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Framelet image watermarking considering dynamic visual masking

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ABSTRACT

It is an important issue to deal with imperceptibility and robustness in image watermarking system. This paper proposed a new watermarking method based on HVS and framelet transform. On the basis of spatial domain HVS feature, this paper establishes a visual masking model for framelet domain. Moreover, an embedding position optimization method in the low-luminance smooth area is proposed, which tries to avoid the visual distortion in that area caused by congregate embedding. In accordance with the framelet visual masking matrix, the framelet coefficients are selected to embed watermark adaptively. Experimental results show that the proposed method delivers better performance than the previous ones.

1. Introduction

Image watermarking has become a necessary technology because the widespread application of digital images through Internet [1,2]. Usually, digital image watermarking embeds watermark information (such as a Logo image) into original image transparently to generate the watermarked image. The most important two characteristics are imperceptibility and robustness. The first is to guarantee the distortion caused by watermark embedding which is not visible for human eyes. The second is to ensure that the watermark can be extracted successfully even if the watermarked image were deliberately attacked by some attacks such as compression, filtering and cropping.

In recent years, many watermarking schemes have been proposed, which can be roughly classified into two categories: frequency domain and spatial domain [3–5]. The latter becomes popular because it usually gains better transparency and robustness than the former. The common frequency analysis methods include Discrete Fourier Transform (DFT), Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT). DWT is one kind of typical multi-resolution analysis transform and has both time and frequency localization ability. It gains better performance than DCT in many signal processing areas. Compared with wavelet, framelet usually has more high frequency filter banks and better time-frequency ability. Moreover, the filter banks of framelet are not orthogonal, which means there exists redundancy between framelet subband coefficients, and helps to improve the invisibility of the watermarking.

Human visual system (HVS) characteristics are usually employed in watermarking [6–8] to improve the imperceptibility. Hengfu Yang [6] proposed an image authentication algorithm based on HVS and gains good performance. The algorithm used the masking properties to calculate the Just Notice Distortion (JND) matrix based on the structure of the image block, and embedded the watermark into the wavelet coefficients in the horizontal and vertical components. In 2008, Huiyan Qi [7] built a HVS model to compute visual masking, and embedded the watermark into the low-frequency coefficients of the DCT block. In the same year, Min-Jen Tsai [8] used wavelet coefficients in low frequency component to construct watermark, and embedded the watermark into the high frequency component according to HVS characteristic.

In this paper, we propose an adaptive image watermarking method by combining framelet transform and HVS. Firstly, referring to Qi's model, the paper builds a visual masking model to measure the distortion concealing ability of framelet coefficients. The candidate positions for embedding are chosen according to the visual masking abilities of framelet coefficients. Then, the candidate positions are optimized dynamically to make sure that there will not be too many embedding points congregate together in the low-luminance smooth area, which will cause the noticeable distortion in these areas. Finally, the watermarks are embedded into host images in the framelet domain using the optimized positions.

The rests of the paper are organized as follows: Section 2 gives some basic knowledge of framelet and HVS. Section 3 illustrates the watermarking strategy based on visual masking model in framelet domain. Experimental results are given in Section 4 to verify the

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0030-4026/

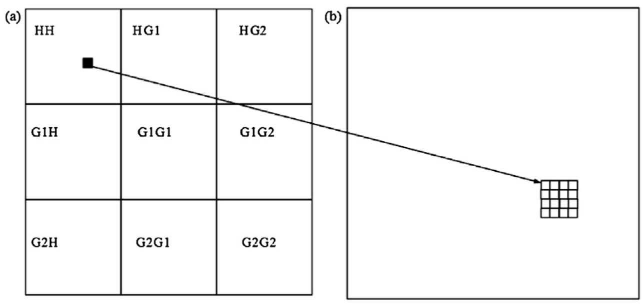

Fig. 1. Framelet coefficient's relation with pixel block.

validity of the proposed algorithm, and the conclusion is obtained in Section 5.

