described spread spectrum techniques are Direct Sequence Spread Spectrum (DS-SS) and Frequency Hopping Spread Spectrum (FH-SS) techniques [3].

In the DS-SS algorithm, a low level wideband signal can be easily hidden within the same spectrum as a high power signal, which each signal appears to be noise to the other. The core component of these spread spectrum systems is a Pseudo Random Noise Sequence (PRNS). For these direct sequence spread spectrum systems, the original baseband bit stream is multiplied by the PRNS to produce a new bit stream. Only those receivers equipped with correct PRNS can decode the original image. At the receiver, the low level wideband signal will be accompanied by noise. By using a suitable detector with the correct PRNS, this signal can be squeezed back into the original narrow baseband. As the noise is completely random and uncorrelated, the desired signal can easily be extracted.

The FH-SS algorithm involves a periodic change of transmission frequency. A frequency hopping signal may be regarded as a sequence of modulated data bursts with time-varying, pseudo-random carrier frequencies. The set of possible carrier frequencies is called the hopset. Hopping occurs over a frequency band that includes a number of channels. Each channel is defined as a spectral region with a central frequency in the hopset. The bandwidth is large enough to include most of the power in a narrow band modulation burst, having the corresponding carrier frequency. Data is therefore sent by hopping the transmitter carrier to seemingly random channels which are known only to the desired receiver. On each channel, small bursts of data are sent using conventional narrowband modulation before the transmitter hops again.

3 Watermarking Embedding

The DS-SS technique is used in the process of watermarking generating to provide robustness to the embedded signal, while the FH-SS technique is utilized to determine the embedding positions in an original image [4].

Firstly, a sequence of information bits, consisting of “-1” and “1”, is spread by multiplying with a large factor, called the chip-rate C_r, to obtain the spread information sequence. The size of this sequence is equal to the value of chip-rate multiplied by number of information bits. The spread sequence is then modulated with a binary pseudo-noise sequence to yield the modulated spread sequence, and is finally amplified with a locally adjustable amplitude factor to obtain the watermark signal. The block diagram of watermark process is illustrated in the block A of Fig. 1.

Each bit of the watermark signal will be embedded into some assigned locations, which is randomly determined by a key-based FH-SS technique, within the image frame, instead of whole frame. Therefore, each watermark bit will only be dispersed over its corresponding locations within some parts of the image. The block diagram of location determining process is shown in the block B of Fig.1.

For example, considering an original image with the size of 256 x 256 pixels, the amount of available pixels in the image is equal to 65 536, and is considered as a hopset.

If 10 % of image frame is required to embed the watermark, 6544 locations within the hopset will be pseudo-randomly determined, with no repeated locations, and used to carry the watermark signal. According to the Figure, those selected locations are used to perform the watermark embedding process.

