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A Reversible Data Hiding Scheme Using Multi-layer Embedding for Images in Intelligent Transportation Systems

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ABSTRACT : This paper proposes a lossless or reversible data hiding method which is based on the pixel difference histogram shifting for images in intelligent transportation systems (ITS) in spatial domain. Pixel differences are generated between a reference pixel and its neighbors in a pre-assigned block. After the difference histogram shifting, a large number of data such as vehicle's plate can be embedded into the host image and multi-layer embedding is used to improve the hiding capacity. The proposed scheme can extract the hidden data and recover the exact original cover image if we received embedding level (EL) number and the watermarked image via communication channel. The receiver can be various police forces who use this information to issue penalty ticket. The Simulation results demonstrate high degree of performance for the proposed method.
key words: data hiding, histogram shifting, lossless, multi-level, reversible, watermarking, intelligent transportation system, embedding level.

INTRODUCTION

Urban commute is made of citizens' daily activities which might be done for work, shopping, education, entertainment and etc. to achieve their goals. Citizens may get use of several transportation means such as walking, bike riding, taxies, buses, metro or their personal cars. However, metropolises have made the number and necessity of these commute more than provided facilities in each city. The application of information technology (IT) in transportation is called intelligent transportation system (ITS) that include a large variety of modern tools for transportation system management (TSM) and serving passengers. Basis of ITS tools contains three features naming information, communication and integration. Collection, information processing, integration and provision of information are the core to ITS. In the mentioned features of ITS, communication and information processing play critical roles. In Shiraz traffic control center, images through video surveillance cameras are received and the transmitted information is processed with the use of intelligent infraction system and automatic license plate recognition (ALPR) in order to be provided to various police forces. This information is used as a method of electronic toll collection.

Typically, after license plate recognition, time and the place of violation have been written along with the car images to be given to different police forces. Giving a large amount of information to police forces in several times per a day requires different tools such as fax, e-mail or commuting between traffic control center and police station which in turn have their own disadvantages. As for the commute, it might increase traffic as well as fuel consumption, also, it waste more time for information transmission. While e-mails and faxes are not sufficiently secure.

Information embedding is commonly done through Steganography and data hiding or watermarking.

Steganography is one such a type that embeds data in a cover or a host image creating a stego image [1]. Imperceptibility, robustness, data embedding capacity, hidden data security and computational complexity, etc., are key issues for good data hiding techniques in digital images. Among different types information carrier, digital image plays an undeniable role in information transmission in the concurrent world of technology and communication.

Hiding techniques can be used for either secure or non-secure applications. For secure application the host image is not of concerned, therefore capacity can be increase image distortion. On the other hand, increasing image distortion can attract hacker attention.

Recently, distortion-free or lossless data hiding scheme (LDH) has attracted more and more attention for information security problems in digital image [2, 3, and 4] and video watermarking processing [5, 6]. It deals with situation where the intactness of the host image after extractions of the watermark bits is highly demanded. A dozen practical problems fall into situation because of unintentional attack, e.g. random noise and lossy compression, often degrade the quality the watermarked image during the transmission, leading to the failure of the extraction of the hidden data. On the other hand, in an irreversible data hiding scheme, the original cover image cannot be restored.

About lossless data hiding, my colleagues and I provided several studies two of which are mentioned here. [5, 6, 7, 8 and 9]

For example, we proposed a semi LDH scheme based on histogram distribution shift in integer wavelet transform (IWT) domain in [10]. To recover the embedded information within the image as well as the original image, IWT was used. In our proposed scheme, the transform approximation image is divided into non-overlapping blokes. In any block, the difference between the neighboring elements is computed and a histogram is made on the difference values. The secret information is embedded into blocks based on a multi-level shifting process of the histogram.

Moreover, in 2013, we proposed a high capacity robust lossless data embedding scheme with great payload capacity, good image quality and acceptable robustness which is based on adjacent pixel difference (APD) and histogram distribution constrained (HDC) technique [11]. The main scenario behind our technique is that we use neighbor pixel that is often highly correlated and spatial redundancy. The secret data is embedded based on a multi-level histogram shifting mechanism and shifting the arithmetic difference values of each block in two steps of embedding strategy.

Regarding the fact that we utilized the first pixel as the basis pixel, the achieved histogram difference around zero point was fairly more. However this difference was less, the embedding capacity could increase. Thus, the embedding capacity improved less than the proposed multi-level embedding schemes which did not fulfill our expectation.

