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Psychovisual Selection of Auspicious Sites for Watermarking

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Abstract

A large number of numerical images flows on computer networks without including copyrights. To overcome such problems, watermarking has been used. This latter is a technique for labeling images. The principle used is to hide informations either in the image pixels or in any transformed space coefficients as DCT, DWT ...

Most of watermarking studies have been considered from a cryptographic point of view. Sophisticated watermarks must also have several qualities. They need to be perceptually invisible, undetectable, undeletable and resistant to both lossy data compression and any image processing. In order to improve these qualities, a Human Visual System (H.V.S) model has been used. The goal of this paper is to describe a new methodology in the selection of sites to be watermarked. This methodology takes into account some of the H.V.S characteristics which include high contrasts sensibility and the spatio-frequential selectivity of the perceptual channels. Hence sites to be selected have to belong both to edges of the image and a given spatio-frequential domain. For this latter, high and low frequencies are not used in order to make the watermark robust and perceptually invisible. Associated to an adaptation of the Weber law, this method allowed us to determine the strength of the watermark for each site. This algorithm has been applied on seven different images. These images have been watermarked by using the maximum strength for each site. According to the CCIR recommendations, subjective tests have been conducted with three observers. The visual quality of the watermarked images has been qualified as excellent, (No impairments are visible).

Introduction

Watermarking techniques have evolved very quickly these last years. The growth of this young field is probably due to an increasingly need to furnish multimedia data with a digital watermark either to protect or to prevent unauthorized applications.

A digital watermark is information that is embedded in original signal such that several requirements are satisfied. Among these requirements, watermark should be

- secret which means not accessible by unauthorized persons,
- robust to all possible processing that may be used,
- imperceptible to not alter host data.

In the watermarking systems the embedding process is generally done by signal adaptive image (see eq. 1)

$$I_t = I_o + M \tag{1}$$

Where I_t is the watermarked image, I_o the original image and M is the watermark depending on a given key and on I_o.

The watermark may be designed either in the spatial domain or in a transform domain like DCT.

The addition may also be done in the spatial domain or in transform domains such as DCT,[1,3,7,9] DWT domain.[5,6,8]

It is well known that the design of a watermarking technique needs a tradeoff between imperceptibility and robustness. This means that a watermark should have an amplitude both as high as possible and below the perception threshold. To do this several authors,[2,4] took into account some of the H.V.S. characteristics. Wolfgang et al. used a Just Noticeable Difference (JND) threshold, and exploited frequency sensitivity, luminance sensitivity, and contrast masking, while Delaigle et al. embedded a Maximum Length Sequence (MLS) in an image, using a masking model and the concept of local energy.

In the same context, the goal of this paper is to consider the H.V.S. properties to determine the best sites and the maximum strength of the watermark to be applied on these sites.

To describe how this has been performed Section II presents a description of the scheme, Section III discusses the sites localization while the Section IV explains how the strength of the watermark is obtained and presents an example of the watermarking process.

Description of the Scheme

The global embedding scheme is given in figure 1. Two steps are necessary to select appropriate sites. In the first one, the spatio frequential selectivity of the H.V.S. is used to select the band where the watermark should be embedded. To choose spatial sites, the second step takes advantages of the sensitivity of the H.V.S. to high contrasts.

The selected sites must belong both to edges of the image and the chosen visual channel. The local band limited contrast is then applied to determine for each site the strength of the watermark.

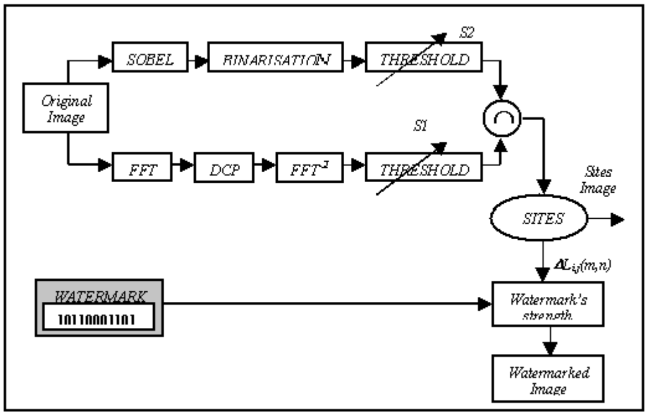

Figure 1. Global embedding scheme.

