Information hiding algorithm based on edge detection and holographic watermarking

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Abstract. In order to improve the robustness of the image watermarking and reduce the influence of the overall image quality of the carrier when watermark is embedded on the carrier, an edge detection method combined with holographic watermarking was proposed to realize the hiding of watermark information. The carrier image is processed by edge detection, the watermark embedding area is segmented in the carrier image, and the suitable embedding area is filtered according to the size of the watermark; the original watermark is processed by a four-step phase shift algorithm to generate a holographic watermark, and the holographic watermark is embedded in the selection. The embedding area is completed to embed the watermark, and the carrier image which the watermark is embedded is carrier image with watermark. The watermark extraction method is to perform the same edge detection segmentation and region screening on the watermark carrier image, find the embedded area of the watermark, extract the holographic watermark, perform holographic inverse transformation to obtain the original watermark image, and complete the watermark recovery. The algorithm which is based on edge detection and holographic watermarking reduces the influence of embedded watermark on the carrier image, increases the flexibility and concealment of embedded position, and improves the robustness of the image when it is under geometric attacks.

1. Introduction
In recent years, the use and dissemination of digital image data has become more and more popular, at the same time, piracy has become easier, the emergence of digital watermarking technology for the protection of digital property rights provides a new means of information security technology, and is widely used in image, video and other digital media. Digital watermarking is to embed some mark information into the digital media without affecting the normal use of the original carrier. Under normal circumstances, such information is not perceived by people's senses. By reconstructing the hidden information, the purpose of copyright protection is achieved.

Digital watermarking technology is a research hotspot in the field of information security. At present, image watermarking algorithms are relatively mature. However, simply embedding watermark in the carrier image not only has a great impact on the quality of the carrier image, but also is easily affected by different attacks, resulting in the inability to extract the watermark smoothly [1,2].

The image consists of pixels with different gray levels. In the detection of gray level discontinuity, although the detection of point and line is very important, edge detection is by far the most common method. Image edge detection is realized by using the extreme value of the first derivative (gradient
operator) or the second derivative (Laplacian operator) information. [3,4,5] edge detection is a process to determine and locate sharp discontinuities in images. Edge detection plays an important role in image analysis. It is one of the traditional segmentation techniques.

In this paper, image segmentation and watermark embedding of carrier image can greatly reduce the impact of embedded watermark on the whole carrier image, and the improved robustness enables watermark to effectively resist most attacks.

2. Edge detection

Edge detection is a very important method for image analysis in image processing and computer vision. The purpose of edge detection is to find the set of pixels in an image whose brightness changes dramatically, which is often the contour. If the edge in the image can be accurately measured and located, then, it means that the actual object can be located and measured, including the area of the object, the diameter of the object, the shape of the object can be measured.

Laplacian operator is based on the second derivative of the image to find the edge and search for the zero crossing. The Laplace transform of an image with pixel intensity value \( I(x,y) \) is shown in the following formula.

\[
L(x, y) = \frac{\partial^2 I}{\partial x^2} + \frac{\partial^2 I}{\partial y^2}
\]

Laplacian operator is sensitive to noise attack. For this reason, Marr and Hildreth proposed an operator combining Gaussian filter and Laplace operator as edge detection based on human visual characteristics. This operator is Laplacian Gaussian operator (LOG). After filtering the image \( f(x,y) \) by using the Laplace Gauss operator, the zero intersection point of the filtering result is the edge point.

When using the Laplace Gaussian operator for edge detection, the image is first convolved with Gaussian function to obtain smooth image processed by Gaussian function.

\[
h(x, y) = f(x, y) * G(x, y)
\]

In the equation above, \( G(x, y) = \frac{1}{2\pi\sigma^2} \exp[-\frac{1}{2\sigma^2}(x^2 + y^2)] \), and \( \sigma \) is the variance of Gaussian function, which is proportional to the smoothness; Then the Laplace transform of the smooth image \( h(x,y) \) is carried out to obtain the Laplacian Gaussian operator edge detection image.

\[
\nabla^2 h(x, y) = \nabla^2 [f(x, y) * G(x, y)] = f(x, y) * \nabla^2 G(x, y)
\]