In this study, we embed required information in the vehicle images which in turn speed up information transmission, boost information security and reduce our organization costs.

The rest of this paper is organized as follows. The details of proposed data hiding method are presented in Section II. Some experimental results are provided in Section III; finally, the paper is concluded in Section IV.

PROPOSED SCHEME

Embedding procedure

To begin with, the cover image I is divided into a number of non-overlapping blocks sized h×w each. For each block, we define its components as $P_1, P_2, P_3, \dots, P_K$ in raster scan order, and the total number of pixels is denoted by k; in other words, we have k =h×w. Then, in each block, we select a pixel as the reference pixel, and calculate pixel differences between the reference pixel and the other pixels. After difference histogram shifting, we can embed bits into the cover image. Details are given below.

Reference Pixel and Pixel Difference

As defined above, for each block, we can obtain a series of pixel values $P_1, P_2, P_3, \dots, P_K$. After sorting these pixels in ascending order, we can obtain a new sequence $\langle P(1), P(2), P(3), \dots, P(K) \rangle$, so $P_1 \le P_2 \le P_3, \dots, \le P_K$.

According to the sorting result, we select the pixel P_r as the reference pixel which is the $\lceil K/2 \rceil$-th order statistics. The reference pixel P_r is given by

$$P_r = \text{mid}\left\{P(1), P(2), P(3), \dots, P(K)\right\} = P\left\lceil \frac{K}{2} \right\rceil \qquad (1)$$

Where the symbol $\lceil . \rceil$ is the ceil function meaning to the nearest integer towards infinity. Then, we compute the k-l pixel differences between P_r and the other pixels, and the sequence of pixel differences is defined as $\langle d_1, d_2, d_3, \dots, d_{r-1}, d_{r+1}, \dots, d_K \rangle$, where d_j is calculated as

$$\mathbf{d}_i = \mathbf{P}_r - \mathbf{P}_i \qquad (2)$$

Where $1 \le i \le k$ and i=r.

Pixel Difference Histogram

The distribution of the pixel differences of original image is illustrated in Figure (1 (b)), where block size is 4×2. The distribution of the pixel differences is referred to as pixel difference histogram in this section of thesis. For simplicity, the terms "pixel difference histogram" and "difference histogram" are interchangeable in this section.

We can observe that the occurrence of difference histogram is much larger than that of image histogram shown in Figure (1 (a)). The difference histogram for most natural images would be similar to this, in the sense that difference values with small magnitudes occur more frequently.

Difference Histogram Shifting and Data Embedding

An integer factor called embedding level (EL) is employed that controls the embedding capacity or the amount of data to be hidden. A larger EL means more embedding capacity and vice versa. The embedding process for any EL is started by a histogram shifting as

$$d'_i = \begin{cases} d_i & \text{if} \quad -EL < d_i < EL \quad , \quad i \neq r \\ d_i + EL + 1 & \text{if} \quad d_i > EL \quad , \quad i \neq r \\ d_i - EL & \text{if} \quad d_i < -EL \quad , \quad i \neq r \end{cases} \qquad (3)$$

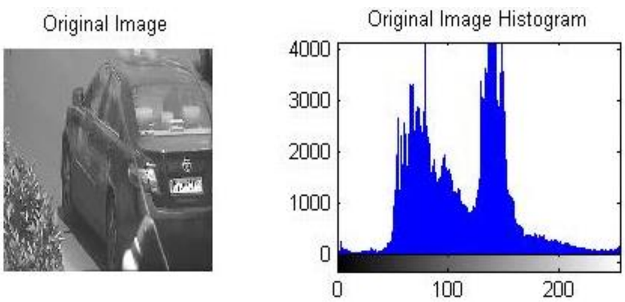
Then, the secret data are embedded by more manipulation of the histogram

$$d''_i = \begin{cases} d'_i & \text{if} \quad -EL < d_i < EL \\ 2 \times EL + b & \text{if} \quad d_i = EL \quad , \quad i \neq r \\ -2 \times EL - b + 1 & \text{if} \quad d_i = -EL \quad , \quad i \neq r \quad EL \neq 0 \end{cases} \qquad (4)$$

Where the secret data bit is indicated with b in Eq. (4). After embedding at the embedding level EL, the embedding process is continued at the embedding level of EL-1. If EL=0, the embedding process is at the end. Then, the watermarked block of image is obtained by

