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A Visible Watermarking Scheme in Spatial Domain Using HVS Model

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Abstract: Most existing visible watermarking techniques only considering the host image characteristics and the visible watermark has low contrast. To achieve optimal balance between the visual quality and the visible watermark contrast, an image adaptive visible watermarking scheme in spatial domain is proposed by considering human visual system characteristics. Firstly, the scaling factor and the embedding factor for watermark insertion are calculated by combining both the host image features and the watermark image features (such as luminance and texture sensitivity). Secondly, the visible watermark is embedded into the host image by adjusting adaptively the scaling factor and the embedding factor. The visible watermark is adaptive to the host image due to the use of visual perception features. Extensive experimental results show that the watermarked image has good perceptible quality and high robustness against attempts of removal and the visible watermark has high contrast to the host image. On the average, the proposed scheme achieves at least 2.1 higher PSNR values than existing approaches.

Key words: Digital watermarking, image adaptive, luminance sensitivity, texture sensitivity, robustness

INTRODUCTION

In recent years, digital watermarking has been proposed as a solution to the problem of copyright protection of multimedia data against unauthorized uses and won extensive attention of many researchers in different fields. Now it has become a research topic in IT (Information Technology) domain. In general, digital watermarks can be classified into two types, visible and invisible watermarks (Cox *et al*., 2006; Khan *et al*., 2008). Invisible watermarking techniques embed unobtrusively information about the copyright owner, the creator or authorized consumer of the digital work into digital media to protect the copyright of the digital media whereas in the case of visible watermarking the embedded data is intentionally perceptible to human eyes (Lixin *et al*., 2010; Yoo and Lee, 2010). Relatively, only a few researchers focus on visible watermarking, which may be caused by the fact that the visible watermark will reduce the commercial value of the watermarked content. In fact, visible watermarking can be widely applied in fields such as digital libraries, e-commerce and future digital TV. An effective visible watermarking must satisfy the following features (Tsai, 2009; Braudaway *et al*., 1996; Mohanty and Ramakrishna, 2000).

- A visible watermark should be obvious in both color and monochrome images. This indicates that visible watermark information should be embedded into the image luminance
- The watermark should spread in a large and important area of the image in order to prevent its deletion by clipping. That is to say, the embedding degree of the watermark should vary with both the host image and visible watermark features
- The watermark should be visible yet must not significantly obscure the image details beneath it
- The watermark must be hard to remove; removing a watermark should be more costly and labor intensive than purchasing the image from the owner
- The watermark embedding should consume little time and little effort, does not need too much manual intervention

Up till now, there are many image visible watermarking schemes are reported in the literature. The IBM digital library organization has used a spatial domain visible watermarking technique to mark the digitized pages of manuscript from the Vatican archive (Braudaway *et al*., 1996). Meng and Chang (1998) presented a compressed-domain visible watermarking approach for MPEG-1 and MPEG-2 video streams. The visible watermark is inserted into the DCT coefficients and is adaptive to the local video features. Kankanhalli and Rajmohan (1999) have proposed a visible watermarking technique in DCT domain in which the location and strength of the watermark image to be embedded is varied in accordance with the content of the host image to be watermarked. In this scheme, the sensitivity of the block to distortion is computed by analyzing the texture, edge and luminance

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information in the image sub-blocks. Mohanty and Ramakrishna (2000) have improved Kankanhalli and Rajmohan's scheme (Kankanhalli and Rajmohan, 1999) and strengthened the adaptivity of the visible watermark. Yong *et al.* (2004) have described a visible watermarking based on integer wavelet transform with parameters. The change of parameters of the integer wavelet and the Hash function guarantees the security of the watermark, which satisfies the public-key system. Yang *et al.* (2009) presented a reversible visible watermarking scheme, which can be applicable to the applications, in which the visible watermark is expected to protect copyright but the authorized user can remove it losslessly to recover the original image. The algorithm superposes the watermark image on a user-specified region of the host image through adaptively adjusting the pixel values beneath the watermark and scaling factors are determined by exploiting the contrast sensitivity. In order to achieve reversibility, a new reconstruction/recovery scheme is devised. Tsaia and Chang (2010) proposed a secure reversible visible watermarking approach. They designed a pixel mapping function to superpose a binary watermark image on a host image to create an intermediate visible watermarked image. At the same time, an almost inverse function generates the recovery data. In this method, the recovery data and hash value for reversibility and authentication are embedded by using reversible data embedding. Experimental results show the proposed scheme is secure and has good visual quality of watermarked images. The above-mentioned algorithms only use the visual perception of the host content, which cannot good balance between the watermarked image perceptual quality and the watermark visibility, Tsai (2009) presented a visible watermarking algorithm with the consideration of the contrast sensitivity of host image. The scheme can obtain the optimal watermark locations and strength at the watermark embedding stage by utilizing the global and local characteristics of the host and watermark images in the Discrete Wavelet Transform (DWT) domain and it have high PSNR values for the watermarked images. However, Tsai's scheme did not utilize fully the HVS model, the watermark transparency needs to be improved.

