Self-similarity based image watermarking

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ABSTRACT

In this paper we present an original way to mark images. Firstly the different techniques in watermarking are presented. In a second part our approach is outlined. It consists in searching an IFS (Iterated function systems) in the image to hide new similarities in it. In a third part two different algorithms are presented: the first uses the luminance domain, the second uses the DCT (Discrete Cosine Transform) domain. Finally results and perspectives of our scheme are outlined.

1 OTHER APPROACHES

Nowadays the boom of electronic and multimedia industries creates new problems in image processing. Two current important challenges for engineers are indexation and watermarking.

In this paper we propose a new method to prevent the pirating of images. The problem of watermarking can be defined as follows: it consists in hiding a mark, a license number or a copyright which is invisible for the observer but which is indelible and robust to image processing techniques such as cropping, blurring, to geometrical transformations, or even lossy compression techniques.

In the literature we can find a lot of methods. Recently, sophisticated techniques benefit from the visual properties of the eye to hide the frequential components inherent to the watermark [FJFC+97]. Others consider the watermarking problem as a matter for the information theory: a signal (the watermark) has to be retrieved out of noise (the original image) [Pit96] [ICS97]. Bender *et al.* [WBM95] describe a watermarking scheme called "texture block coding", wherein textured areas are replaced by identical textured blocks. The watermark is identified by autocorrelation. This method is particularly efficient with textured images.

2 OUR APPROACH

2.1 The Fractal Code

Our approach is based on the fractal compression method developed by Jacquin [Jac92]. This scheme express the image by a fractal code. It consists in searching an Iterated Function System (IFS) in the image:

- The image is partitioned into two kind of blocks: the range and the domain blocks that are respectively extracted from a range partition R and a domain partition D. Contrary to Jacquin's scheme, our scheme does not use the decoding phase, therefore the size of Domain blocks or Range blocks can be identical.
- The following step consists in building a fractal code which can be seen as a "Collage Map": we associate to each block R_i of the partition R , the block D_j which is more similar to R_i (except itself). This test of self-similarity consists in minimizing a quadratic error e between the block R_i and the affine transformed block D_j [Jac92].

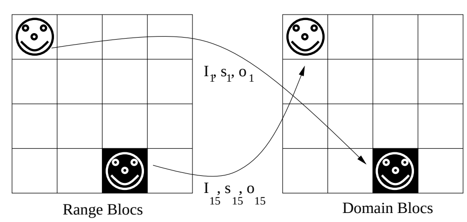

Figure 1: Principle of Collage Map

Therefore, to each image corresponds a fractal code (a Collage Map) composed of a range partition R, the indices I_j of associated blocks of partition D, the scale s_j and the offset o_j parameters of the associated grey level affine transforms. It can be written as follows:
$Fractal\ Code = \{R, I_1, ..., I_n, s_1, ..., s_n, o_1, ..., o_n\}$
The fractal code can also be expressed in the DCT domain and is used in image compression[BV94].

2.2 Embedding the watermark

Image watermarking is then done by altering the Collage Map. Indeed it is statistically rare to find a block equal to another in an ordinary image (except when the image is a fractal image). Our algorithm consists in adding artificial and visually invisible local similarities into the image in order to control the Collage Map. The similarities are added by substituting a Range block R with a new block $\hat{R} = s.D + o$. By this way we force new exact mappings instead of the default best original mappings. By adding exact domain similarities in the image (that define the watermark), we control the IFS (the fractal code).

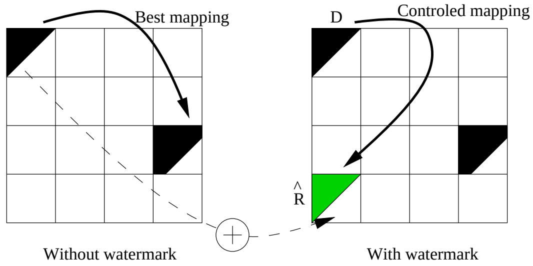

Figure 2: Adding of a watermark (collages are represented by solid lines)

2.3 Block Selection

To be robust to the different compressing methods, marking must have a significant low-frequency component. The non-stationary areas satisfy those criteria. A criterion such as the standard-deviation of the blocks makes it possible to select the Domain blocs (fig 3.b) .
To ensure an efficient detection step, one Domain block must not be similar to another. Consequently, we proceed to a bloc quantization of the Domain pool (fig 3.c). This can be done by examinating the previous criterion.
The Range blocks R are selected to be similar with $\hat{R} = s.D + o$ for specifics real values s and o. Therefore the information added will be as invisible as possible (cf figure 3). The distance between two blocs is calculated using the quadratic error (fig 3.d).