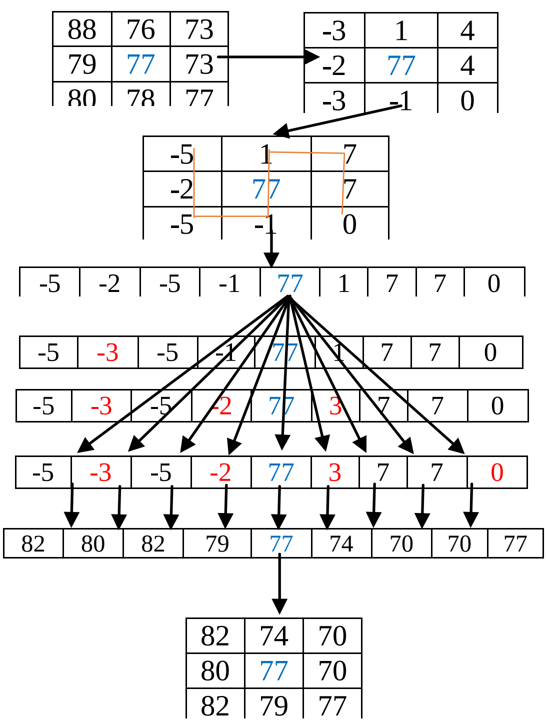
$$P'_i = P_r - d''_i \, , \qquad i \neq r \qquad (5)$$

In Figure 2, the embedding principle for EL=2 is shown. We suppose that secret data is sequence, $S = \{0110\}$. According to Eq. (3), the histogram of image blocks will shift. In the next step, data secret are embedded in blocks based on Eq. (4) (marked as red).



(a) (b)

Figure 1. (a) Histogram for Car; (b) Difference histogram for Car



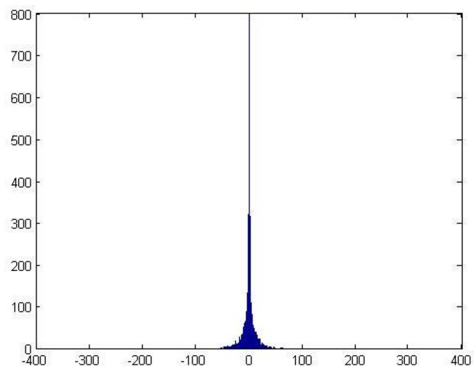


Figure 2. Illustration of the embedding

Given a 3×3 block with pixel values being P_1 = 80, P_2 = 79, P_3 = 80, P_4 = 78, P_5 = 77, P_6 = 76, P_7 = 73, P_8 = 73 and P_9= 77, the sequential sorting results are $P_{(1)}$=73, $P_{(2)}$ =73, $P_{(3)}$= 76, $P_{(4)}$=77, $P_{(5)}$=77, $P_{(6)}$=78, $P_{(7)}$=79, $P_{(8)}$ =80 and $P_{(9)}$=80.

The pixel P_r=$P_{[9/2]}$=$P_{(5)}$=77 is selected as the reference pixel by using Eq. (1): in other words, we have r=5.

The pixel differences are generated between the pixel P_r and the other pixels, i.e., d_1 = P_r -P_1 = 77 -80 = -3, d_2 = P_r -P_2 = 77 -79 = -2, d_3 = P_r-P_3 = 77 -80 =-3, and so forth. According to Eq. (3), the difference larger than 2 is added by 3 and those smaller than -2 are subtracted by 2.

Now, the secret data can be embedded. For EL=2, only, $\acute{d}_2 = -2$ then, 0 bit is embedded into block, d''_9 is set to -3 based on Eq. (4). Also, the other pixels do not change. In the next step, the EL decreased by one.

So, in next round and we obtain $d''_4 = -2,\ d''_6 = 3$, and 1, 1 embedded into block. In the third round, the embedding level is set to 0. We obtain $d''_9 = 0$, and 0 bit embedded into block. Now, the marked block is generated by rearrange the marked pixels.

A. Extraction Method

In a reverse process the hidden data are extracted from the watermarked image and the original cover image is reconstructed. Firstly, the reference pixel based on Eq. (1) is recognized. Then, the differences between reference pixel and other pixels are computed and inverse scan of watermarked blocks is accomplished.

After, we receive the EL factor via channel, for any embedding level (EL), we execute the following equations.

