FRACTAL IMAGE CODING WITH DIGITAL WATERMARKS

Ing. Marek Čandík
Prof. Ing. Dušan Levický, CSc.
Ing. Zita Klenovičová, CSc.
Dept. of Electronics and Multimedia Communication
Technical University of Košice
Park Komenskeho 13, 041 20 Kosice
Slovak Republic

Abstract

In this paper are presented some results of implementation of digital watermarking methods into image coding based on fractal principles. The paper focuses on two possible approaches of embedding digital watermarks into fractal code of images – embedding digital watermarks into parameters for position of similar blocks and coefficients of block similarity. Both algorithms were analysed and verified on gray scale static images.

Keywords

fractal image coding, digital watermarking

1. Introduction

Fractal image coding is a new and modern technique for lossy image compression [1]. Image compression addresses the problem of reducing of data needed to present a digital image. The application of this method is very effective for a higher compression ratio. Fractal image compression is a typical block-based lossy compression with an iterative decoding on the decompression side. Fractal compression is an asymmetric process, compression takes longer time in comparison with decompression [2].

With onset of the World Wide Web, authors of digital media can easily distribute their works by making them available on Web pages or other public forums. Anyone having access to those forums can copy the author´s media. By the nature of digital media, a copy is an exact, perfect duplicate of the original. This brings to front a potential problem – authorisation of materials in digital form. One method is to embed additional information and only distribute the media that contains this additional information. The embedded information is know as a watermark and can provide, for example, information about the media, the author, copyright, or licence information.

The aim of this paper is to connect two new trends – fractal image coding and digital watermarking and to give some results of their program implementation.

2. Fractal image coding

Encoding algorithm consists of three basic steps [3]

- image partitioning into the image blocks,
- calculation of the blocks similarity,
- calculation of the fractal coding parameters.

In the first step the original image is divided into non-overlapped R_i (Range) blocks, that cover all image, and overlapped D_i (Domain) blocks. The size of D_i blocks is larger than size of R_i blocks.

In the next step for each R_i block is searched the most similar D_i block is searched. Due to the size of D_i blocks which is larger than size of R_i blocks we have to reduce the size of D_i to equal size of R_i blocks by using contraction. Reduced D_i block is denoted as B_i

$$B_i = \nu(D_i), \qquad (1)$$

where $\nu()$ - is operation of contraction e.g. subsampling or averaging of D_i block.

After contraction of D_i blocks the most similar B_i block is searched for each R_i block by using of metrics which describes distance between R_i and B_i blocks.

The Euclidian distance is used for calculation of distance. It means that parameter d in the following equation should be minimal for most similar blocks

$$d^2(R,B) = \sum_{i=1}^{n}(r_i - b_i)^2, \qquad (2)$$

where n is number of pixel in R_i and B_i block.

For reconstruction of R_i blocks from the most similar B_i blocks we can used the following transformation

$$R_i = s.B_i + o.\underline{1}, \qquad (3)$$

where s- offset
o- brightness.

The transformation parameters can be expressed in the following form [1]

$$s = \frac{\left[n\sum_{i=1}^{n} r_i b_i - \sum_{i=1}^{n} r_i \sum_{i=1}^{n} b_i \right]}{\left[n\sum_{i=1}^{n} b_i^2 - \left(\sum_{n=1}^{n} b_i \right)^2 \right]}, \qquad (4)$$

$$o = \frac{1}{n}\left[\sum_{i=1}^{n} r_i - s\sum_{i=1}^{n} b_i \right]. \qquad (5)$$

After calculation of transformation parameter for each R_i and B_i blocks we obtain the set of fractal coding parameters in the following form [4]

$$R_i \approx (x, y, s, o, \iota) \qquad (6)$$

where

x,y- coordinates of position of the most similar D_i block in image (e.g. coordinates of its top left corner)

s,o- transformation parameters

ι - izometry, that means of position of the most similar D_i block in sense its rotation and reflection (8 positions).

