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An Improved Data Hiding Algorithm for Increasing Hidden Capacity

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Abstract

Illegal manipulation and alteration of digital content are becoming a social issue. To address this problem, there is an increasing demand for the development of technologies to prevent the manipulation and alteration of digital content.

This paper proposes a data hiding algorithm capable of embedding a larger amount of confidential data in the original cover image while minimizing the degradation of image quality in stego images. The algorithm presented in this paper analyzes the characteristics of the image to extract corner points and then uses a method to insert watermarks around these extracted corner points. Additionally, through experimentation, it has been proven that this algorithm can insert a greater amount of watermark without degrading the image quality compared to other existing algorithms.

Keywords: *data hiding, steganography, reversible data hiding, embedding capacity, cover image, stego image*

1. Introduction

In modern society, with the advancement of digital technology, the illegal manipulation and alteration of digital contents are increasing, urgently requiring countermeasures. Particularly, the illegal manipulation of digital content has emerged as a social issue, and technical solutions to solve and prevent this problem are becoming increasingly important.

In this paper, we proposes research in the technical aspects of preventing the manipulation and alteration of digital content. Specifically, it introduces a data hiding algorithm that can effectively embed a larger amount of watermark(confidential data) in the original cover image while minimizing the degradation of image quality in stego images. The proposed algorithm utilizes a method of inserting watermarks around the extracted corner points after analyzing the characteristics of the image and extracting corner points. The key feature of the algorithm presented in the paper is that it can insert a larger amount of watermark compared to existing algorithms without causing degradation in image quality. This was demonstrated through experimental methods by comparing performance with existing algorithms.

Thus, this paper presents a new technical solution to the illegal manipulation and alteration of digital content,

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aiming to contribute to enhancing information protection and security in the digital environment.

The structure of this paper is as follows. Chapter 2 introduces existing watermarking methods and explains the characteristics of each. In Chapter 3, we propose a new data hiding algorithm that can increase the amount of information to be hidden while minimizing damage to image quality. Chapter 4 examines the results of implementing the proposed algorithm and compares and analyzes them with the results of other similar studies. Finally, in Chapter 5, we conclude and discuss future research tasks.

2. Related Works

DE(Difference Expansion) algorithm is a method proposed by Tian[1, 2]. It is a technology that selects pixel pairs of the original image to insert a watermark and uses their integer average and difference values. This method has a very large watermark hiding capacity of up to 0.5bpp, but has the disadvantage that it is difficult to control the capacity of the hidden data.

Tseng's method[3] is an improvement on Tian's method and does not use a location map. A watermark is inserted considering the correlation between neighboring pixels, the watermark is extracted using the difference value between the predicted pixel and the watermarked pixel, and the original image is restored. However, there is a limit to increasing the hiding capacity because the size of the difference value that can hide data is limited.

Lee's method[4] is effective in complex general images. Qershi[5] mixed Tian, Chiang[6], and Alattar's methods[7] to take advantage of each other's strengths. Cho[8] divided the image into complex blocks and simple blocks and applied an advantageous data hiding algorithm to each block. In this algorithm, the original cover image is divided into small blocks of size 8×8. The complexity of the image is calculated by applying PIM (Picture Information Measure) to each 8×8 divided area. PIM is a method of measuring the complexity of an image and it is defined as equation (1).

$$PIM = \sum_{i=0}^{L-1} h(i) - Max_i(h(i)) \tag{1}$$

In equation (1), *i* is the brightness gray level of the image. And *h(i)* is the histogram of the pixel with gray level *i*. *L* is the level of gray level, with a maximum of 256. *PIM* is defined as the difference between the total number of pixels in the block and the maximum value of the histogram. For example, if *PIM* is 0, the image has only one brightness value and can be said to be a simple image. On the contrary, if there are various brightness values present and the histogram values for each gray level are relatively small, *PIM* will have a very high value. Such images can be considered complex. The complexity of the image is calculated using this property of *PIM*.

3. Proposed Algorithm

The hybrid data hiding algorithm presented in this paper is as follows. First, corner information is extracted using the Harris Corner Detector algorithm[9]. The main idea behind the Harris corner detector is to identify corners by looking for significant changes in intensity in all directions. It operates by analyzing the variations in intensity for small shifts of a window of pixels. Corners are characterized by a high change in intensity for any direction of the shift. Among this corner information, points with characteristics that are invariant to image distortion can be usefully used for image matching. Corner points must exhibit significant changes in image brightness in all directions, as shown in Figure 1. Points A and C demonstrate large changes in brightness in all directions. However, point B shows changes in brightness vertically but not horizontally, and in the case of point D, there is almost no change in brightness in any direction.

