A novel image transmission method based on mosaic image creation and secret image recovery for electric power security

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Abstract. Image transmission is very important for various applications. In order to ensure the security of image transmission, a novel image transmission method based on mosaic image creation and secret image recovery is proposed. The proposed method has two phases: 1) Mosaic image creation. A mosaic image is generated, which includes the fragments of an input secret image with color corrections according to a similarity criterion based on color variations. 2) Secret image recovery. Based on the received signal, the secret image is recovered losslessly from the generated mosaic image. Experimental results show that the proposed method has better feasibility.

1 Introduction

Electric power security is very important for social development. Therefore, real-time monitoring of electric power security is very important. As an important way of information transmission, image is applied to electric power security. These images usually contain private information so that they should be protected during transmissions. Hence, many scholars have proposed some methods for securing image transmission, and the commonly methods are image encryption and data hiding.

Image encryption is a technique that utilizes the natural properties of images, to get an encrypted image based on Shannon's confusion and diffusion properties [1–5]. Some researchers have proposed many schemes to improve the image transmission problem. In [1], a block scrambling-based encryption method is proposed to enhance the security of Encryption-then-Compression systems with JPEG compression, which allow us to securely transmit the images through an untrusted channel provider, such as social network service providers. A digital image encryption algorithm based on bit-planes is proposed in [2], and experimental results show that the proposed algorithm offers good encryption. In [3], a new framework for the chaos-based quantum encryption of healthcare images is proposed. According to the DNA encryption algorithm and the double-chaotic system which contains

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the optical chaos and the coupled map lattice chaotic system, the authors of [4] proposes a novel image encryption-then-transmission system. In [5], in order to improve encryption power, on the premise of maintaining the JPEG's compression efficiency, a new joint image compression and encryption scheme based on a lossy JPEG standard is proposed.

As another important means, data hiding has been studied by many scholars [6-10]. In order to achieve high perceptual quality of images and video at the end-user despite channel losses, a robust error concealment scheme based on data hiding is proposed in [6]. The scheme involves embedding a low-resolution version of each image or video frame into itself using spread-spectrum watermarking, extracting the embedded watermark from the received video frame, and using it as a reference for reconstruction of the parent image or frame, thus detecting and concealing the transmission errors. In [7] propose a new reversible method based on MSB (most significant bit) prediction with a very high capacity. In order to improve the error resilience of object-based video by adaptively embedding the shape and motion information into the texture data, a new data hiding scheme is proposed in [8].

The above analysis mainly discusses image encryption and data hiding. In order to ensure image transmission for electric power security, we propose a novel image transmission method based on mosaic image creation and secret image recovery. The proposed method is inspired by the method in [10].

The rest of this paper is organised as follows. The proposed method is proposed in Section 2. In Section 3, the performance is discussed. Finally, conclusion is given in Sections 4.

2 Proposed method

In order to secure the image transmission, a novel image transmission method is proposed, which includes two phases: mosaic image creation and secret image recovery.

(1) Mosaic image creation. According to a similarity criterion of color variations, a mosaic image is generated, which contains the fragments of an input secret image with color corrections. The phase includes four stages: a) fit the tile images of the secret image into the target blocks of a preselected target image; b) transform the color characteristic of each tile image in the secret image to become that of the corresponding target block in the target image; c) rotate each tile image into a direction with the minimum root mean square error (RMSE) value with respect to its corresponding target block; and d) embed relevant information into the created mosaic image for future recovery of the secret image. (2) Secret image recovery. Based on the received signal, the secret image is recovered losslessly from the generated mosaic image. The phase includes two stages: a) Extract the received signal for secret image recovery from the mosaic image; b) Recover the secret image based on the extracted information.

Suppose $Q = \{p_1, p_2, \dots, p_n\}$ and $A = \{p'_1, p'_2, \dots, p'_n\}$ as two pixel sets, where $p_i = (r_i, g_i, b_i)$, $p'_i = (r'_i, g'_i, b'_i)$, R, G and B are the three color channels. The means and standard deviations of Q and A is expressed respectively as

$$\beta_c = \frac{1}{n} \sum_{i=1}^n c_i \quad \text{and} \quad \beta'_c = \frac{1}{n} \sum_{i=1}^n c'_i \quad (1)$$

$$\rho_c = \sqrt{\frac{1}{n} \sum_{i=1}^n (c_i - \mu_c)^2} \quad \text{and} \quad \rho'_c = \sqrt{\frac{1}{n} \sum_{i=1}^n (c'_i - \mu'_c)^2} \quad (2)$$

where c_i is the C-channel values of pixel p_i , c'_i is the C-channel values of pixel p'_i , $c = r, g, b$, $C = R, G, B$. The new color values (r''_i, g''_i, b''_i) for each p_i in Q is given by

$$c''_i = q_c(c_i - \beta'_c) + \beta'_c \quad (3)$$

where $q_c = \rho'_c / \rho_c$, and $c = r, g, b$.