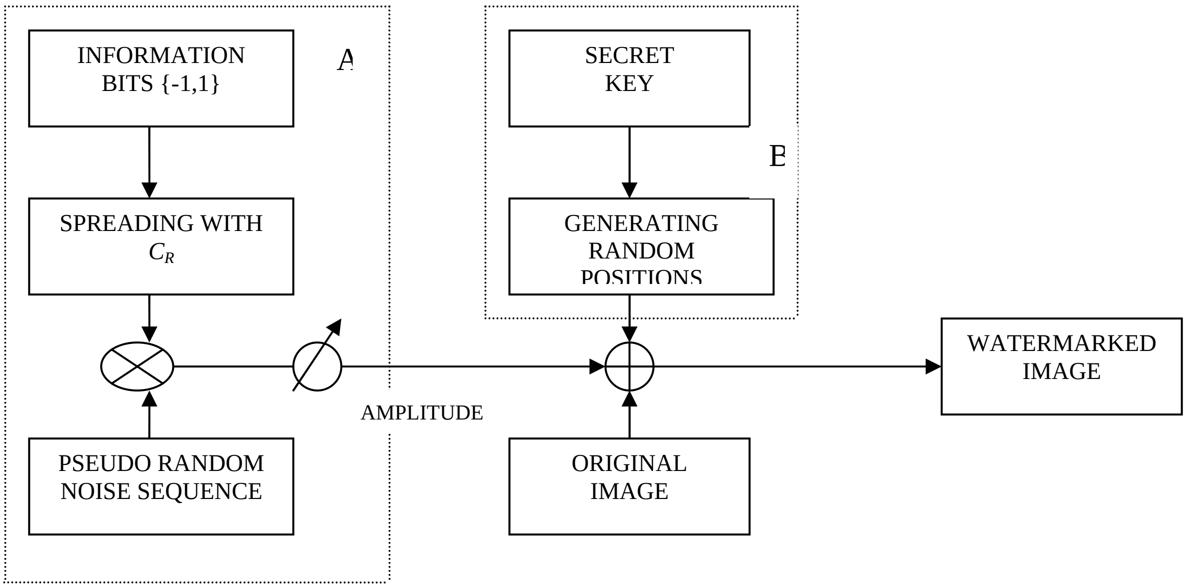

Fig.1 Block diagram of the watermarking scheme, with blocks A) watermarking generating, B) determining of locations

Each watermark bit is merely embedded into the assigned pixels by using additive operation [5]. The output will be the watermarked pixels. This ratio is up to the applications and user's satisfaction. Furthermore, in the proposed scheme, only some of the selected pixels will be used to carry the watermark signal. Note that in the ordinary watermarking scheme are used 8 bits within a pixel, ranging between 0-255 pixels, while in the proposed scheme 5 bits represent the number ranging between 0-31.

To recover the embedded information, it is necessary to precisely determine the hopping locations, where the watermark signal is added. The watermarked pixels are firstly correlated with the same pseudo-noise sequence used in the generating process. The correlation here is performed by demodulation followed by summation over the width of the chip-rate. Finally, the sign of the correlation sum determines the embedded information bit.

4 Some Results

In experiments are used various 8-bit standard images with the size of 256 x 256 pixels such as *Airplane*, *Barbara*, *Boat*. Since the Peak Signal-to-Noise Ratio (*PSNR*) is the standard metric for evaluating the differences between two versions of image, it is used to evaluate the quality of the watermarked images. It can be said that the lower the value of *PSNR*, the more different the two images are. In other words, if the value of *PSNR* is high, it implies that the quality of the watermarked image is close as that of the original one.

The simulation was carried by embedding the watermark signal into parts of the image *Barbara* at different levels ranging from 10, 20, …,100 %. These results are shown in Fig.2.

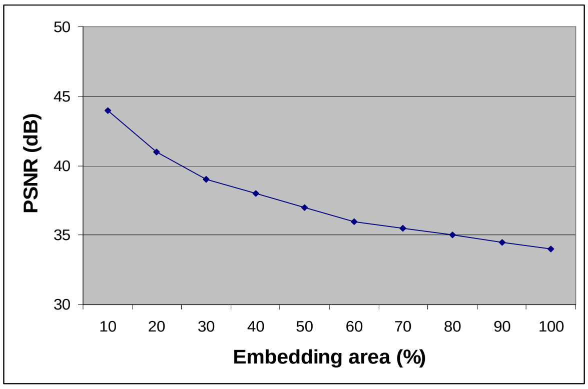

Fig.2. PSNR value at various level of embedding area within the image *Barbara*

When the image area used to embed the watermark signal was decreased, it apparently reduced the amount of information rate in the embedded signal. Therefore, the technique of reducing the block size used to carry the watermark signal was applied. In other words, only some selected bits within the selected pixels were used to carry the watermark signal. The smaller the block size, the smaller value the chip-rate required to recover the information bits correctly.