To obtain optimal balance between the watermarked image visual quality and the watermark visibility, we proposed an image adaptive visible watermarking algorithm in this study, Both the HVS masking characteristics of the host image and the watermark image such as texture and contrast are fully exploited in the watermark insertion stage.

ADAPTIVE VISIBLE WATERMARKING ALGORITHM IN SPATIAL DOMAIN

Human visual system masking characteristics: In order to design an effective visible watermarking, it is necessary to take into account the HVS masking characteristics of the visible watermark image and the host image. The following factors will be considered in our scheme (Kankanhalli and Rajmohan, 1999; Yang *et al*., 2010a, b).

- Human eyes have different sensitivity to different luminance, most sensitive to medium luminance usually, Weber ratio keeps const 0.02 within a large range of medium gray and sensitivity declines nonlinearly within the low and high luminance range. We can define contrast sensitivity as follows:

$$\omega(i,j) = \frac{|I(i,j) - 128|}{128} \quad (1)$$

  where, $I(i, j)$, $0 \le i < M, 0 \le j < N$ is the pixel value at the spatial position (i, j) of the host image I with size $M \times N$
- Human eyes are more sensitive to the noise in image smooth areas than that of image texture areas. Let $H(i,j)$ be the entropy of the 4×4 neighborhood of pixel (i,j), greater entropy value is corresponding to the image texture or edge area, while less entropy value corresponds to image smooth area., so we can use the entropy $H(i,j)$ to depict the texture characteristics of the 4×4 neighborhood of pixel (i,j)

Based on all the above considerations, we devise a visual perception factor computational model to incorporate the effect of HVS masking characteristics into the visual factor of each pixel as follows.

$$J(i,j) = \omega(i,j) \times H(i,j) \quad (2)$$

Determination of the scaling and embedding factors: In this watermarking scheme, to achieve high PSNR value for the watermarked image and good watermark invisibility, we exploit the perceptual features of both the host image and the watermark image. So the following formula is used to embed the visual watermark in the watermark insertion stage.

$$I'(i,j) = \alpha(i,j) \times I(i,j) + \beta(x,y) \times w(x,y), \quad 0 \le i < M, 0 \le j < N, 0 \le x < m, 0 \le y < n \quad (3)$$

Where the $\alpha(i,j)$ and $\beta(x,y)$ are the scaling factor for host image and the embedding factor for the watermark respectively. $I(i,j)$ and $w(x,y)$ denote the pixel values of host image F with size $M \times N$ in location (i,j) and the watermark image W with $m \times n$ in location (x,y) respectively.

The proposed algorithm inserts the watermark directly in spatial domain, which utilizes both the original image and the visible watermark image features. The scaling factor $\alpha(i,j)$ and the embedding factor $\beta(x,y)$ are calculated as follows.

Step 1: Divide the host image and the watermark image into 4×4 sub-blocks, respectively

Step 2: Compute the visual factor J for each pixel using Eq. 2

Step 3: Obtain the scaling factor $\alpha(i,j)$ and the embedding factor $\beta(x,y)$ by scaling the visual factor J as follows

$$\begin{cases} \alpha(i,j) = (b-a) \times \dfrac{J(i,j) - \min(J)}{\max(J) - \min(J)} + a \\ \beta(x,y) = (d-c) \times \dfrac{J(i,j) - \min(J)}{\max(J) - \min(J)} + c \end{cases} \quad (4)$$

where, a, b, c, d are the predetermined parameters, Functions max() and min() return the maximum and minimum respectively

Visible watermark embedding: In watermark embedding, we take full advantage of both the original image features and the watermark image features. The detailed watermark embedding strategy is composed of the following steps.

Step 1: The original image I (to be watermarked) and the watermark image W are divided into blocks of size 4×4

Step 2: Calculate the scaling factor $\alpha(i,j)$ and the embedding factor $\beta(x,y)$ for each sub-block by using Eq. 4

Step 3: Select the sub-blocks of the original image for watermark embedding

Step 4: Modify the pixel value of the selected host image sub-blocks using Eq. 3 and then the watermarked image is obtained

EXPERIMENTAL RESULTS

To evaluate the effectiveness of the proposed scheme, extensive experiments are conducted on many standard test images. In the experiment, We use some gray-scale image with size 512×512 as the original images and use grayscale images with free size as the watermark images. Let a, b, c, d in Eq.(4) be 0.94, 0.980, 0.05, 0.2060, respectively.

Fig. 1: The visible watermark image

Transperancy: The visible watermark to be embedded is shown in Fig. 1. We tested our scheme on some grayscale images as shown in Fig. 2 and the corresponding watermarked images are shown in Fig. 3. We can see that the watermarked images have high PSNR values and the watermark strength is dependent on the original image content by observing Fig. 3. More test results on the watermark transparency are shown in Table 1. From Table 1, our scheme has steady PSNR values for different types of images and can obtain an average PSNR value as high as 29.0 dB. This indicates that the proposed algorithm can achieve good visual quality of the watermarked images for various types of images. Take lena image as an example, some watermarked images are generated when different sizes of watermarks or many visible watermarks are embedded into the host image and Fig. 4 shows the test results. From Fig. 4, we can see that the visible watermark strength is also adaptive to the watermark image features.