The marked differences of watermarked block are calculated as:

$$d_i = P_r - P'_i \ , \quad i \neq r \qquad (6)$$

Then, the original differences of block are obtained as

$$d'_i = \begin{cases} d_i - EL - 1 & \text{if} \quad d_i > 2\times EL + 1 \ , \ i \neq r \\ d_i + EL & \text{if} \quad d_i < -2\times EL \ , \ i \neq r \\ k & \text{if} \quad d_i \in \{2\times k, 2\times k+1\} \ , \ k = 0,1,\ldots,EL \ , \ i \neq r \\ -k & \text{if} \quad d_i \in \{-2\times k, -2\times k+1\} \ , \ k = 0,1,\ldots,EL \ , \ i \neq r \ , \ k \neq 0 \end{cases}$$

(7)

So, the cover block is reconstructed by:

$$P_i = P_r - d'_i \ , \qquad i \neq r \qquad (8)$$

For any embedding level (k), the original difference is computed and then, the value of k decreased by one. When, the embedding level reaches zero value, extraction procedure of original difference is finished, and the original cover image is obtained. The hidden data are extracted by:

$$W_R = \begin{cases} 0 & \text{if} \quad d_i = 2\times k \ , \ k = 0,1,\ldots,EL \ , \ i \neq r \\ 0 & \text{if} \quad d_i = -2\times k + 1 \ , \ k = 1,\ldots,EL \ , \ i \neq r \\ 1 & \text{if} \quad d_i = 2\times k + 1 \ , \ k = 0,1,\ldots,EL \ , \ i \neq r \\ 1 & \text{if} \quad d_i = -2\times k \ , \ k = 1,\ldots,EL \ , \ i \neq r \end{cases} \qquad (9)$$

After each extraction procedure, k decreased by one and extraction procedure is repeated to reach k=0. As an example, the data extraction and original image recovery of example shown in Figure 2, for EL=2, is depicted in Figure 3.

For instance, firstly, the marked block of original image is scanned into a sequence. The reference pixel of block is recognized and it is not changed. The differences between reference pixel and other pixels are computed. For the difference $d_i > 5$, the original differences are set to $d_i - EL - 1$=$d_i - 3$, the results are 4, and 4, respectively. And, for difference $d_i < -4$, the original differences are set to $d_i + EL = d''_j + 2$, so, the results are -3 and -3 respectively. If $4 \le d_i \le 5$ or $0 \le d_i \le 1$ or $2 \le d_i \le 3$, so the original differences are set to 2, 1 and 0, respectively, else if $-2 \le d_i \le -1$ or $-3 \le d_i \le -4$, the original differences are set to 1 and 2, respectively. According to our example, for k=2, if $d_i = 4 \text{ or } -3$, 0 bit can be extracted, else if $d_i = 5 \text{ or } -4$, 1 bit can be extracted. For k=1, if d_i=2 or -1, 0 bit can be extracted, else if $d_i = 3 \text{ or } -2$, 1 bit can be extracted. For k=0, if $d_i = 0$, 0 bit can be recovered, else if $d_i = 1$, 1 bit can be recovered. So, the secret data {0110} are obtained.