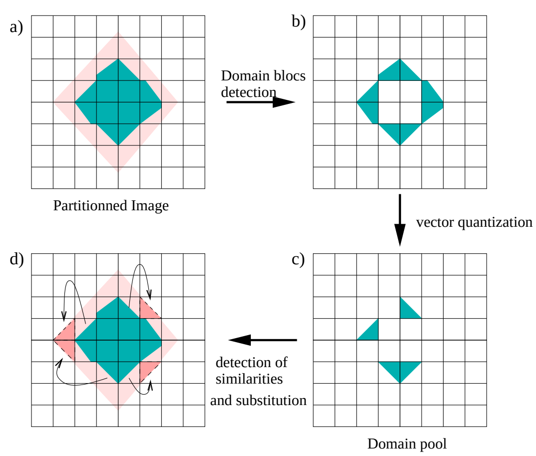

Figure 3: The embedding stage

2.4 Spatial domain embedding

The image is partitioned in blocks of 8×8 pixel size. The dynamic of each $\hat{R}$ block is chosen les than 20.0. Otherwise block artifacts will appeare and the similarities are perceptible.
According to the image and the hiding quality, the number of Domain Blocks is between 50 to 100.
The magnitude of the watermark is fixed by a factor S. For each blocks D and R, $\hat{R}$ is calculated as follows:

$$\hat{R} = \delta * S * \frac{D}{max(D)} + \bar{R} \quad (1)$$

where $\bar{R}$ is the mean of R and

$$\delta = \begin{cases} +1 & \text{if the embedded bit} = 1 \\ -1 & \text{if the embedded bit} = 0 \end{cases}$$

The quadratic error between R and $\hat{R}$ is then calculated.

2.5 DCT domain embedding

To avoid block artifact and to improve the watermark invisibility, we perform the embedding scheme in the DCT domain. The 8×8 blocks of the image are transformed to DCT coefficients and we consider the similarity between only the low frequency coefficients (cf figure 4). Thus the higher frequency coefficients permit to mask the watermark and moreover the low frequency coefficients are less altered by compression techniques.
In this case, $\hat{R}$ is given by:

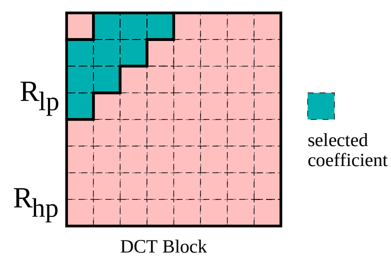

Figure 4: DCT block and modified coefficients

$$\hat{R} = R_{hp} + \delta * S * \frac{D_{lp}}{max(D_{lp})} \quad (2)$$

where $.hp$ and $.lp$ are the high-pass components (plus the DC coefficient) and low-pass components, and

$$\delta = \begin{cases} +1 & \text{if the embedded bit} = 1 \\ -1 & \text{if the embedded bit} = 0 \end{cases}$$

To obtain invisibility of the watermark maximum DCT coefficients magnitudes must be smaller than 200.0. The similarities are searched in the luminance space to avoid quantization problems after the inverse DCT transform.

2.6 Watermark detection step

The detection can be applied to prove the existence of the watermark and to read it. To perform this, the identifier needs the location of the Domain blocks and the associate Range Blocks. Let p_1 be a counter that express the number of matched blocks. Our detection scheme consists in :

1. Get a Domain block D of the image
2. Create a bloc $\hat{R}$ (cf formula 1 and 2) and search the Range block R witch minimize the quadratic error.
   - If the index R is the same that the index in the table, p_1 is increased and the embedded bit is deduced from the sign of δ.
   - If the index of R is not the same than the index in the table, p_1 is then reduced.
3. Get another Domain block D of the image and go to 2 until the end.