3. Four-step phase shift algorithm

The basic principle of the phase transfer method is that the reference of the stagnation method is transferred to the arm phase device, and the optical path difference between the beam and the test beam is changed by referring to it through the interferometer moving reference mirror, the position of the stripe moves appropriately, and the match of these, the intensity of the light at the point of interference is the change in the cosine, the photoelectronic element for collecting ccd, or the interference of the phase with different points. As a result, the interference between the zero-order image and the conjugated image can be eliminated. The reference light wave and the object light wave interfere with each other on the CCD, and the intensity distribution of the interference field recorded on the CCD is:

\[
I(x, y, \theta) = |R_0(x, y)\exp(j\theta)+O_0(x, y)\exp(j\varphi)|^2 = \\
|R_0|^2 + |O_0|^2 + R_0O_0\exp(-j\varphi)\exp(j\theta) + R_0O_0\exp(-j\theta)\exp(j\varphi)
\]

In the equation: \( \theta \) is the introduced step phase shift angle, \( R \) and \( O \) are the amplitudes of the plane wave and scattered light reaching the recording medium CCD, respectively, and \( \psi \) is the original angle with the Z axis. In the process of recording a hologram, a four-step phase shift algorithm generally
uses a phase shifter to take four phase shift values with respect to the reference light for a state to be measured with an object. $0, \pi/2, \pi, 3\pi/2$, and the intensity distribution of the four recorded images can be obtained:

$$
\begin{align*}
I(x, y, 0) &= |R_0|^2 + |O_0|^2 + 2R_0O_0 \cos \varphi \\
I(x, y, \pi/2) &= |R_0|^2 + |O_0|^2 + 2R_0O_0 \sin \varphi \\
I(x, y, \pi) &= |R_0|^2 + |O_0|^2 - 2R_0O_0 \cos \varphi \\
I(x, y, 3\pi/2) &= |R_0|^2 + |O_0|^2 - 2R_0O_0 \sin \varphi
\end{align*}
$$

A four-step phase shift algorithm can be used to obtain the complex amplitude distribution of physical waves in CCD:

$$
\theta(x, y) = \frac{1}{4R} \left\{ I(x, y, 0) - I(x, y, \pi) \right\} + j \left\{ I(x, y, \pi/2) - I(x, y, 3\pi/2) \right\}
$$

The above formula is the formula of the digital hologram we need, and this method erases the zero-class image and the conjugated image, increases the signal-to-noise ratio of the digital hologram, and improves the quality of the reproduced image.

4. Experimental procedure

4.1. image preprocessing

A picture is randomly selected as the carrier image (Figure 1). Here, we choose the interior design picture with the resolution of 2084X1963 as the carrier. Firstly, the vector image was edge detected, and the threshold parameter was set as 0.2. The strong edge point connection line was used to divide the vector image into various regions, and the regions suitable for embedding were selected according to the size of the watermark image, and the vector relationship between the embedding starting position and the boundary was recorded.

![Fig.1 original carrier image](image-url)
4.2. watermark embedding

The image with resolution of 64X64 was selected as the watermark (Figure 3), and the channel image was generated into a hologram using the four-step phase shift method, and four holograms with different phase shifts were obtained. After that, the hologram (H0) with phase shift of 0 is embedded into the embedding region selected from the carrier graph by means of wavelet transform, and the carrier graph after embedding watermark is obtained (FIG. 4), and the embedding process of the watermark graph is completed.

Fig.3 Original watermark

Fig.4 Holograms H0, H1, H2 and H3 generated by the four-step phase shift method
4.3. watermark extraction
The watermark carrier is segmented by edge detection again (4.1), the embedded region is found according to the recorded feature information, the holographic watermark is extracted from the embedded region, and the holographic inverse transformation is performed to obtain the watermark (Figure 6).

5. Conclusion
Through the results of the experiment, it can be seen that the recovered watermark pictures are quite clear. The method of generating holograms using four-step phase shift has better confidentiality than the method of directly embedding the watermark, because only one of the four holograms is embedded in the carrier image is used as the key, and four holograms are needed to recover the original watermark image, this way strengthens the security and anti-tampering ability of the watermark.

This algorithm uses image segmentation to preprocess the carrier image. Because it embeds a part of the image, it greatly reduces the influence of the embedded watermark on the carrier image and has good concealment; when the carrier image is irregularly distorted and deformed, the carrier image can be restored according to the image segmented blocks and the watermark can be extracted from it. It is highly robust against distortion attacks, and the watermark effect recovered in digital pictures is particularly prominent.

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