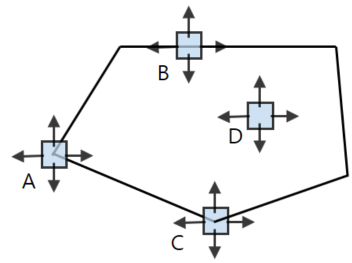

Figure 1. Characteristics of corners

This idea is defined by Moravec[10] as the sum of squared difference(SSD) as shown in equation (2). Here, *w(x,y)* is a window of a specified size and is a mask with only the corresponding size portion having a value of 1.

$$E(u,v) = \sum_y \sum_x w(x,y) \cdot (I(x+u,y+v) - I(x,y))^2 \tag{2}$$

Since the image change amount (SSD) is the sum of the squares of the brightness change when irradiated from the current pixel in the u and v directions, the change must be substantial in all directions for the SSD value to be large.

The Moravec algorithm is vulnerable to noise because it uses a binary window with only values 0 and 1, and since it is limited to four directions, it can only consider edges at 45-degree intervals. To overcome this limitation and achieve more precise corner detection, Harris[9] proposed the following improvement. First, equation (3) is extended by applying a gradually changing Gaussian mask (G) instead of a binary window. This modification reduces sensitivity to noise.

$$E(u,v) = \sum_y \sum_x G(x,y) \cdot (I(x+u,y+v) - I(x,y))^2 \tag{3}$$

Because calculating eigenvalues requires a complex process of eigenvalue decomposition, the Harris detector does not directly compute eigenvalues. Instead, it utilizes them in the form of a corner response function through the determinant(det) and the trace, which is the sum of the diagonal elements, as follows.

$$M = \begin{pmatrix} d_x^2 & d_x d_y \\ d_x d_y & d_y^2 \end{pmatrix} = \begin{pmatrix} a & c \\ c & b \end{pmatrix}$$
$$R = \det(M) - k \cdot trace(M)^2 = (ab - c^2) - k \cdot (a+b)^2 \tag{4}$$

Here are the key steps of the proposed data hiding algorithm:

Step 1: Compute the image gradients in both the x and y directions using Sobel operator.

Step 2: Structure Tensor Calculation. It is computed by convolving the squared gradients with a Gaussian window.

Step 3: Calculate a corner response function for each pixel using the elements of the structure tensor.

Step 4: Apply a threshold to the corner response values to select the most prominent corners.

Step 5: Original cover image is divided simple blocks and corner blocks.

Step 6: The extracted corner image blocks are processed using Lee's algorithm[4], while Qershi's algorithm[5] is applied to the remaining parts of the image excluding the corner image blocks.

The Harris corner detection method has the characteristic of being invariant in translation and rotation of the image, and is robust to affine transformation and illumination changes. However, it is affected by changes in the size of the image. These characteristics of the Harris corner detector match the essential conditions for data hiding. Therefore, the data hiding algorithm presented in this paper is robust to movement, rotation, and affine transformation of the stego image.

4. Experimental Results

In this paper, we experimented in Windows 11 Pro environment of PC with Intel Core i7 2.8GHz CPU. The images used in this experiment are MRI, Zelda, Boat, and F16. Figure 2 shows the images with corner points extracted using the Harris corner detection algorithm.

(a) MRI (b) Zelda (c) Boat (d) F16

Figure 2. Corners detected images

Table 1 shows the hidden capacity for the experimental image, measured in bits per pixel(bpp). As shown in Table 1, Tian's method is efficient for both general and medical images. Chiang's method can only be applied to medical images, and there is almost no hidden space in complex general images. Lee's method is effective in complex general images. Qershi combined the methods of Tian, Chiang and Alattar to utilize the strengths of each.

