Adaptive positioning of a visible watermark in a digital image

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Abstract

Digital watermarking has recently emerged as a solution to the problem of providing guarantees about copyright protection of digital images. However, several problems related to robustness of invisible watermarking techniques to malicious or non-malicious attacks still remain unsolved. Whereas visible watermarking is an effective technique for preventing unauthorized use of an image, based the insertion of a translucent mark, which provides immediate claim of ownership. This paper describes an approach for adaptive positioning of a visible watermark based on the analysis of local characteristics of the host image. Watermark positioning deals with the problem of selecting the most suitable image position to place the visible mark. Our efforts have been directed to find the best region of the host image where watermark insertion can ensure robustness and unobtrusiveness to the watermark.

1. Introduction

There is a growing diffusion of digital libraries where multimedia data, such as text, images, video and audio are made available through the Internet to a large number of people. Since the digital network is often used to offer digital media for profit, there is a strong need for copyright protection and a considerable interest in methods for data authentication to avoid unauthorized reproduction, redistribution and modification of multimedia documents. Recently, digital watermarking has been imposed as a possible solution for the copyright problem [7]: watermarking is defined as the process of embedding a small amount of identifying information into a multimedia object. Depending on applications and target media, there are several types of watermarking systems: a visible digital watermark consists in a translucent mark overlaid on the document, on the contrary an invisible (or transparent) watermark is hidden.

Invisible watermarking has the considerable advantage of not degrading the host data and not reducing its commercial value. For that reason a lot of research has been carried out in this field [2][6][10], while visible watermark has received much less attention [8][9]. However, in order to be effective for copyright protection, invisible watermarking requires a high degree of robustness against attacks and should be utilized in conjunction with encryption, site security and a proper legal framework [5]. On the contrary, visible watermarking prevents unauthorized use of a multimedia document by degrading its quality and provides immediate claim of ownership to the owner. Visual watermarks are embedded in a host image (or video) such that the watermark is perceptible to an observer, although it is not so obtrusive to strongly distort the original image. The paper is organized as follows: in section 2 an overview of related works and a motivation of our approach is given. Section 3 gives some suggestions about the embedding procedure; section 4 describes the watermark positioning method; in section 5 some experimental results are reported and section 6 draws some concluding remarks.

2. Related works and motivation

Some of the required characteristics of visible watermarks can be summarized as [4]:
- the watermarked image should preserve as much as possible the details of the host image
- the most important characteristics of the watermark image should be clearly visible
- the visible watermarking process should not introduce any artifacts or inconsistence which may distract or mislead a human observer
- the watermark must be robust to attack; removing a watermark should be more costly and labor intensive than purchasing the image.

The most relevant attacks to remove or damage the watermark could be carried out by reversing of the insertion procedure and subtracting the watermark or replacing colors if the background is quite uniform.

In order to fulfill the above requirements the few approaches for visible watermarking presented in the literature have proposed methods for combining together watermark and host image in the spatial or frequency domain. The approach proposed by IBM group [8] to protect the Vatican library is based on pixel level processing; the watermark is inserted by modifying pixel luminance values, randomization is adopted in order to make the approach more robust to collusive attacks. A statistic approach is proposed in
[1], where the strength of the embedded watermark locally depends on the standard deviation of luminance in the host image. Other approaches work in the frequency domain: in [9] and [5] a coefficient modulation in the DCT domain is proposed, where the scaling factors are calculated by exploiting the human visual system, to ensure that the perceptual quality of the host image is preserved; in order to avoid visual discontinuity due to block by block changes of the scaling factors in the DCT domain, in [4] a method based on some concept of image fusion is presented, which inserts the watermark in the wavelet domain. All the above-cited methods place the watermark all over the host image. On the contrary, ImageProtect™ [3] proposes a web-based and dynamic protection system: the visible watermark is significantly smaller than the host image and moves around the image instead to be static. This “dynamic watermark” does not reduce the quality of the original image, however it can be simply removed by means of a “cut and paste” of the image taken when the watermark is placed in different locations. To our knowledge, no related work exists that deals with the watermark positioning problem. The problem can be stated as: find the best position inside the host image in order to superimpose a visible watermark whose dimensions are significantly lower than ones of the image itself. The “best” position should fulfill the following conditions:

- the region should be not excessively uniform, in order to avoid a simple watermark removal by substituting the background color.
- the region should be not too detailed, since the watermark could obscure the details beneath it.

In this paper we propose a technique for automatically place the watermark in a region of the host image that better respect the two above conditions: the first in order to guarantee the watermark robustness property, the second for ensuring watermark unobtrusiveness property.

3. Visibility of watermark

In this section we explain the watermarking method used in this work and motivate the need of a positioning procedure. We tested different methods to overlay the watermark, in order to make the mark well visible in any kind of images. We used as host images both very detailed and homogeneous samples in order to study the different effects of watermarking. We adopted a very simple method for inserting the watermark based on layer blend modes. We tested the overlay blend mode and the hard light blend mode (figure 1) coupled with an embossed version on the watermark. Both the methods multiply or screen a pixel color: the overlay blend depends on the base color, while the hard light blend depends on the watermark color, such that blending with pure black or white results in pure black or white. If \( i \) denotes a point from the host image and \( w \) a point from the watermark image, where \( i \) and \( w \) are floating point values between 0 (black) and 1 (white), the overlay and hard light blend formulas are the following:

\[
OB(i, w) = \begin{cases} 
2 \cdot i \cdot w & \text{if } i < \frac{1}{2} \\
1 - 2 \cdot (1 - i)(1 - w) & \text{otherwise}
\end{cases}
\]

\[
HLB(i, w) = \begin{cases} 
2 \cdot i \cdot w & \text{if } w < \frac{1}{2} \\
1 - 2 \cdot (1 - i)(1 - w) & \text{otherwise}
\end{cases}
\]

Figure 1. Overlay (left) and Hard light (right) blend diagrams: result of blending a horizontal gradient with a vertical gradient and the curves reflecting 9 vertical lines at given base colors.

