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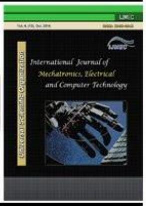

A Reversible Data Hiding Using Image Segmentation and Histogram Shifting

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Abstract

Today, due to the advancement of new technology, the embedding of secret information in the image has great importance. In this paper, a reversible watermarking method based on local statistics in pixels is proposed. The proposed algorithm can be thought of as an improved version of the traditional Quad tree segmentation and histogram shifting tecniquies. One of the advantages of the proposed method is that it is completely reversible. In this method, the Quad-tree is deleted and the image is divided into non-overlapping homologous blocks. Then, due to block with the lower energy is more suitable for watermarking; it selects a block with the least energy for watermarking. At the end, in order to show the efficiency of proposed algorithm, two criteria of Mean-Squared-Error (MSE) and Peak Signal-to-Noise Ratio (PSNR) have been calculated on multiple images. The PSNR shows that image quality has not changed too much after hiding the information than the original image. In addition, the computational results show that the speed of proposed algorithm is higher than the quad-tree and it has less execution time.

Keywords: *Quad-tree, Mean Squared Error, Peak Signal-to-Noise, watermarking.*

1. INTRODUCTION

Recently, with the rapid advancements in digital technology as well as the increasing growth of information technology, and in particular the widespread use of personal computers connected to the Internet, easy access to digital devices such as audio, video or photographic equipment (photo, image, etc.) has been broadly extended for the people. In addition to the advantages such as high quality of digital content, there is also disadvantages include the possibility of making any number of copies of a single original without losing quality or the possibility of forging and altering their content. For this reason, digital products should be reasonably protected. In general, there are two general techniques for protecting copy right of digital data that have grown together in complementary form: encryption and watermarking. Encryption techniques can be used to protect digital data during the sending process from sender to receiver. However, the important thing about digital information is that the resulted information after the decryption is exactly the same as the initial information and thereafter there is no protection mechanism on them and the original owner cannot claim any ownership of original image and he/she cannot prevent it from reproducing in any way. The problem will be solved using watermarking methods. The purpose of watermarking is to hide information or confidential messages in the form of a normal message and extract it in the destination. Many studies have been proposed different data hiding technologies to embed secrete copyright information, secret message, or trademark into digital contents to secure the data, and provide negligible modification of original contents [1-4]. In some watermarking techniques, original media which hide the transmission of some secret data cannot be transformed back to its original media at the extraction stage. It is important in sensitive images [5-7] such as military or medical images, to reverse marked image back to the original

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image after data hiding. There are many studied which efforts on reversible watermarking that can protected the original images from distorting.

In [8], Tain presents a difference method for reversible watermarking. The method can provide very high hiding capacity, but it also destroys the original image very much. Also there are several variants of difference expansion proposed to improve the stego- image quality and hiding capacity [9-12]. In [13], Ni abrings up a histogram shifting algorithm. The algorithm is simpler and has less complexity than most of other watermarking algorithms.

This algorithm utilizes the zero or the minimum points of the histogram of an image and slightly modifies the pixel grayscale values to embed data into the image. It can embed more data than many of the existing reversible data hiding algorithms. It can preserve very high peak signal-to-noise ratio (PSNR) after embedding the data in the image. However Ni's algorithm can't provide sufficient capacity for most applications; so many studies tried to improve Ni's algorithm.

For example, Hwang uses the intensities between the maximum points to raise capacity [14], but it is not significant to increase amount of hiding data. Chung proposed a method which used a dynamic programming [15] to maximize histogram shifting hiding capacity. The method increases capacity indeed, but it has two problems: it is suitable only for specific kind of images and its execution is very high.

For preserving the quality of image, we intend to use the method of histogram shifting, and improve its hiding capacity. The method is enhanced to utilize the characteristics of an image for maximizing its hiding capacity.

This paper is organized as follows: In section 2 Ni's histogram shifting algorithm is described; In section 3 energy gradient is given. In section 4 the proposed method is presented. Section 5 is devoted to show experimental results. Finally conclusion is drawn in section 6.

2. Histogram shifting

At first, Ni's histogram shifting algorithm[13] computes the histogram h(x). The step of this algorithm is as follows:

Step 1: create the histogram h(x), $x \in [0,255]$ for host image I. Then find the maximum and the minimum point in the histogram as Eq (1):

$$\begin{cases} m_1 = arg_x \ \max h(x) \\ m_2 = arg_x \ min\, h(x) \end{cases} \tag{1}$$

As shown Eq 1 the m_1 corresponding to grey level with most frequently in host image I and $m_2$is minimum number of pixel render with in the image. We suppose$m_1 < m_2$.