It is well admitted that the human visual system analyses the visual input by a set of channels selectivity sensitive to a restricted range of spatial frequencies and orientations. Several modelisations have been proposed in the literature.

Here we are concerned by the spatial frequency partition given in Figure 2. For this decomposition, three band pass radial frequency channels are needed (corona numbers V, IV and III), each of them being decomposed into angular sectors associated with an orientation selectivity of 30, 30 and 45 degrees respectively. The low frequencies are called BF.

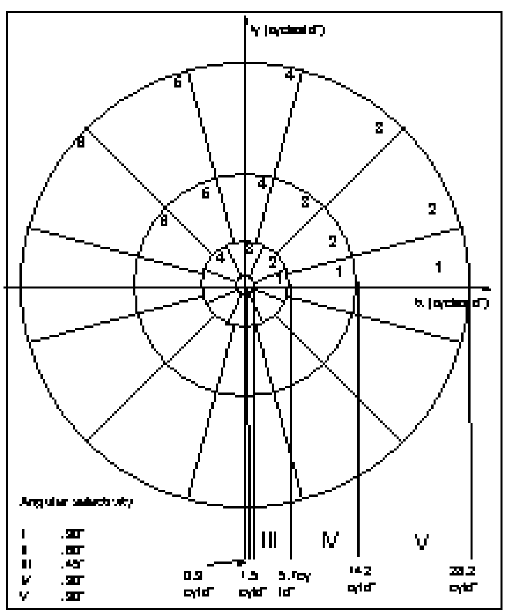

Figure 2. Spectral decomposition.

Sites Localization

Spectral Selection

It is known that in low frequencies image, an embedded mark will be robust but may be perceptible, whereas in an high frequencies image, an embedded mark will be very fragile (a low pass filter will remove it easily) but less perceptible. In fact, to satisfy the tradeoff robustness / invisibility, the watermark should be embedded in the same frequencies as those of original image. Based on the spectral partition of figure 2 the coronas III and IV seem to be the best candidates. Hence by applying this decomposition on the images's spectrum, one can extract a sub band, a corona, or a combination between them.

In this paper we'll just be concerned by sub band (IV, 3). The oblique direction has been chosen as the H.V.S. is less sensitive than for horizontal or vertical ones.

One can notice that sub band (IV, 2) is strictly equivalent to (IV, 3).

To extract this last sub band, (see Fig. 1, lower branch) an FFT is computed on the original image and the decomposition of Fig. 2 is applied. The filters used to achieve this visual radial / angular decomposition are called the cortex filters.[10] These filters are defined as product between the DOM filters (Difference of Mesa) which characterize the radial selectivity and the fan filters providing the angular selectivity. Each of these filters incorporates a soft transition between the unity gain in the bandpass domain to almost a zero gain at normalized radial frequency. The first Mesa filter has a transfer function (u and v are the horizontal and vertical spatial frequencies) given by :

$$M_0(u,v) = \left(\frac{\gamma}{f_0}\right)^2 e^{-\pi\left(\frac{r\gamma}{f_0}\right)} * \Pi\left(\frac{\pi}{2f_0}\right) \tag{2}$$

where $r = u^2 + v^2$ and $\Pi\left(\frac{\pi}{2f_0}\right)$ is a rectangular pulse of unity height and a $2f_0$ width centered at the origin. The softness of the gain transition is controlled by parameter γ. DOM filters for radial subband i are given by :

$$DOM_i(u,v) = M_i(u,v) - M_{i+1}(u,v) \tag{3}$$

with $M_i(u,v) = M_0(s_i u, s_i v)$
where the set of parameters s_i depends on a radial cut-off frequencies. The fan filters also have soft transitions at the edges of the orientation selectivity domain. Then the transfer function of the filter associated to the i^{th} radial band-limited channel and j^{th} band orientation is :

$$F_{i,j}(u,v) = DOM_i(u,v).g_j^i(u,v) \tag{4}$$

where $\left\{g_j^i ; j \in [1, D_i]\right\}$ is the set of direction selective filters for the i^{th} corona. These filters satisfy

