Homogeneity-based image watermarking to protect ROI

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Abstract

An image watermarking algorithm that aims to protect the region of interest (ROI) is proposed based on homogeneity. The ROI in an image is determined by user, and is mapped to the subband of wavelet decomposition. A visually significative watermark is scaled according to the size of the ROI. Embedding is completed by enforcing the relationship between the subband coefficients and approximate coefficients. The parameters and strength is determined based on the homogeneity analysis to the image. Extraction is blind that requires neither the host image nor the original watermark. Experimental results show that this algorithm can robustly resist cropping, patching, and compression.

Keywords: Watermarking; ROI; homogeneity; relationship

1. Introduction

Recently, digital watermarking technique has become an active research area, which embeds a digital signal into a kind of media [1]. There are three main requirements for watermarking technique: 1) Perceptual transparency: in most applications, embedding a watermark should not affect the quality of the original media. 2) Robustness: the ability of watermarking system resists the attacks. 3) Capacity: the amount of watermark bits that can be stored in the host media.

Many literatures aim to protect the whole image using watermarking, not the region of interest. Cox *et al.* used a pseudorandom series as a watermark [2], and embedded it in the first *k* larger coefficients to achieve the robustness. Hsu *et al.* [3] improved the method in [2] by putting the watermark into the middle coefficients in order to take care of both transparency and robustness. They did not consider the feature of image regions. Podichuk and Zeng calculated the just noticeable differences (*JND*) to limit the modification [4]. Kundur *et al.* used a human vision model to embed a logo [5]. Their algorithms protected the whole image, as the same in our former work [6]. But when attackers cut part of the image, or they patch the object to another image, the watermark cannot be extracted correctly. The protection to the image is ineffective. In reality, there are region of interests (ROIs) in most images, which can be any parts of the images. They are often the observational focus of the images, such as the target objects. An algorithm to protect the region of interest in medical image has been studied, but the result is not intuitive [7]. In this paper, we will propose a novel algorithm based on homogeneity to protect the target object of an image, which can robustly resist cropping, patching, and compression.

2. Proposed scheme

2.1. Homogeneity of image

Homogeneity is related to the local information of

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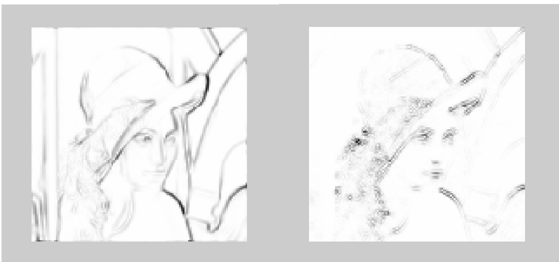
an image and reflects the uniformity of an image region. It is defined as a composition of two components: standard deviation and discontinuity of the intensities [8]. Standard deviation describes the contrast within a local region [9]. Discontinuity is a measure of abrupt changes in gray levels and could be obtained by applying edge detectors to the region. The standard deviation of pixel $x(i,j)$ is denoted as $v(i,j)$, and the discontinuity at location (i,j) is described as $e(i,j)$. The corresponding normalized values are $V(i,j)$ and $E(i,j)$, which have a range from 0 to 1. The homogeneity is represented as:

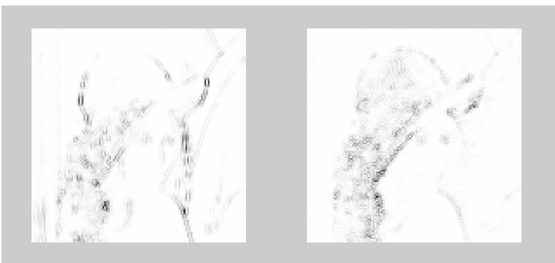
$$H(i,j) = 1 - V(i,j) \times E(i,j) \qquad (1)$$

The more uniform the image region surrounding a pixel is, the larger the homogeneity value the pixel has.

If a wavelet coefficient matrix of an image is regarded as an image, the corresponding homogeneity values can be attained. Fig. 1 is an example for the wavelet coefficients when Lena image is decomposed to 1-level. Fig. 1(a), (b), (c) and (d) are the homogeneities of LL_1, HL_1, LH_1, and HH_1, respectively.