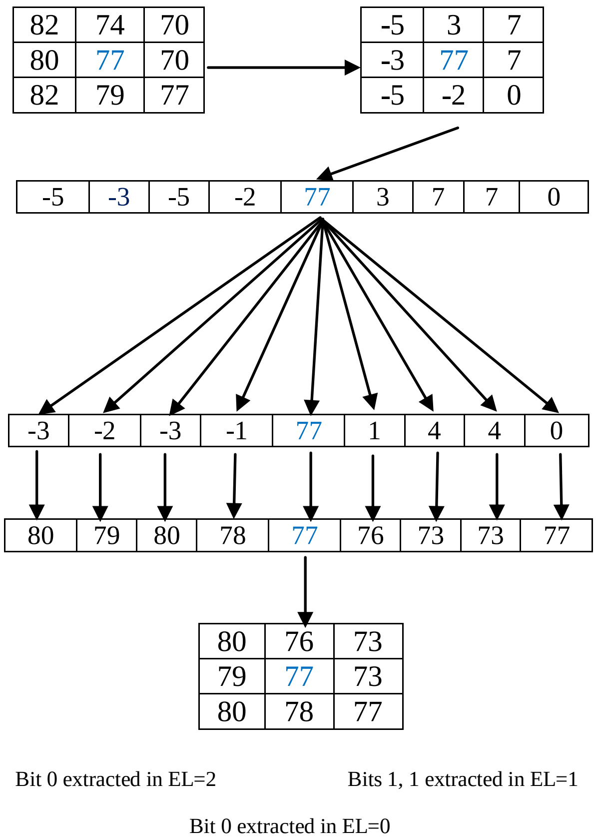
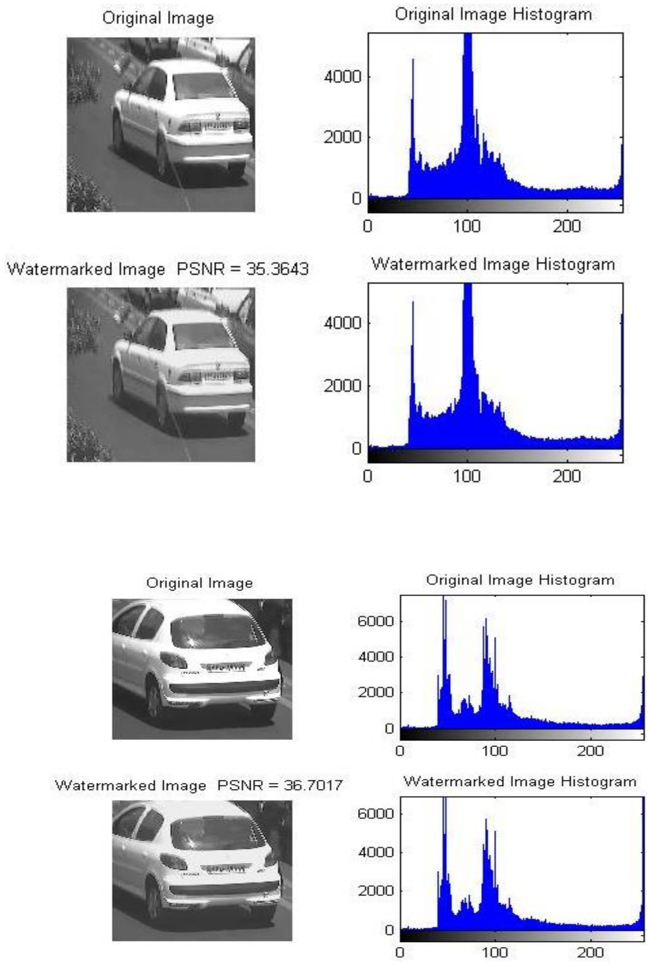


Figure 3. Illustration of the extraction procedure with EL=2



PERFORMANCE OF PROPOSED METHOD

In the data embedding process, one may encounter the overflow/underflow problem, which means that after data embedding, the grayscale values of some pixels in the marked image may exceed the upper bound (255 for a gray level image having eight-bit per pixel) and/or the lower bound i.e. zero. The other solution to control of under/overflow is use of the location map which seems to be a more effective method.

Or other words, under this condition, coordinates of pixel locations should be recorded, denoting the positions unable for embedding. These coordinates are called the location map. However, the location map has to be transmitted to the decoder as overhead information or appended it to the embedded bits. As a result, the embedding capacity decreased considerably. Thus, how to use a small amount of side information for lossless data hiding is a challenging task.

All the test images are preprocessed before data embedding. The pixel values of each test image need to stay in the range of [10,245] due to prevention of overflow/underflow layer embedding, i.e., the pixels with value less than 10 or larger than (255-10) in each test image are reset to 10 and 245, respectively. The compressed information and secret data will be concatenated and be embedded into the corresponding cover image together.

Figure 4 illustrates good watermarked image quality while maintaining a high hiding capacity. The amount of embedding capacity is 256*256 bits.