Decoding of original image is an iterative process of reconstruction $\hat{R}_i$ blocks from the set of fractal coding parameters by using eq.(3). The decoding process of each R_i block can be described in a following form [4]

$$\begin{aligned} \hat{R}_i^1 &= s.B_i + o.\underline{1} \\ \hat{R}_i^2 &= s.(s.B_i + o.\underline{1}) + o.\underline{1} \\ &. \\ &. \qquad (7) \\ &. \\ \hat{R}_i^k &= s^k.B_i + \left(o\sum_{p=0}^{k-1} s^p \right).\underline{1} \end{aligned}$$

The important question in decoding process is the start condition. It means the form of starting image at the decoder side. In standard decoding algorithm we can consider, that the image frame at the decoder side is zero. Result of decoding process after k-th iteration is the reconstructed image called attractor.

3. Digital watermarking

A watermark is a hidden information within a digital signal. To achieve maximum protection of intellectual property with watermarked media, several requirements must be satisfied [5]:

- Imperceptible – the watermark should be imperceptible, not to affect the viewing experience of the image or the quality of signal.
- Undeletable – the watermark must be difficult or even impossible to remove by a hacker, at least without obviously degrading the host signal.
- Statistically undetectable – A pirate should not be able to detect the watermark by comparing several watermarked signals belonging to the same author.
- Robustness – The watermark should be survive by the using of the lossy compression techniques and signal processing operations (signal enhancement, geometric image operations, noise, filtering, etc.).

For the watermarking several techniques have been developed. Watermarking technique can be divided into two main groups:

- spatial domain watermarking,
- frequency domain watermarking.

Watermarking in frequency domain use the selected discrete transformations (DCT, wavelet) for embedding of the hiding information into the spectral coefficients.

The schematic algorithm of watermarking in frequency domain is shown on Fig. 1. and algorithm of extraction of watermark is shown on Fig. 2.

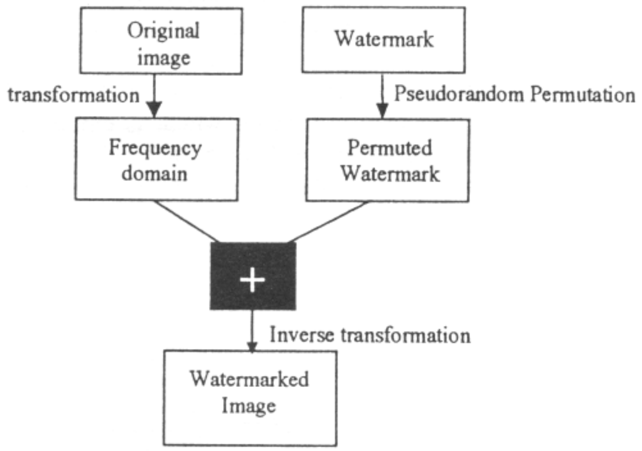

Fig.1 Algorithm of watermarking in frequency domain

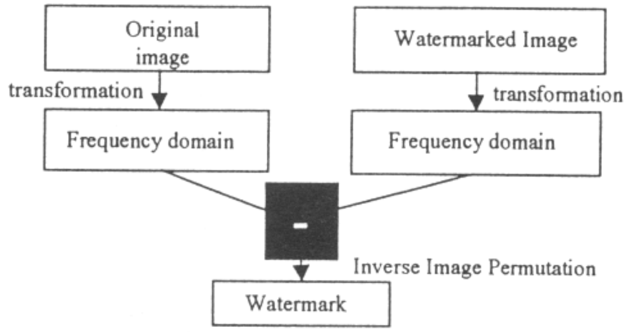

Fig.2 Algorithm of extraction of watermark

4. Digital watermarking in fractal image coding

Digital watermarking in fractal image coding is very similar to watermarking in frequency domain [6]. After fractal image coding we obtain an output code in the following form (Fig.3).

$$\begin{matrix} x_1 & y_1 & s_1 & o_1 \\ x_2 & y_2 & s_2 & o_2 \\ & \vdots & & \\ x_n & y_n & s_n & o_n \end{matrix}$$