(a) Homogeneity of LL_1 (b) Homogeneity of HL_1



(c) Homogeneity of LH_1 (d) Homogeneity of HH_1

Fig.1 Homogeneity of 1-level wavelet decomposition

2.2. Embedding of watermark based on homogeneity

A significative watermark is embedded in the relationship between the subband coefficients and approximate coefficients. The embedding parameters are determined based on the homogeneity analysis. There are 4 steps:

Step 1. The original image is first decomposed to L-level wavelet coefficients. Calculate the homogeneity values of the detail corresponding coefficients. Homogeneity correctly reflects the feature of image, which can use to determine corresponding parameters.

Step 2. Choose the region of interest of the original image, which has the size of $M_r \times N_r$. Then determine the size of ROI in each level of subband: $M_{r,l} \times N_{r,l}$. their sizes have the following relation.

$$M_{r,l} = M_r / 2^l, \quad N_{r,l} = N_r / 2^l \qquad (2)$$

where, l indicates the decomposition level.

Select the subband to embed watermark using the key. According to the size of the ROI in the selected subband, the original watermark is scaled to the same size as ROI.

Step 3. The weighted approximate coefficient is a bench value, whose children are used to embed the watermark. Subband coefficient $y_{o,l}(m,n)$ and its root-father have the position relation as shown in Fig. 2.

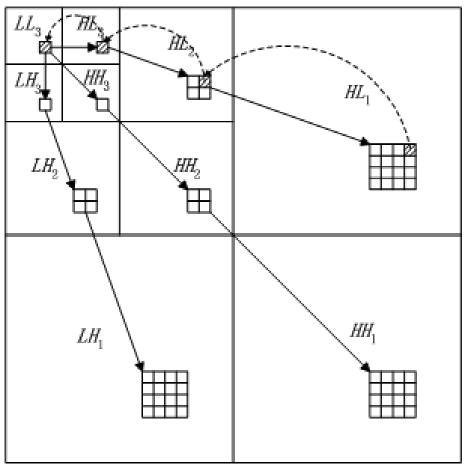


Fig. 2 Subband coefficients and corresponding root-father

Their values have the following relation: if the absolute value of $y_{o,l}(m,n)$ is not smaller than that of the weighted $y_{a,L}(u,v)$, then the relation $r_{o,l}(m,n)$ has value 1; otherwise the relation $r_{o,l}(m,n)$ has value 0.

That is,

$$R = \mathrm{Re}lation(Y_{o,l}) = \{r_{o,l}(m,n), o = h,v,d, 2 \le l \le L\} \quad (3)$$

and,

$$r_{o,l}(m,n) = \begin{cases} 1, & \text{if } |y_{o,l}(m,n)| \ge |s \times y_{a,L}(u,v)| \\ 0, & \text{otherwise} \end{cases} \quad (4)$$

where, $0 \le u < M/2^L$, $0 \le v < N/2^L$, and u and v are related to m and n.

$$u = \begin{cases} \left\lfloor \frac{m}{2^{L-l}} \right\rfloor, & 2 \le l \le L-1 \\ m, & l = L \end{cases} \text{ and } v = \begin{cases} \left\lfloor \frac{n}{2^{L-l}} \right\rfloor, & 2 \le l \le L-1 \\ n, & l = L \end{cases} \quad (5)$$

s is the scaled factor, and determined according to the homogeneity. When the homogeneity value at coefficient $y_{o,l}(m,n)$ is larger than 0.95, s is set to s_1; otherwise, s is set to s_2. And $s_1 < s_2$. They can be got experimentally. Here s_1 is set to 0.004, and s_2 is set to 0.0045.

Step 4. If $r_{o,l}(m,n)$ is different from $w(m,n)$, then modify the value of $y_{o,l}(m,n)$ to make them the same; otherwise, retain the relation. Let the difference between $y_{o,l}(m,n)$ and corresponding bench value be $\triangle$, then modify the coefficients as below.

$$\tilde{y}_{o,l}(m,n) = \begin{cases} s \cdot y_{a,L}(u,v) + \lambda \cdot \Delta, & \text{if } w = 1 \\ s \cdot y_{a,L}(u,v) - \lambda \cdot \Delta, & \text{if } w = 0 \end{cases} \quad (6)$$

where, $\tilde{y}_{o,l}(m,n)$ is the modified coefficient.