Step 2: traverse the host image and for each pixel I (x, y) do the following modifying operation (Eq 2) according to its gray level:

$$I'(x,y) = \begin{cases} I(x,y)+1 & m_1 < I(x,y) < z_1 \\ I(x,y)+s_i & I(x,y) = m_1 \\ I(x,y) & otherwise \end{cases} \tag{2}$$

Upon receiving the marked image (I'), for extracting the secrete message <s_i> and the host image I, the extraction method is as followes:

Step1: for each pixels $I'(x,y)$ in the received image, extract the secrete datadata <s_i> as Eq 3:

$$s_i = \begin{cases} 0 & I'(x,y) = m_1 \\ 1 & I'(x,y) = m_1 \end{cases} \tag{3}$$

Step 2: all of pixel is considered to convert into their original gray level according Eq4:

$$I(x,y) = \begin{cases} I'(x,y) - 1 & m_1 < I'(x,y) \le m_2 \\ I'(x,y) & otherwise \end{cases} \quad (4)$$

3. Energy Gradient

Energy gradient in an image is calculated with Sobel operators. This operator takes a weighted derivative in the horizontal and vertical direction of pixels and is a good criterion to determine the change in the image. Obviously, the pixel placed at the change location will have a large derivative in the horizontal or vertical direction, and it should be considered important and should be kept as possible. On the other hand, any point or pixel with less gradient magnitude will have less variation around it.

4. The proposed method

In the proposed method, the quad tree is completely deleted, and the image is first blocked in the form of non-overlapping windows with specified dimensions. The blocks located in each window are not necessarily the same in terms of energy. Afterwards, the blocks are determined by minimum energy, because the blocks with the least energy have the smallest changes to watermark and to embed secret content. To calculate the energy of the blocks, the gradient function of the image has been used with Sobel Mask, which is one of the most common used masks to calculate the gradient. It should be noted that when blocking the image, the gradient blocks are simultaneously extracted and the absolute value of the energy in each block is calculated individually.

Because the optimal block dimensions are not known, in the implementation, the image with different dimensions was windowed to provide an implicit view of the effect of the selected block dimensions for the information watermarking. In this simulation, the image blocking dimensions are considered to be 4 × 4, 8 × 4, 8 × 8, 16 × 8, 16 × 16, 32×8, 32 × 16 and 32 × 32. For each of these dimensions, the image is divided into equal blocks and the energy of each block is calculated individually. After that, the histogram of block with minimum energy is computed and is hidden by the histogram of the digitized information shifting.

If a block does not provide watermarking adequacy, the second and third blocks will be used with at least minimum energy to hide other information. Considering that a 4x4 block i.e. 16 pixels is very small and may have all the pixels with exactly the same brightness level, it's not possible to watermark information. In those cases where the histogram has single value, that block is used as an inappropriate block for watermarking and will be deleted. For this purpose, watermarking takes place on blocks whose histograms have at least two values.

In this method, given that the quad tree is completely deleted and the image blocking is simply done with repeating loops, the execution speed will be much higher, and the complexity of the quad tree is completely eliminated. However, due to same blocking, information security in this state is less than previous one and the attacker can easily access the information and their contents in an attack process. Figure 1 shows an example of an image before and after data watermarking. As this figure shows, there is no difference with the base image in terms of quality.

FIGURE 1. An Example of image before(a) and after(b) embed secrete data

5. Computational result

In order to investigate the efficiency of the proposed algorithm, seven high-quality images were selected and the proposed algorithm was used to test its information watermarking. Two PSNR and MSE criteria were used to compare the images before and after the watermarking. The values of the MSE and PSNR obtained from the watermarking using the proposed algorithm are shown in Tables 1 and 2, respectively. In these tables, the results obtained from the proposed algorithm are compared with the results presented in [17].

According to Table 1, the mean squared error in the proposed method is lower than the Quad-tree. In terms of PSNR, the proposed algorithm is better than quad-tree which indicates that the quality of the images is better than the quad tree method after watermarking. In terms of image quality, with increasing dimensions, the size of the windows has become larger and the form of their changes has had a greater impact in final quality because the number of pixels displaced during the shift of the histogram is smaller than the small windows. However, in term of runtime, larger windows have less runtime which will help them more efficiently. Table 3 shows that normal windowing algorithms have a higher rate of run-time than the quad tree method and this could lead to a more desirable method.