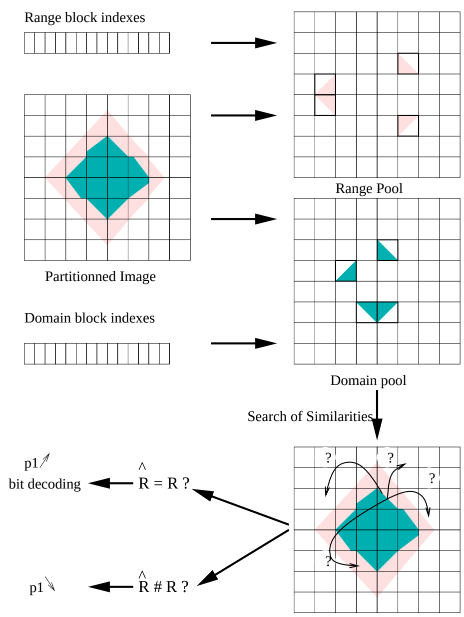

Figure 5: Detection Stage

2.7 Results and Perspectives

2.7.1 Results

The "spatial" and "frequential" algorithms have been tested on lena 256×256. For each scheme 50 Domain blocks have been selected. The number of Range blocks detected (and the number of decoded bits) is calculated for different quality factors with the JPEG compression scheme (cf figure 6 and 7).

For a same distortion ($PSNR = 52dB$) we can notice that the DCT scheme is more robust to the JPEG test (more blocks are detected). This is due to the low-pass embedding of the DCT method. Furthermore this

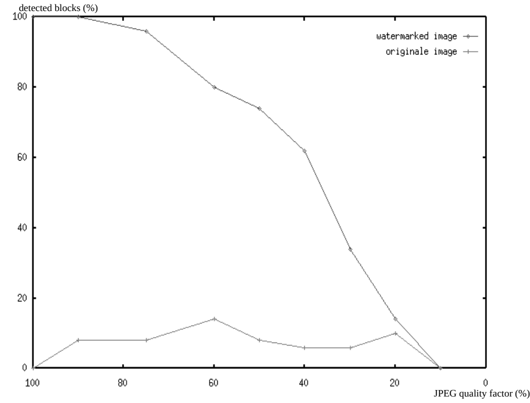

Figure 6: JPEG-test with the DCT scheme

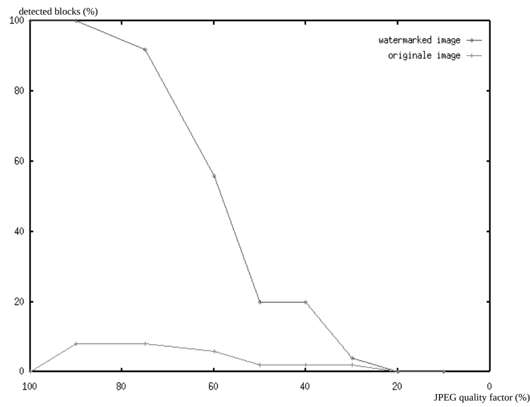

Figure 7: JPEG-test with the spatial scheme

method does not produce disturbing block artifact as the spatial method does.
The number of Domain blocks is limited by the dynamic of the image. If the image does not contain edges or contains low-dynamic edges the detection step is less robust to compression techniques.

2.7.2 Perspectives

This work uses similarities to watermark images. It shows that like in many watermarking schemes, frequential domain is more appropriate. A spatial/frequential scheme using wavelet decomposition ([Mal89]) will be added to our work. The similarities are added in the low-pass component.
Moreover we plan to search local similarities in the image (the Range block is near the Domain block). In that way our embedding scheme will became faster and robust to cropping.
As many watermarked schemes, our scheme is not efficient versus geometric attacks as rotating or stretching operations. Theses attacks are often visually invisible and difficult to detect without the original image. To counter this drawback we can use an adaptative Delaunay partitioning [DSC95] (figure 9). This tessellation