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$$\sum_{i=1}^{k}\sum_{j=1}^{D_i} F_{i,j}(u,v) = M_0(u,v) \quad (5)$$

The sub band (IV, 3) is extracted and an inverse FFT is calculated. The corresponding spatial image obtained is then thresholded with its mean value.

Spatial Selection

As said before, the method takes advantage of the sensitivity of the H.V.S. to high contrasts. Indeed the visibility of degradations (a watermark may be assumed as degradations) varies depending on whether the degradations is presented alone (on local uniform background) or superimposed with strong signals as edges. This means that modifications are less perceptible on the edge. Hence there is a double advantage of embedding the watermark on the image edges : invisibility and cropping resistance may be assumed.

To achieve this selection (see Fig. 1, highest branch) a Sobel filtering is applied on the original image followed by a binarisation.

The binarisation threshold being the mean value of the obtained Sobel's grey level image.

As it was said in the introduction, the threshold is image-adaptive and can be modified so as to refine the spatial sites.
In fact, the binarisation threshold is adapted to the Sobel's image content which is itself adapted to the original signal.

Strength of the Watermark

The determination of the watermark strength is based on the fact that the H.V.S. is sensitive to contrast than luminance changes.

Considering the facts that the perceived contrast may vary greatly across an image and that the human contrast sensitivity is spatial frequency dependent an appropriate contrast definition is given by equation 6.

$$C_{i,j}(m,n) = \frac{L_{i,j}(m,n)}{\overline{L_i}(m,n)} \quad (6)$$

$\overline{L_i}(m,n)$ is the local mean, i,j is sub-band number, $L_{i,j}(m,n)$ is the original image luminance, (m,n) is the pixel's position, and $C_{i,j}(m,n)$ is the local contrast.

The local mean represents in fact the low pass filtered version of the image restricting to the spatial frequencies lower than the maximum frequency associated to the $(i,j)^{th}$ radial band. In our case the mean luminance of the BF and the corona III.

The strength of each pixel of the sites is given (see equation 7) by the first approximation of the Weber law.

$$\Delta L_{i,j}(m,n) = L_i(m,n) \times \Delta C_{i,j} \quad (7)$$

$\Delta L_{i,j}(m,n)$ being the watermark's strength in each site previously selected $\Delta C_{i,j}$ is the measured perception threshold of the sub band (i,j).

In order to test the choice of these sites, we embedded the maximum value $\Delta L_{i,j}(m,n)$ for each site.

At least five images have been watermarked and their quality has been evaluated by subjective tests according to the CCIR recommendations. As example the boat original image and the watermarked version are given in Fig. 3 and Fig. 4.

The visual quality of seven watermarked images judged by three observers has been qualified as excellent which means that no impairments were visible.

Figure 3. Original image.

Figure 4. Watermarked image.

Conclusion

In this paper, the problem of watermark invisibility was treated, a new methodology was implemented.

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Our goal was to find for an image, on the one hand, the best localization of the pixels to be watermarked, and, on the other hand, the maximum strength we can provide to the watermark, for each of those pixels. The maximum strength must be added to the original image without visually deteriorating its quality The first step of this work is the selection of the spectral sites, and the second one is the spatial selection, a Human Visual System Model has been used in order to find the sites and to give the maximum strength.

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Biography

Florent AUTRUSSEAU was born in Clermont-Ferrand in November 1975. He received the MS degree in Electronic Systems and Imaging Processing from the university of Nantes, in 1999. He is now a graduate student pursuing a Ph.D. degree at IRESTE, university of Nantes. His research interests include image modeling based on the human visual system and watermarking.