2. Basic theory

From framelet definition [9], we can see that framelet has at least one mother wavelet function. The framelet adopted in our algorithm has one scaling function $\phi(t)$ and two mother wavelet functions $\psi_1(t)$ and $\psi_2(t)$, which can be represented by the following low pass filter(scaling function) $h_0(n)$ and high pass filters(wavelet function) $h_1(n)$ and $h_2(n)$:

$$\begin{aligned} \phi(t) &= \sqrt{2}\sum_n h_0(n)\phi(2t-n) \\ \psi_i(t) &= \sqrt{2}\sum_n h_i(n)\phi(2t-n), \quad i=1,2 \end{aligned} \tag{1}$$

By using the decomposition method proposed by Mallat [10], One-level framelet decomposition on image generates nine subbands shown in Fig. 1(a). Each subband is with 1/4 size of the original image. HH subband is the low frequency part and contains most image energy. The other subbands give the image detail information in horizontal, vertical and diagonal direction. Continuous decomposition on HH will generate the pyramid structure of framelet decomposition.

Human eyes have different sensibility to different image contents. Researchers have established the visual models to provide guidance for image processing. The most considered factors in visual model are luminance, texture and edge. By integrating luminance masking model, texture masking model and edge masking model, Huiyan Qi formed the visual masking model according to the three principles of Barni.

2.1. Luminance masking model

Chou's luminance model is a classic and easy computing one [11], which considers two factors: the average background luminance and the non-uniformity of background luminance. First, take each 5×5 pixels as an image block, assign greater weights to pixels near the block center and calculate the weighted average background luminance. Second, calculate the weighted average value of the image block for each one of the four standard weight matrixes defined by Chou and choose the maximum average as the non-uniformity of background luminance. Then, luminance masking is obtained based on the average background luminance and the non-uniformity of background luminance.

2.2. Texture masking model

There are many texture detection algorithms and the one put forward by Huiyan can not only detect the texture but also calculate the Just Noticeable Distortion (JND) value of the texture. It takes

Fig. 2. Visual masking results of Lena.

3×3 pixels as a block and calculates the texture masking value for the center pixel by using formula (2), where p is the center pixel value and p is the average pixel value of 3×3 image block.

$$M_T = |p - \bar{p}| \tag{2}$$

2.3. Edge masking model

Human eyes are more sensitive to changes on edge. There are commonly two ways to detect edges: un-sharp and Laplace filter. The first kind is easy to miss out on some small edges while the second detects too many edges. Huiyan Qi proposed an edge filtering method and calculated the edge masking value. This method delivered better performance because it used canny operator to process the edge detection results generated by Laplace filter.

After the calculation of the three masking models, assuming luminance masking value M_L, texture M_T, edge M_E and the final masking value is gained through formula (3) according to Barni principles.

$$M_F = \max(M_L, \min(M_E, M_T)) \tag{3}$$

The comprehensive masking value represents each pixel's ability to conceal distortion and also can be regarded as JND value of the pixel. It can not only be used to compare the masking ability among different pixels but also to control the watermarking strength. Fig. 2 gives the comprehensive masking value results for Lena image, where the big value indicates the corresponding pixel in the original image has better masking ability. As can be seen from Fig. 2, the masking values of pixels in smooth regions such as face and hat are usually low. However, the masking values of complex texture region such as hair and cap are high. In addition, the masking values of some regions such as shoulder and face region with high luminance are slightly higher than the surrounding regions. These results illustrate the masking value conforms to the HVS model.

3. Our proposed method

Generally, frequency watermarking modifies the frequency coefficients' magnitude to embed the watermark information and the original image is needed to be compared with a watermarked image to extract the watermark. In order to improve the imperceptibility, the watermark should better be embedded in the position which is not sensitive to human eyes. In this paper, based on the Huiyan Qi's visual masking model in pixel domain, we built a