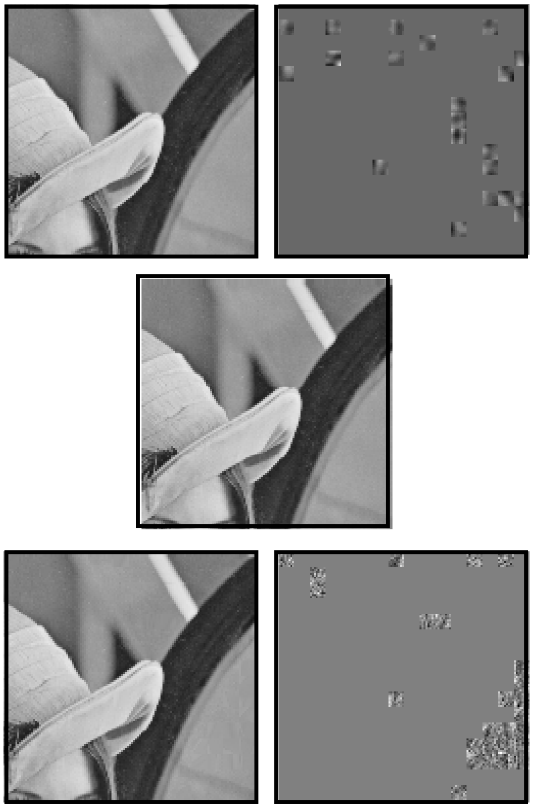

Figure 8: In the upper part: the watermarked image and the added information (rescaled) using our DCT algorithm, in the lower part: the watermarked image and the added information (rescaled) using our spatial algorithm, in the middle part: the original image

is flexible and leads to a natural classification of the blocks (textures/homogeneous). Moreover it is more robust to geometrical transformation than classic partitioning (Quad-tree, square)[DSC95].

3 CONCLUSION

This paper proposed an original approach in the watermarking context. This new method is based on fractal coding tools. We have presented an algorithm which can be applied in the luminance domain and in the DCT domain. The results show that the DCT method is more robust to image compression than the spatial one. The techniques used are still basic and the general framework of the scheme permits to envisage various improvements.

References

[BV94] K. U. Barthel and T. Voyé. Adaptive fractal image coding in the frequency domain. In *Proceedings of International Workshop on Image Processing: Theory, Methodology, Systems and Applications*, Budapest, Hungary, June 1994.

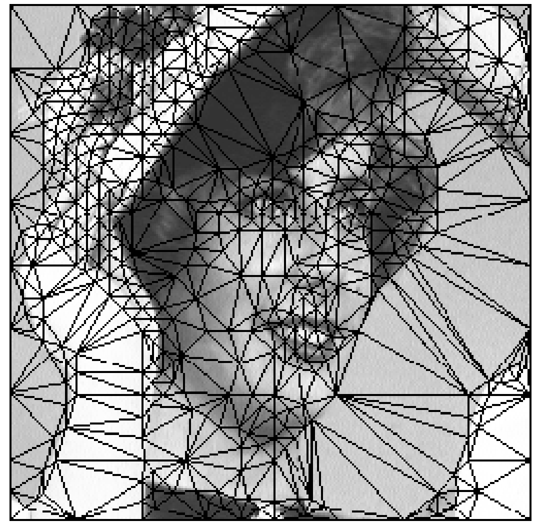

Figure 9: Adaptative triangular partitioning of an 512×512 image

[DSC95] F. Davoine, J. Svenson, and J.-M. Chassery. A mixed triangular and quadrilateral partition for fractal image coding. In *ICIP*, volume 3, pages 284–287, Washington, D.C., 1995.

[FJFC+97] Goffin F., Delaigle J.-F., De Vleeschouwer Ch., Macq B., and Quisquater J.-J. A low cost perceptive digital picture watermarking method. In *Proceedings of the SPIE: Electronic Imaging*, volume SPIE Vol. 3016, February 1997.

[ICS97] T. Leighton I. Cox, J. Killian and T. Shamoon. Secure spread spectrum watermarking for multimedia. *IEEE Transactions on Image Processing*, 6(12):1673–1687, December 1997.

[Jac92] A. E. Jacquin. Image coding based on a fractal theory of iterated contractive image transformations. *IEEE Transactions on Image Processing*, 1(1):18–30, January 1992.

[Mal89] S. G. Mallat. A theory for multiresolution signal decomposition: The wavelet representation. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 11(7):674–693, 1989.

[Pit96] I. Pitas. A method for signature casting on digital images. In *Proceedings of the ICIP-96*, volume 3, pages 215–218, 1996.

[WBM95] D. Gruhl W. Bender and Morimoto. Techniques for data hiding. In *Proc. SPIE*, volume 2420, page 40, February 1995.