Step 5. Inverse DWT is applied to the modified coefficients to get a watermarked image $\tilde{X}$.

2.3. Extraction of watermark based on homogeneity

The extraction of watermark requires neither the original image nor the original watermark. It has the following steps:

Step 1. L-level wavelet decomposition is applied to the suspicious image to get an approximate subband and $3L$ detail subbands.

Step 2. Determine the subband that perhaps contains the watermark. Calculate the homogeneity of the subband, then estimate the parameters during embedding.

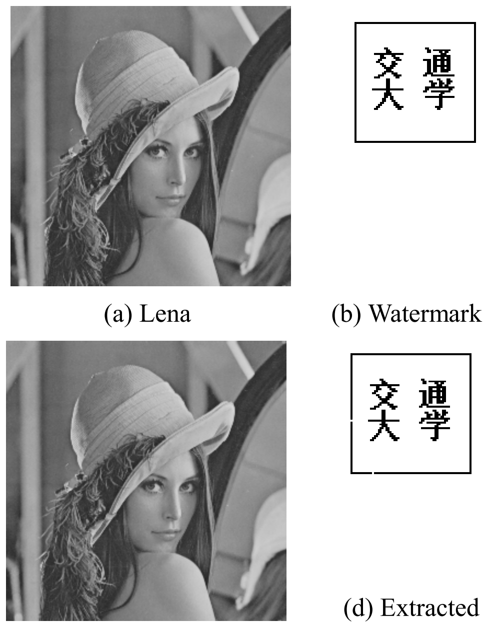
Step 3. In the selected subband, produce the relation between the detail coefficients and corresponding approximate coefficients. This relation table is the extracted watermark.

When the region of interest is cut and patched to another image, the intuitive watermark can be extracted.

3. Experimental results

3.1. Embedding and extraction of watermark

Lena image of size 512×512 is to be protected, shown in Fig. 3(a). The head portrait of Lena is the region of interest. Fig. 3(b) is the binary watermark of size 64×64. Fig. 3(c) is the watermarked image, whose *PSNR* with the original image is 44.164dB. Fig. 3(d) is the extracted watermark.



(a) Lena (b) Watermark

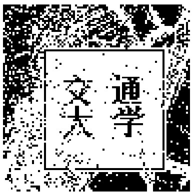
(c) Watermarked Lena (d) Extracted watermark

Fig. 3 Embedding and extraction of watermark

3.2. Robustness against cropping

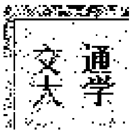
When the watermarked image is cropped by an open software: Stirmark [10], the watermark can also be extracted clearly. Fig. 4(a) is the watermarked image that is cropped 25%, Fig. 4(b) is the extracted watermark from (a). Fig. 4(c) is the watermarked image that is cropped 50%, Fig. 4(d) is the extracted watermark from (c).

(a) image is cropped 25%



(b) Extracted watermark from (a)

(c) image is cropped 50%



(d) Extracted watermark from (c)

Fig. 4 Robustness against cropping

3.3.Robustness against patching

When the target object is cut and patched to another image, the watermark in the target object can be extracted. As shown in Fig. 5, Lena head portrait is regarded as a target object and patched to another image to counterfeit a new image (Fig. 5(a)), the corresponding watermark is extracted (Fig. 5(b)). The significative label of watermark can be identified.

(a) Patched image

(b) Extracted watermark from (a)

Fig. 5 Robustness against patching

3.4.Robustness against compression

After JPEG compression, the extracted watermark is cut the side to be the same size as the original watermark. The similarity measurement between them is given in Table 1.

Table 1. Robustness against compression

Quality factor	90	80	70	60	50	40
Our scheme	0.978	0.951	0.925	0.908	0.893	0.874

Table 1 shows that as the compression ratio increases, the similarity measurement between extracted watermark and original watermark decreases accordingly, and can contain at higher values.

4. Conclusions

In this paper, a new watermark algorithm is proposed, which protects the region of interest based on homogeneity. Embedding is completed by enforcing the relationship between the subband coefficients and approximate coefficients. The parameters and strength is determined based on the homogeneity analysis of the image. Extraction is blind that requires neither the host image nor the original watermark.

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