Image Watermarking Based on the Watershed Segmentation

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Abstract: Image watermarking is a technology that enables copyright protection of images, but causes a deterioration of host image. The purpose of this paper is to suppress the quality degradation of the cover image. Our methods divides the image into similar nonoverlaped blocks for each pixel using the watershed segmentation, and embeds a watermark of spread sequence. This division narrows the range of pixel values in the block, so that a smaller watermark can be embedded. The embedding approach in the proposed method uses the smear transform. As a result, a watermarked image can be generated while suppressing the image quality deterioration.

Keywords: Watermarking, Watershed segmentation, Image copyright protection

1. Introduction

In recent years, digital contents such as images, movies and music have been developed and used in various fields. However, digital content has excellent quality and does not deteriorate even when copied. In addition, the rapid spread of the Internet has made it easy to obtain digital contents, and problems such as unauthorized use and copyright infringement have become serious. As a technique to solve this problem, digital watermarking technology [1] is attracting attention. Digital watermarking is a scheme that embeds user information and copyright information in digital content so that it is not perceived by humans. However, the content deteriorates when a watermark is embedded. The most common approaches in watermarking are summarized in [1]–[5].

The properties required for digital watermarking are shown below:

1. The quality of digital contents is not significantly degraded by digital watermark embedding.
2. A digital watermark with a sufficient amount of information can be inserted into digital content.
3. The digital watermark is robust and can detect the digital watermark even if the digital content changes.
4. Knowing the detection algorithm cannot detect the presence of the watermark or remove it.

In this study, we propose an image digital watermarking method using the watershed segmentation [6] for the purpose of improving the quality of watermark embedded images. An image watermarking method using tile image segmentation is a conventional method [7]. Tile image segmentation divides an image into squares. On the other hand, the watershed segmentation used in the proposed method is a technique of segmenting an image at a portion with a large gradient. By dividing the area with a large gradient, changes in pixel values within each region can be suppressed. As a result, it is possible to embed a watermark with a smaller value when embedding a watermark in the pixel value, so that it can be expected to suppress image degradation. In addition, smear transform [8] is used as a digital watermark technique. Smear transform is a conversion that spreads the embedded watermark information. It suppresses image degradation caused by embedding watermark information, and can generate a watermark embedded image where the watermark information is not conspicuous.

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2. Watermarking

This section shows the embedding and detection procedures of the conventional method [7] and the proposed method. We also describes the techniques used in these methods.

2.1 Conventional embedding method

The following shows the procedure for embedding a digital watermark using tile image segmentation:

1. Perform tile image segmentation on the input original image. It is divided into $M \times M$ size areas.
2. Convert the divided area into a one-dimensional sequence.
3. Apply the smear transform to the resulting one-dimensional sequence. Pixel value information is diffused.
4. Embed watermark information in the one-dimensional sequence with smear transform. The pixel value information at the embedded position protrudes.
5. Apply the desmear transform to the watermark embedded one-dimensional sequence. The diffused pixel value information is restored and the embedded watermark information is diffused.
6. Return the one-dimensional sequence to its original position in the original image.

2.2 Conventional detection method

The following shows the procedure for detecting a digital watermark using tile image segmentation:

1. Perform tile image segmentation on the input watermark embedded image. It is divided into $M \times M$ size areas.

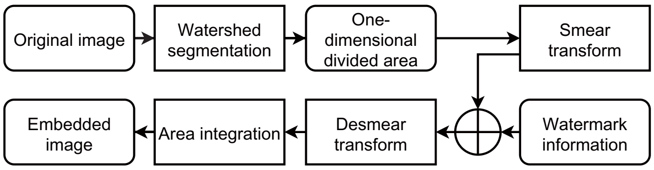

Figure 1. Embedding procedure of the proposed method

2. Convert the divided area into a one-dimensional sequence.
3. Apply the smear transform to the resulting one-dimensional sequence. Pixel value information is diffused and the watermark information that was diffused is restored.
4. Find the maximum value sequence position from a one-dimensional sequence.
5. If the watermark embedding position matches the maximum value sequence position, it is determined that the detection is successful.