Fig.3 Output code of fractal image coding

The embedding of digital watermarks into fractal output code is possible to implement by the parameters which describe

- position of blocks (x_i, y_i; i=1,2,...,n)
- coefficients of block similarity (s_i, o_i; i=1,2,...,n)

Embedding digital watermarks into position of blocks [5] must be implemented in coding process. Each Range block is defined by a near neighborhood, where maximal distance between Range and Domain is $d_{neigh.}$ According to pixel in permuted watermark (white or black i.e. 1 or 0) the Domain block is searched in a near neighborhood (actual pixel in permuted watermark which is embedded into original image is white, i.e. 1) or a far neighborhood (in case the actual pixel is black, i.e. 0) of actual Range block (Fig.4).

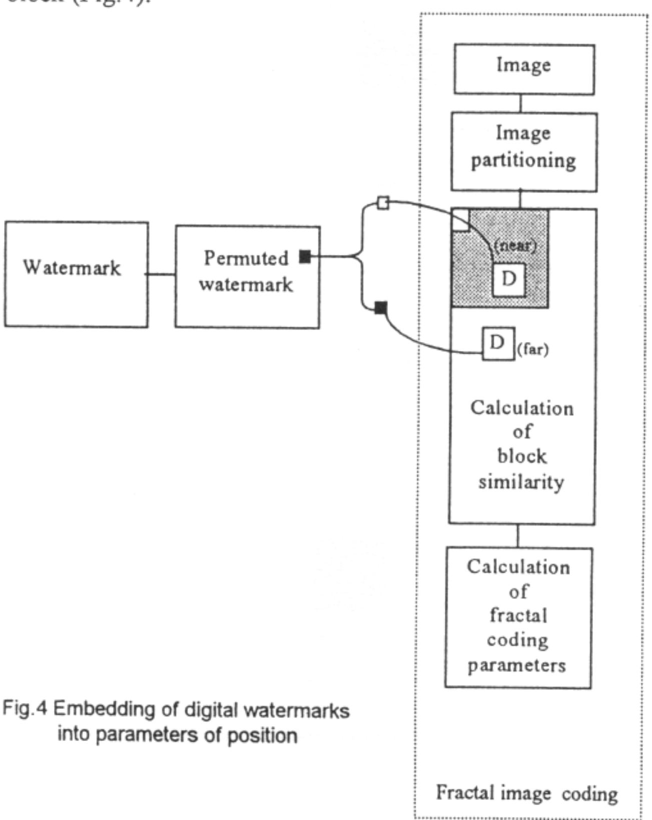

Fig.4 Embedding of digital watermarks into parameters of position

A watermark extraction is based on the calculation of Euclidian distance between Range (R) and Domain (D) blocks (Fig.5). The distance between each Range block and its self-similar Domain block is given by parameters of position of Domain block in fractal output code (x_i and y_i). Quantitative designation of this distance gives Euclidian metric - eq. (2).

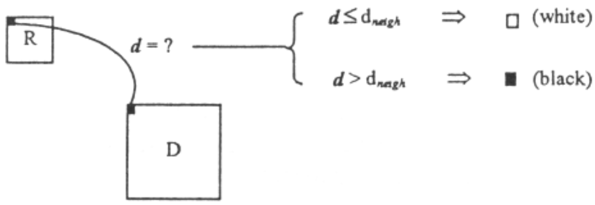

Fig.5 Extraction of watermark from parameters of positions

Embedding digital watermarks into parameters of blocks similarity (s_i, o_i) [6] is possible to implement after fractal coding (Fig. 6.), embedding is realized into fractal output code.