TABLE 1: Mean Square Error

		Number of immage	**1**	**2**	**3**	**4**	**5**	**6**	**7**
		Quad-tree segmentation[17]	2.7E-03	4.0E-04	1.1E-03	0.0E+00	3.7E-03	2.2E-03	6.2E-03
4	4	Proposed method	1.1E-04	1.1E-04	1.1E-04	9.5E-05	1.1E-04	1.2E-04	1.6E-04
8	4		1.5E-04	1.2E-04	1.2E-04	8.8E-05	1.3E-04	1.5E-04	2.1E-04
8	8		1.2E-04	1.5E-04	1.3E-04	9.2E-05	1.7E-04	1.4E-04	2.7E-04
16	8		1.4E-04	1.4E-04	1.4E-04	9.2E-05	2.4E-04	1.8E-04	2.5E-04
16	16		1.1E-04	1.3E-04	1.8E-04	2.4E-04	4.3E-04	3.5E-04	4.6E-04
32	8		3.8E-04	3.3E-04	1.9E-04	1.8E-03	2.5E-04	5.1E-04	8.9E-04
32	16		3.8E-04	2.4E-04	6.5E-04	1.3E-03	4.0E-04	5.8E-04	1.6E-03
32	32		1.0E-03	6.9E-04	7.5E-04	3.9E-03	2.3E-03	1.1E-03	1.4E-03

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TABLE 2: Peak Signal to Noise Ratio

		Number of image	**1**	**2**	**3**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
		Quad-tree segmentation [17]	73.8	82.1	77.6	72.5	74.6	70.2	76.1	72.9	78.5	74.9	77.5	72.8	80.4	74.5
4	4	Proposed method	87.5	87.5	87.5	87.;5	87.4	86.2	87.5	96.3	87.8	87.5	87.3	87.5	87.5	85.4
8	4		86.3	87.3	87.3	86.9	86.4	84.8	87.4	84.3	86.9	86.3	83.9	86.9	87.4	84.6
8	8		87.4	86.4	87.0	85.9	86.8	83.7	86.4	86.4	85.8	87.0	84.3	86.9	87.5	80.6
16	8		86.8	86.5	86.5	84.3	85.5	84.1	84.3	83.0	85.2	81.4	83.5	86.3	84.0	77.6
16	16		87.5	87.0	85.5	81.7	82.7	81.5	84.4	80.9	82.7	83.1	81.0	82.6	86.6	76.0
32	8		82.4	83.0	85.2	84.1	81.1	78.6	81.3	79.4	81.7	76.5	78.2	86.0	80.6	73.0
32	16		82.4	84.3	80.0	82.1	80.5	76.1	81.7	76.7	79.6	82.5	76.4	79.4	79.8	73.8
32	32		78.0	79.7	79.4	74.6	77.7	76.5	76.4	74.7	77.3	81.1	74.3	78.7	79.8	71.2

TABLE 3 Running time (second)

		Number of image	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
		Quad-tree segmentation	29.85	27.82	26.28	28.49	26.83	23.97	24.46	27.63	27.06	24.69	27.75	30.48	25.26	26.36	32.47
4	4	Proposed method	10.33	10.27	10.26	10.90	10.37	10.61	10.26	10.16	10.18	10.27	10.27	10.25	10.22	10.25	10.24
8	4		5.19	5.12	5.14	5.51	5.28	5.25	5.15	5.10	5.13	5.16	5.14	5.15	5.15	5.16	5.15
8	8		2.61	2.59	2.60	2.82	2.62	2.58	2.58	2.57	2.56	2.61	2.59	2.60	2.59	2.60	2.58
16	8		1.34	1.32	1.33	1.42	1.34	1.31	1.30	1.31	1.29	1.33	1.31	1.33	1.30	1.33	1.32
16	16		0.70	0.69	0.69	0.73	0.69	0.67	0.67	0.67	0.68	0.68	0.68	0.69	0.67	0.70	0.68
32	8		0.70	0.69	0.69	0.72	0.69	0.67	0.67	0.67	0.66	0.68	0.68	0.69	0.67	0.70	0.67
32	16		0.37	0.37	0.37	0.38	0.37	0.35	0.35	0.35	0.35	0.36	0.36	0.37	0.35	0.37	0.35
32	32		0.21	0.21	0.21	0.22	0.21	0.19	0.18	0.19	0.19	0.21	0.20	0.21	0.19	0.21	0.19

Conclusion

In this paper, a watermarking method based on local statistics in pixels was proposed. In this algorithm, the image is first divided into non-overlapping same blocks using a regular repeat loop. Then, it selects the block with less energy for watermarking. The proposed method is considered as a substitute and simplifier for the quad tree method. One of the advantages of the proposed algorithm is that it can be completely reversible. The algorithm has been analyzed for several dimensions of the non-overlapping blocks which show that the quality of the images after the watermarking in the proposed algorithm is better than the quad tree according to the PSNR criterion. Also, in terms of run-time, it is faster than the quad tree. In addition, a sample of several images in form of original image and an image with watermarked information are investigated and the results are presented to demonstrate the capabilities of the proposed method in term of maintaining quality.

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