2.3 Novel embedding method

Figure 1 shows how to embed a digital watermark using watershed segmentation. Our procedure for the watermark embedding method is shown below:

1. Apply the watershed segmentation to an input original image. A segmented region along the edge of the object is extracted.
2. Convert the divided area into a one-dimensional sequence.
3. Apply the desmear transform to the watermark embedded one-dimensional sequence. Pixel value information is diffused.
4. Embed watermark information in a one-dimensional sequence with smear transform. The pixel value information at the embedded position protrudes.
5. Apply the desmear transform to the watermark embedded one-dimensional sequence. The diffused pixel value information is restored and the embedded watermark information is diffused.
6. Return a one-dimensional sequence to its original position in the original image.

2.4 Novel detection method

Figure 2 shows a scheme for detecting digital watermarks using watershed segmentation.

1. The image area is divided from the embedded information when the watermark is embedded.
2. Convert the divided area into a one-dimensional sequence.
3. Apply the desmear transform to the watermark embedded one-dimensional sequence. Pixel value information is diffused and the watermark information that was diffused is restored.

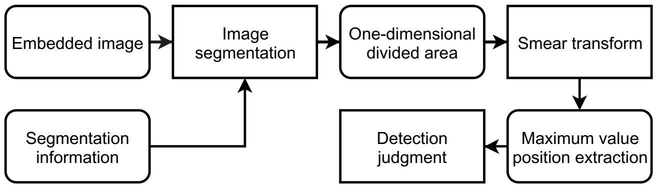

Figure 2. Detection procedure of the proposed method

Figure 3. The image divided into 64 by tile image segmentation

4. Find the maximum value sequence position from a one-dimensional sequence.
5. If the watermark embedding position matches the maximum value sequence position, it is determined that the detection is successful.

2.5 Tile image segmentation

Tile image segmentation is the process of dividing an image into $M \times M$ size areas. This method is used in the conventional method and the original JPEG standard. Figure 3 shows the image divided into 64 by tile image segmentation.

2.6 Watershed segmentation

Watershed segmentation is the process of segmenting an image using the watershed algorithm [6]. The watershed algorithm is divides a region by regarding the luminance value of the pixel of the image as the altitude of the mountain, and regarding the minimum and maximum luminance values as the valley bottom and ridge, respectively. Figure 4 shows the image divided into 64 by watershed segmentation. The watershed segmentation algorithm is explained below:

1. The pixels that are the basis for enlarging the area are determined so as to be the same number as the divided areas at equal intervals. Then, each selected pixel is labeled.
2. Four neighboring pixels centered on the selected pixel are searched, and the gradient with the center pixel is calculated.
3. The smallest neighboring pixel among all the obtained gradients is set as the target pixel. If there are only one kind of labels for the four neighboring pixels, the center

Figure 4. The image divided into 64 by Watershed segmentation

pixel is labeled with the same label as that label. If there are two types of labels for the four neighboring pixels, the center pixel is watershed.

4. The four neighboring pixels of the pixel of interest are searched to find the gradients. Add to the slope record already found.
5. Repeat steps 3-4 until there are no recorded pixels.

2.7 Smear transform

Smear transform [8] is used to efficiently spread and embed signature information. The smear transform is a conversion that spreads the information of each point in a sequence over the entire sequence. As a result, the information held by one pixel of the image is diffused throughout the image. Also, by desmear transform, which has the inverse characteristics of smear transform, each pixel information that has been diffused throughout the entire sequence is converged on each pixel and restored. By using this property, it is possible to reduce the visual influence by spreading the impulse sequence of watermark information throughout the sequence, and to be resistant to attacks that delete the watermark information.

An arbitrary intensity series $\mathbf{x}$ is

$$\mathbf{x} = (x_0, x_1, ..., x_{L-1})^T \tag{1}$$

The spreading sequence $\tilde{\mathbf{x}}$ is

$$\tilde{\mathbf{x}} = (\tilde{x}_0, \tilde{x}_1, ..., \tilde{x}_{L-1})^T \tag{2}$$

where T represents a transposed matrix, and L represents the length of a one-dimensional sequence. The smear and desmear transforms are expressed as follows using the smear transform matrix $\mathbf{S}$ and desmear transform matrix $\mathbf{D}$.

$$\tilde{\mathbf{x}} = \mathbf{S} \cdot \mathbf{x} \quad \text{(smear)} \tag{3}$$

$$\mathbf{x} = \mathbf{D} \cdot \tilde{\mathbf{x}} \quad \text{(desmear)} \tag{4}$$

Then the smear transform matrix $\mathbf{S}$ is defined as

$$\mathbf{S} = \mathbf{F}^{-1} \begin{pmatrix} e^{j\theta_0} & 0 & \dots & 0 \\ 0 & e^{j\theta_1} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & e^{j\theta_{L-1}} \end{pmatrix} \mathbf{F} \tag{5}$$

where $j = \sqrt{-1}$. Then the discrete Fourier transform matrix $\mathbf{F}$ is as follows.