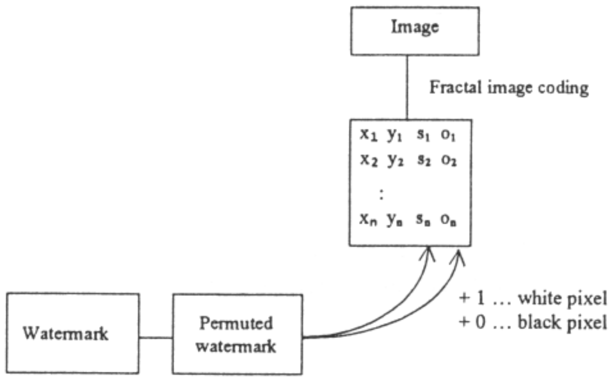

Fig.6. Embedding of digital watermarks into coefficients of block similarity

Practical experiments show that embedding of watermark in fractal image coding gives better image quality in parameter of brightness (o_i). In this case the extraction of embedded watermark is realized by following figure (Fig.7).

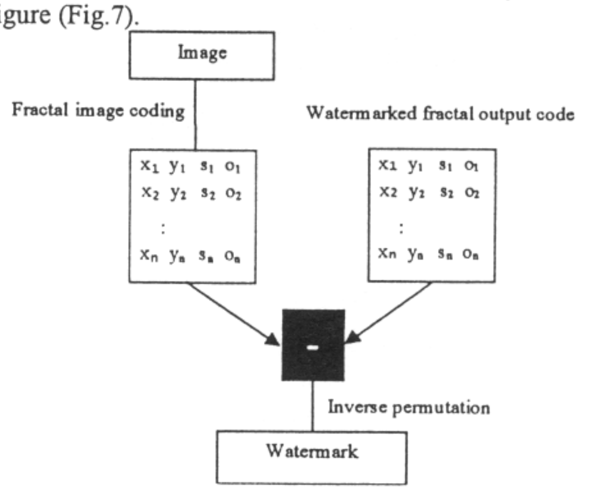

Fig.7. Extraction of watermark from parameters of block similarity

5. Experimental results

The experiments were orientated on testing of image quality of watermarked images. Quantitative measure of image quality was analysed with Peak-Signal-to-Noise-Ratio

$$PSNR = 10\log_{10}\frac{255^2}{\left(\frac{1}{N_1.N_2}\right)\sum_{i=1}^{N_1}\sum_{j=1}^{N_2}\left(Original(i,j)-Attractor(i,j)\right)^2}$$

and setting of fractal image coding was:

- compression ratio $C_r = 8$,
- size of Range block = 8,
- size of Domain block = 32,
- Step between Domain blocks = 32.

Original image　　Watermark

Fractal image compression　　Watermarked image (brightness)　　Watermarked image (position)

Fig.8 Comparing of image quality of watermarked image CLAUDIA

CLAUDIA			
	FRACTAL IMAGE COMPRESSION PSNR[dB]	WATERMARKED IMAGE (BRIGHTNESS) PSNR[dB]	WATERMARKED IMAGE (POSITION) PSNR[dB]
1.ITERATION	21,0685	21,1672	20,5637
2.ITERATION	26,0759	26,1379	22,7878
3.ITERATION	27,2674	27,2642	23,2994
4.ITERATION	27,3614	27,3469	23,3648
5.ITERATION	27,3888	27,3672	23,3903
6.ITERATION	27,3977	27,3739	23,3965
7.ITERATION	27,4021	27,3766	23,4048
8.ITERATION	27,4034	27,3778	23,4057
9.ITERATION	27,4040	27,3778	23,4106
10.ITERATION	27,4040	27,3778	23,4108

Original image　　Watermark

Fractal image compression　　Watermarked image (brightness)　　Watermarked image (position)

Fig.9 Comparing of image quality of watermarked image EINSTEIN

EINSTEIN			
	FRACTAL IMAGE COMPRESSION PSNR[dB]	WATERMARKED IMAGE (BRIGHTNESS) PSNR[dB]	WATERMARKED IMAGE (POSITION) PSNR[dB]
1.ITERATION	19,6462	19,7222	20,5637
2.ITERATION	22,4770	22,5146	22,7878
3.ITERATION	23,3983	23,4056	23,2994
4.ITERATION	23,5213	23,5185	23,3648
5.ITERATION	23,5810	23,5695	23,3903
6.ITERATION	23,6132	23,5940	23,3965
7.ITERATION	23,6290	23,6028	23,4048
8.ITERATION	23,6296	23,6034	23,4057
9.ITERATION	23,6349	23,6055	23,4106
10.ITERATION	23,6351	23,6058	23,4108