Table 1. Maximum available capacity(bpp)

	MRI	Zela	Boat	F16
Tian	0.330	0.499	0.500	0.489
Chiang	0.232	0.001	0.001	0.000
Qershi	0.426	0.747	0.342	0.712
Lee	0.232	0.873	0.767	0.899
Alattar	0.291	0.365	0.434	0.576
Tian+Chiang	0.428	0.433	0.500	0.487
Proposed	0.423	0.456	0.545	0.488

Figure 3 and Figure 4 are comparative graphs of the watermark hiding capacity and image quality of the algorithm proposed in this paper and the existing algorithm. Figure 3 is the result of an experiment using a Boat image, and Figure 4 is the result of an experiment using an F16 image. The experimental results show that the method presented in this paper is superior to Tian's method and has comparable results to Lee's method, which was designed to have excellent performance in complex images.

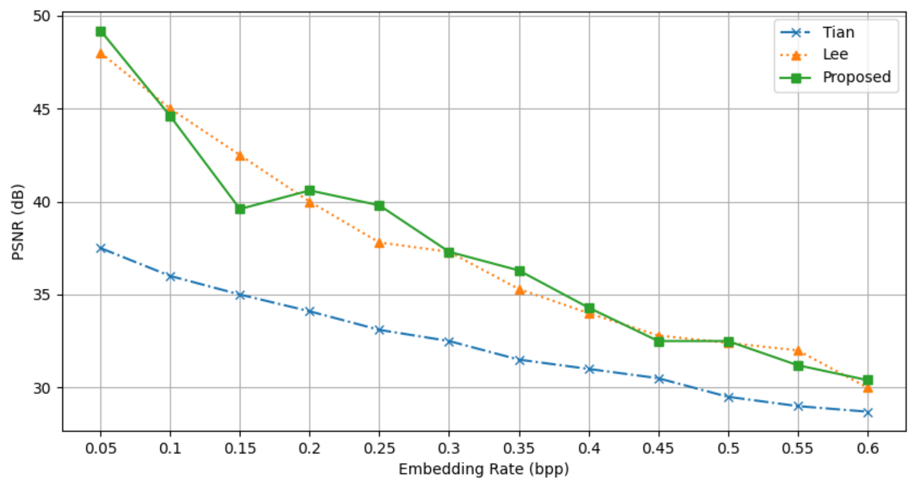

Figure 3. Embedding capacity versus image quality curves for Boat image

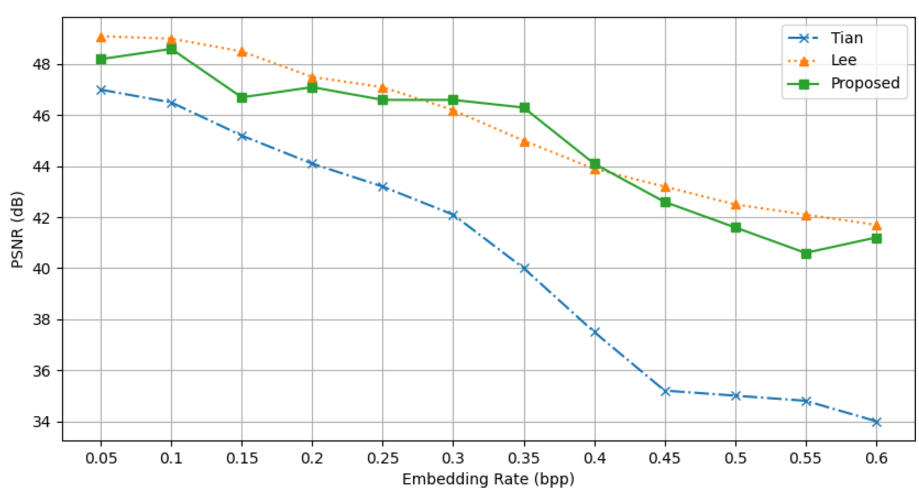

Figure 4. Embedding capacity versus image quality curves for F16 image

5. Conclusion

In this paper, we proposes research in the technical aspects of preventing the manipulation and alteration of digital content. Specifically, it introduces a data hiding algorithm that can effectively embed a larger amount of watermark in the original cover image while minimizing the degradation of image quality in stego images. The proposed algorithm utilizes a method of inserting watermarks around the extracted corner points after analyzing the characteristics of the image and extracting corner points. The key feature of the algorithm presented in the paper is that it can insert a larger amount of watermark compared to existing algorithms without causing degradation in image quality. This was demonstrated through experimental methods by comparing performance with existing algorithms. In this paper, the image was separated into complex and simple parts, and Lee's method was applied to the complex part and Qershi's method to the simple part. Therefore, it has a high hiding capacity regardless of the complexity and type of the image.

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