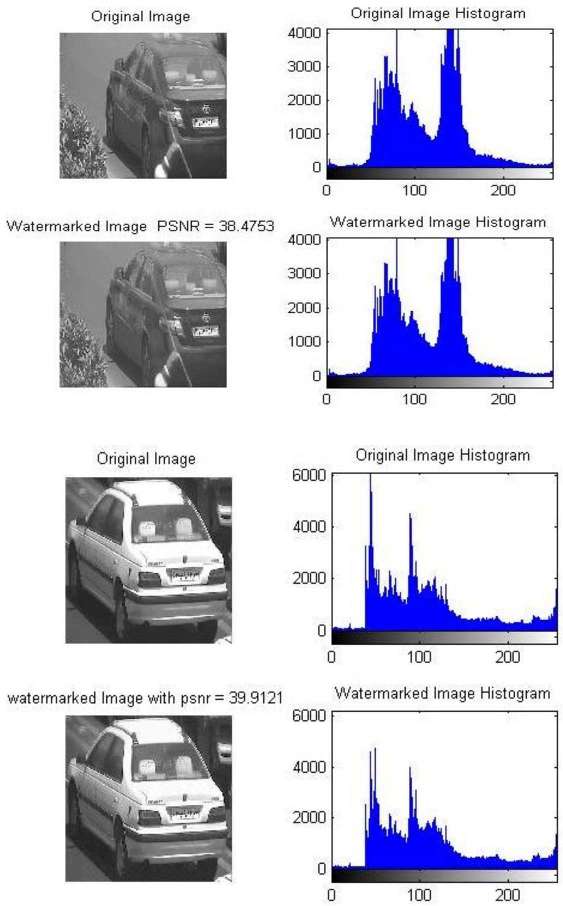


Figure 4. Cover images with watermarked images

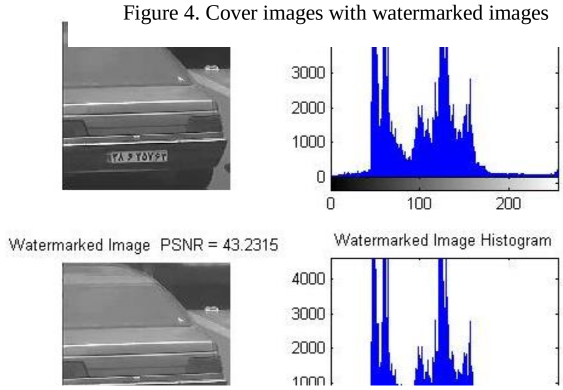


Figure 7. Reconstracted image with PSNR=84.46 dB alone with recover embedded information with bit

The more data embedded within the vehicle's image the less qualified is the image. PSNR is the criterion for evaluating the image quality. The more the PSNR the more is the image quality.

Figure 5 shows a sample of data embedded within the vehicle's image. The vehicle's image, license plate information, as well as time and place of the occurrence are totally reversible if no compression process has been applied on the image containing hidden information (figure6).

Figure 5. The sample of Embedded

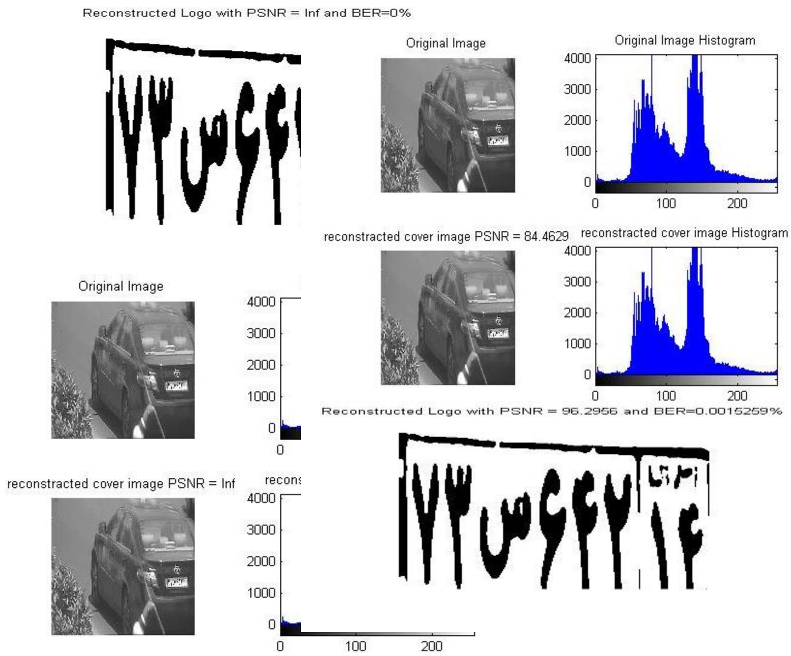


Figure 6. Reconstracted image with PSNR=inf alone with recover embedded information without error

above mentioned method is affected by noise, attacker or compression process, our proposed method can considerably resist all. While in watermarked images with a large amount of compression, minor error may appear in the original reversed image and vehicle license plate which is measured by bit error rate (BER). Figure 7 indicates a sample of compression through Jpeg with 30% of compression.

CONCLUSIONS

From transportation point of view, this study has the following features: 1- reduction the crowd, fuel consumption. 2- Increase productivity and performance practicality. 3- Traffic management. 4- High information security. 5- Increase information transmission to police force 6- and reduce our organization costs. From data hiding point of view, the proposed method enables the exact recovery of the original host signal upon extracting the embedded information, if the watermarked image is not affected by any other process.

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