Figure 2. A detailed and a homogeneous image marked with two visible watermarks.

In figure 2 an example of watermarked images on a homogeneous and a detailed images is shown. The same mark has been inserted in the top-left angle of the host image using the hard light blend mode (with opacity 50%), and in the bottom-right angle using the overlay blend mode. In the right side image, the watermark is clearly seen, while in the left side image, the watermark tends to hide in the most detailed portion of the host image. Moreover, the strong colors of the hard light blend mode easily contrast from the color of the host image, whereas with the overlay blend mode watermark’s colors tend to blend into the image, making the watermark itself less visible. The analysis of these results suggests some considerations:

- the overlay blend mode, makes the logo much more appealing and less distracting in the homogeneous image, but it is quite not visible in the detailed one
- using the hard light blend mode, the logo obstructs the view of the image, but it is more distinguishable if inserted in a highly textured position. To avoid
covering of parts of the image, blending can be improved by reducing the opacity of the watermark.

- in any cases highly textured positions are not well-suited for watermark insertion, the mark is hardly distinguishable mainly in presence of fine art.
- totally homogeneous regions should be avoided since the watermark can be easily removed by filling the background color.

4. The positioning approach

The analysis of figure 2 helps in the definition of the criteria that a region suitable for watermark insertion should fulfill, in order to ensure robustness and unobtrusiveness of the watermark. The requirements concern the level of details of the region, which can be measured as the local variance of brightness intensity:

- regions with a rather constant intensity have a low variance
- regions rich of details or textures have high variance

Our positioning method is based on the idea of inserting the watermark over the region, which has the lowest pixel variance greater than a threshold chosen in order to avoid uniform regions. First a binary mask of the same dimensions of the watermark is constructed, then the host image is convoluted with the mask in order to evaluate the pixel variance over the mask and finally the insertion position is chosen as the point which has the minimum variance over a fixed threshold. We noted that the variance is not a significant measure if calculated on a large region, i.e. when the area of the watermark grows. Therefore we decide to evaluate a local measure of the amount of intensity variation within the host image, then to select the region having the lowest mean value. One simple method of expressing the local intensity variation of pixels is to evaluate the difference between the highest and lowest pixel within a sliding window of 3x3 pixels. The resulting image, called "spread image" S, is convolved with the watermark mask W to calculate the mean spread. This operation is performed in the Fourier domain. Then the best region is selected as the area having the lowest mean intensity (over the threshold). A functional scheme of the positioning method is reported in figure 3.

5. Experiments and discussion

We have tested our approach on several standard images with different characteristics: some homogeneous images (i.e. cliparts and cartoons), some normal images and some detailed images. In the examples reported in figure 4 we adopted the hard light blend mode with opacity 50% as insertion method, in order to make the watermark more visible. The watermark can be inserted in both color and monochrome images: the positioning procedure works on the luminance channel, while the watermark insertion is performed into the RGB color space. All the experimental results indicate that the watermark is positioned in a region where it could be visually...
pleasant and unobtrusive to main details of the host image. As concerns the choice of the threshold to reject homogeneous regions, we set it to the fixed value of 5%. This setting proved to be good for all the images in the test set.

The results of the positioning procedure can be influenced by the presence of noise in the image. For example, the addition of a 10% uniform noise could considerably change the position selected for watermark insertion. In order to avoid this drawback, the positioning procedure should be slightly modified: first, a blur filtering should be applied to the image, before starting the selection procedure, second, the criterion for region selection should become the lowest number of detailed points instead of the lowest mean (thus performing a counting instead of an averaging operation). This criterion can be easily implemented by a simple binarization of the “spread image”, before performing the convolution with the mask. We not included these ideas into the main method because the presence of noise is to be considered in contrast with the need of a visible watermarking for copyright protection; in fact the noise causes a reduction of the commercial value of an image.

6. Conclusion

In this work we have dealt with the problem of adaptive positioning a visible watermark into an image for copyright protection. The contribution of our approach is the idea of performing an adaptive positioning in order to preserve as much as possible the details of the host image and, at the same time, to make the watermark difficult to remove. We followed the idea of positioning the watermark into the region of the host image that better ensures robustness and unobtrusiveness to the watermark. Such a region is selected as the area having the lowest local spread, calculated over a mask of the dimension of the watermark. Of course, the proposed approach is exclusively based on perceptive criteria and is not able of taking into account semantic roles deriving for example by the need of protecting a particular object depicted in the image. Our adaptive positioning effectively ensures the persistence of the watermark, by positioning the watermark in a not uniform region where its elimination would require a manual pixel to pixel replacement. This method tries to avoid the insertion of the watermark inside a detailed region, sensitive to changes. However it could be coupled with an adaptive insertion method such as the one proposed in [5] that exploits the human visual system in order to vary the opacity of the watermark depending on sensitivity of the underneath region.

7. References