Since a smaller value of chip-rate was used, the amount of information bits to embed into the image frame would be increased. Table 1 shows the smallest value of chip-rate required to correctly recover the embedded bits at various block sizes.

Table 1. The smallest value of chip-rate required at various block sizes

ORIGINAL IMAGE	BLOCK SIZE 3	BLOCK SIZE 4	BLOCK SIZE 5
AIRPLANE	20	65	235
BOAT	20	95	270
BARBARA	18	68	245

When the information rate was kept constant while the block size used to carry the watermark signal was changed, the improved value of *PSNR* would be obtained, which is shown in Fig.3.

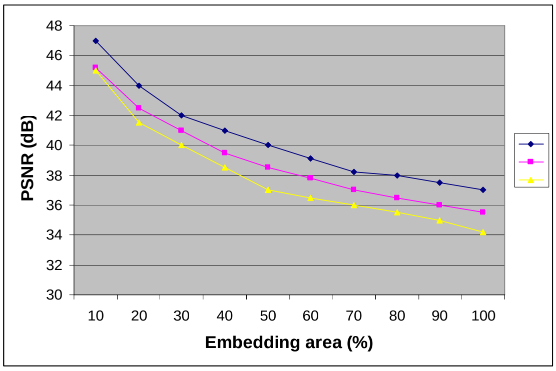

Fig.3. PSNR values at different block sizes (the highest curve corresponds to 3, in the middle to 4, while the lowest corresponds to 5 block size)

It can obviously be seen that the quality of the watermarked image was significantly improved since the watermark signal was embedded into some parts of the image frame only. The proposed scheme provides the same security level as the existing scheme, where the watermark signal was embedded into the whole image frame. One advantage of using the FH-SS technique is that the embedded signal is robust to some potential attacks, since attempting to determine the watermark's location from different copies will not be possible.

After reducing the embedding area within the image, it can be compensated by using some selected bits within the selected pixels to carry the watermark signal.

In spread spectrum watermarking, the watermark could be extracted without using the original, unwatermarked image. The input watermarked image is highpass filtered to remove major components of the image itself. The filtered image is then demodulated with the pseudo-noise signal that is perfectly synchronized with the one used for embedding [6].

5 Conclusion

We have presented in this paper the watermarking scheme based on the spread spectrum technique. This method used the FH-SS algorithm to locate the watermark embedding positions, while the DS-SS technique was used to generate the watermark signal. The proposed scheme improved the quality of watermarked image, while provided the same level of security, compared to the existing schemes. The decreasing of the embedding area could be compensated by adding the watermark signal into some selected bits within a pixel.

Acknowledgement

The authors would like to thank to the National Scholarship Programme of the Republic of Slovakia, for financial support throughout this work.

References:

[1] C.T.Hsu, J.L.Wu: "Multiresolution watermarking for digital images", *IEEE Transactions on Circuits and Systems II: Analog and Digital Signal Processing*, Vol.45, No.8, 1998, pp 1097-1101

[2] J.Turán: *Fast translation invariant transforms and their applications*, Elfa, Košice, 1999.

[3] R.Pickholtz, D.Schilling, L.Millstein: "Theory of spread spectrum communications: a tutorial", *IEEE Transactions on Communications*, Vol.30, 1982, pp 855-884

[4] I.Cox, J.Kilian, F.Leighton, T.Shamoon: "Secure spread spectrum watermarking for multimedia", *IEEE Transactions on Image Processing*, Vol.6, 1997, pp 1673-1687

[5] F.Hartung, B.Girod: "Watermarking of uncompressed and compressed video", *Signal Processing (Special issue on watermarking)*, Vol.66, 1998, pp 283-301

[6] O.Koval, S.Voloshynovkiy, F.Perez-Gonzales, F.Deguillaume, T.Pun: "Spread spectrum watermarking for real images: is it everything so hopeless", in the *Proceedings of the 12th European Signal Processing EURASIP conference*, Vienna, Austria, 6-10. September 2004.