Original image　　Watermark

Fractal image compression　　Watermarked image (brightness)　　Watermarked image (position)

Fig.10 Comparing of image quality of watermarked image LENNA

LENNA			
	FRACTAL IMAGE COMPRESSION PSNR[DB]	WATERMARKED IMAGE (BRIGHTNESS) PSNR[DB]	WATERMARKED IMAGE (POSITION) PSNR[DB]
1.ITERATION	15,9197	15,9755	20,0492
2.ITERATION	21,0190	21,0780	22,7211
3.ITERATION	23,0600	23,0790	23,2505
4.ITERATION	23,3971	23,3968	23,2944
5.ITERATION	2,5157	23,5064	23,3153
6.ITERATION	23,5921	23,5803	23,3337
7.ITERATION	23,6446	23,6307	23,3501
8.ITERATION	23,6838	23,6684	23,3648
9.ITERATION	23,7142	23,6978	23,3780
10.ITERATION	23,7386	23,7218	23,3900

Original image Watermark

Fractal image compression Watermarked image (brightness) Watermarked image (position)

Fig.11 Comparing of image quality of watermarked image GIRL

GIRL			
	FRACTAL IMAGE COMPRESSION PSNR[DB]	WATERMARKED IMAGE (BRIGHTNESS) PSNR[DB]	WATERMARKED IMAGE (POSITION) PSNR[DB]
1.ITERATION	17,7401	17,8262	20,0481
2.ITERATION	24,0411	24,1057	24,9351
3.ITERATION	25,8605	25,8528	25,6867
4.ITERATION	25,9705	25,9380	25,7332
5.ITERATION	25,9866	25,9437	25,7454
6.ITERATION	25,9912	25,9450	25,7491
7.ITERATION	25,9922	25,9455	25,7505
8.ITERATION	25,9927	25,9456	25,7507
9.ITERATION	25,9928	25,9459	25,7509
10.ITERATION	25,9929	25,9467	25,7509

6. Conclusion

In this paper new digital image authentication techniques of embedding digital watermarks into images were proposed. The fractal image coding was used for image transformation into compressed form and watermark´s pattern was embedded into the image.

References

[1] Fisher, Y. : Fractal Image Compression, Theory and Application. Springer – Verlag New York, 1995.

[2] Král, P. - Levický, D. - Čandík, M. : Fast methods for fractal image coding. Int. Conf. Digital signal processing DSP´97 Herľany, pp.172-175, 1997.

[3] Lu, N. : Fractal Imaging. Academic Press, San Diego, 1997.

[4] Král, P. - Levický, D. : A Method for Fractal Image Compression. Int. Conf. Nové smery v spracovaní signálov III., Liptovský Mikuláš, pp. 70-73, 1996.

[5] Puate, J. – Jordan, F.: Using fractal compression scheme to embed a digital signature into an image. http://www.dlib.org.

[6] Levický, D. - Čandík M. - Klenovičová, Z.: Digital Watermarking by using Fractal Image Coding., The 4-th Int. Conf. Digital Signal Processing DSP´99, Herľany, pp. 19-21, 1999.

About authors...

Marek ČANDÍK was born in Košice, Slovakia 1974. He graduated from the Technical University of Košice in 1997, then he started Ph.D. study at Department of Electronics and Multimedia Communications, Faculty of Electrical Engineering and Informatics, Technical University in Košice. His work includes digital image processing and transmission.

Dušan LEVICKÝ was born in Slanec (Slovak Republic) in 1948. He received the M.Sc. and PhD. degrees at the Technical University of Košice and now he is proffesor at the Department of Electronics and Multimedia Communications Technical University in Košice. His research interests include digital image processing, image transmission, cryptography.

Zita KLENOVIČOVÁ – she received the M.Sc. and PhD. degrees at Technical University of Košice and now she is assistant professor at Department of Electronics and Multimedia Communications, Technical University of Košice. Her research interests include digital image processing and cryptography.