$$\mathbf{F} = \frac{1}{\sqrt{L}} \begin{pmatrix} W_{0,0} & W_{0,1} & \dots & W_{0,L-1} \\ W_{1,0} & W_{1,1} & \dots & W_{1,L-1} \\ \vdots & \vdots & \ddots & \vdots \\ W_{L-1,0} & W_{L-1,1} & \dots & W_{L-1,L-1} \end{pmatrix} \tag{6}$$

where $W_{p,q} = e^{-j2\pi pq/L}$. If the inverse discrete Fourier transform matrix is $\mathbf{F}^{-1}$, the following holds.

$$\mathbf{F}^{-1} \cdot \mathbf{F} = \mathbf{I} \tag{7}$$

where $\mathbf{I}$ is the identity matrix. θ_k in (5) shows the phase characteristic of the smear transform, and is as follows.

$$\theta_k = \begin{cases} 2\pi\alpha(k^2 - \frac{L}{2}k) \\ \qquad (k = 0, 1, ..., L') \\ -2\pi\alpha\{(L-k)^2 - \frac{L}{2}(L-k)\} \\ \qquad (k = L'+1, L'+2, ..., L-1) \end{cases} \tag{8}$$

where L' is as follows.

$$L' = \begin{cases} \frac{L-1}{2} & (L = \text{odd number}) \\ \frac{L}{2} & (L = \text{even number}) \end{cases} \tag{9}$$

Then α indicates the diffusion coefficient. The diffusion coefficient is a value that indicates the degree of diffusion when applying smear transform.

In the desmear transform, the desmear transform matrix $\mathbf{D}$ is the inverse of the smear transform matrix $\mathbf{S}$, so

$$\mathbf{D} = \mathbf{S}^{-1} \tag{10}$$

Therefore, the desmear transform matrix $\mathbf{D}$ is defined as

$$\mathbf{D} = \mathbf{F}^{-1} \begin{pmatrix} e^{-j\theta_0} & 0 & \dots & 0 \\ 0 & e^{-j\theta_1} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & e^{-j\theta_{L-1}} \end{pmatrix} \mathbf{F} \tag{11}$$

The following relationship holds between the smear transformation matrix $\mathbf{S}$ and the desmear transformation matrix $\mathbf{D}$.

$$\mathbf{D} \cdot \mathbf{S} = \mathbf{I} \tag{12}$$

Therefore, the sequence subjected to smear and desmear transforms is completely restored to the original sequence.

3. Results

In the experiment, the quality evaluation is performed by calculating the PSNR in the two methods to be compared. We used 256-scale grayscale images Lenna and Girl with 256×256 size and density values from 0 to 255. As a feature of the image watermarking method, the degradation of quality

Table 1. Experimental result

Image	Number of divisions	PSNR[dB]	
		Previous method	Proposed method
Lenna	4	47.61	48.42
	16	43.05	43.47
	64	37.69	37.71
Girl	4	47.55	48.41
	16	36.48	36.65
	64	26.25	26.67

(a) Previous method

(b) Proposed method

Figure 5. Watermark embedded images

becomes remarkable as the amount of embedded information increases. Also, embedding the watermark strongly deteriorates the quality. In consideration of this point, in this experiment, experiments are performed with multiple divisions, and the embedding strength is set to 100 in all images.

Table 1 shows theexperimental results of calculating the average PSNR after100 embedding operations. Also, Figure 5 shows a watermark embedded images created by both methods.

4. Discussion

PSNR means that the larger the numerical value, the smaller the difference from the original image. In other words, the proposed method embeds the watermark with less degradation than the conventional method.

The tile image segmentation used in the conventional method divides an image into square blocks regardless of pixel values. The watershed segmentation, on the other hand, performs segmentation in areas with large gradients. The part with a large gradient is often the boundary of the object, and the change of the pixel value in the object tends to be small, so the change of the pixel value in the block can be suppressed. For this reason, the minimum value required for embedding a watermark is smaller than that of the conventional method, and it is considered that the degradation is suppressed.

5. Conclusions

In this paper, we studied the image watermarking method using watershed segmentation. From the comparison of PSNR between watermarked images of the conventional method and the proposed method, it was clarified that watershed segmentation was effective for image watermarking.

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