Watermark visibility: Good watermark visibility of the proposed scheme can be illustrated by difference images between the original images and its corresponding watermarked ones (generated by the presented algorithm) with luminance enhancement by 10 times as shown in Fig. 5. It is clear that the watermark is mainly embedded into the image regions with high contrast. This may be attributed to the full consideration of both the host image and the watermark image characteristics.

Robustness against removal attacks: Moreover, to test the robustness of the visible watermark, we perform

(a) Lena (b) Boat (c) Cameraman (d) F-16

Fig. 2: Some test images

(a) Lena (b) Boat (c) Cameraman (d) F-16

Fig. 3: Different watermarked images

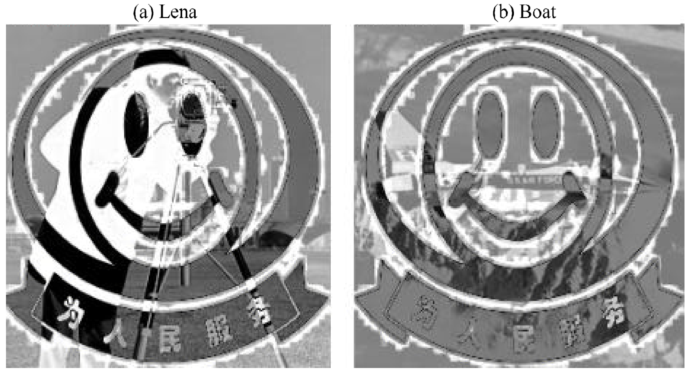
Table 1: The watermark transparency for various test images

Images	Barbara	Goldhill	Jet	Opera	Tiffany	Zelda	Peppers
PSNR(dB)	23.0622	22.9773	22.2536	23.0377	24.0841	21.9730	23.1694

(a) Watermark at an arbitrary position (29.8720 dB) (b) Insert 4 watermarks (23.7475 dB)

Fig. 4: Adaptivity to different size watermarks

(a) Lena (b) Boat



(c) Cameraman (d) F-16

Fig. 5: Difference images scaled by 10 times

several attacks on the watermarked lena image, including histogram equalization, mean filtering, JPEG compression and contrast enhancement and so on Fig. 6 illustrates the experimental results, which show that the visible watermark is hard to remove under common signal processing attacks.

Performance comparison: Figure 7 shows the performance comparison of the embedding distortion in terms of PSNR with various watermark size imposed by our algorithm and previous works (Mohanty and Ramakrishna, 2000; Tsaia and Chang, 2010; Yang *et al*., 2009) for lena image. From Fig. 7, our proposed approach consistently achieves about 5.7, 4.3 and 2.1 dB higher average PSNR values than Mohanty and Ramakrishna (2000) method, Tsaia and Chang (2010) approach and Yang *et al*. (2009) method, respectively. These comparison results suggest that the fidelity of the watermarked images generated by our method is better than those by the previous three methods. This may be

(a) Histogram equalization (b) Mean filtering

(c) Contrast enhancement by 50% (d) JPEG compression (quality factor 1)

Fig. 6: Robustness to removal attacks

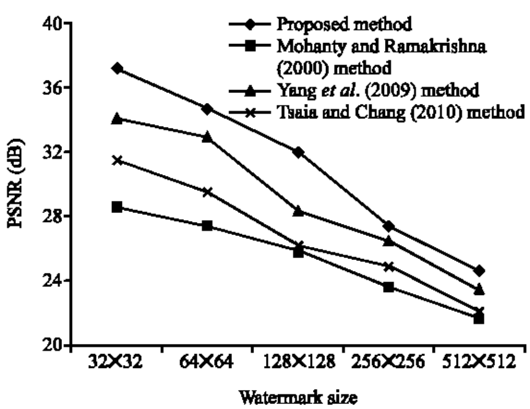


Fig. 7: Performance comparison of embedding distortion in terms of PSNR with various watermark sizes for lena test image

attributed to the fact that the HVS characteristics and the image content are taken into consideration in our method, but not fully considered in the previous methods.

CONCLUSIONS

An image adaptive visible watermarking technique is proposed. A visual perception computational model is developed for this purpose exploiting the masking characteristics of the HVS. The proposed scheme has low computational complexity because that the visible watermark is embedded in spatial domain. The watermark strength is dependent on both the host image content and the visible watermark features. The experimental results demonstrate the effectiveness of this algorithm. The scheme provides high PSNR values for the watermarked images and good watermark invisibility by combining the HVS masking characteristics of host image and the visible watermark. In addition, the visible watermark preserves good watermark visibility under various signal processing operations and the proposed scheme is robust against attempts of removal.

Future work will combine pseudo random chaotic map and human visual perception to develop a new visible watermarking which offers authorized removal of the visible watermark from the watermarked image by using a private key.

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