The detailed algorithms for Algorithm 1 is mosaic image creation, Algorithm 2 is secret image recovery.

Algorithm 1

Input: secret image T , a target image Q , secret key K .

Output: a secret-fragment-visible mosaic image D .

Stage 1: fit the tile images into the target blocks.

1. If the size of the target image Q is different from that of the secret image T , change the size of Q to be identical to that of T ; and divide the secret image T into n tile images $\{Q_1, Q_2, \dots, Q_n\}$ as well as the target image Q into n target blocks $\{A_1, A_2, \dots, A_n\}$ with each Q_i or A_i being of size M_T .

2. Compute the means and the standard deviations of each tile image Q_i and each target block A_j for the three color channels according to (1) and (2); and compute accordingly the average standard deviations for Q_i and A_j , respectively, for $i=1$ through n and $j=1$ through n .

3. Sort the tile images in the set $T_t = \{Q_1, Q_2, \dots, Q_n\}$ and the target blocks in the set $T_{tar} = \{A_1, A_2, \dots, A_n\}$ according to the computed average standard deviation values of the blocks; map in order the blocks in the sorted T_t to those in the sorted T_{tar} in a 1-to-1 manner; and reorder the mappings according to the indices of the tile images, resulting in a mapping sequence L of the form: $Q_1 \rightarrow A_{j1}, \dots, Q_n \rightarrow A_{jn}$.

4. Create a mosaic image D by fitting the tile images into the corresponding target blocks according to L .

Stage 2: perform color conversions between the tile images and the target blocks.

5. Create a counting table TB with 256 entries, each with an index corresponding to a residual value, and assign an initial value of 0 to each entry.

6. For each mapping $Q_i \rightarrow A_{ji}$ in sequence L , represent the means β_c and β'_c of T_i and A_{ji} , respectively, by 8 bits; and represent the standard deviation quotient q_c appearing in (3) by 7 bits.

7. For each pixel p_i in each tile image Q_i of mosaic image D with color value c_i where $c = r, g, b$, transform c_i into c''_i by (3); if c''_i is not smaller than 255 or if it is not larger than 0, then change c''_i to be 255 or 0, respectively; compute a residual value R_i for pixel p_i ; and increment by 1 the count in the entry in the counting table TB whose index is identical to R_i .

Stage 3: rotating the tile images.

8. Compute the RMSE values of each color-transformed tile image Q in D with respect to its corresponding target block A_{ji} after rotating Q_i into each of the directions; and rotate Q_i into the optimal direction $\theta = 0$ with the smallest RMSE value.

Stage 4: embed the secret image recovery information.

9. Construct a Huffman table HT using the content of the counting table TB to encode all the residual values computed previously.

10. For each tile image Q in mosaic image D , construct a bit stream N_i for Q_i recovered, including the bit-segments: 1) the index of the corresponding target block A_{ji} ; 2) the optimal rotation angle θ_o of Q_i ; 3) the means of Q_i and A_{ji} and the related standard deviation quotients of all three color channels; 4) the bit sequence for overflows/underflows with residuals in Q_i encoded by the Huffman table HT constructed in Step 9.

11. Concatenate the bit streams N_i of all Q_i in D in a raster-scan order to form a total bit stream N_i ; use the secret key K to encrypt N_i into another bit stream N_i ; and embed N_i into D by the mapping scheme in [11].

12. Construct a bit stream I including: 1) the number of conducted iterations M_i for embedding N'_i ; 2) the number of pixel pairs M_p used in the last iteration; 3) the Huffman table HT constructed for the residuals; and embed the bit stream I into mosaic image D by the same scheme used in Step 11.

Algorithm 2

Input: a mosaic image D with n tile images $\{Q_1, Q_2, \dots, Q_n\}$ and the secret key K .

Output: the secret image T .

Stage 1: extract the secret image recovery information.

1. Extract from D the bit stream I by a reverse version of the scheme [14] and decode them to obtain the following data: 1) the number of iterations M_i for embedding N'_i ; 2) the total number of used pixel pairs M_p in the last iteration; 3) the Huffman table HT for encoding the values of the residuals of the overflows or underflows.

2. Extract the bit stream N'_i using the values of M_i and M_p by the same scheme used in the last step.

3. Decrypt the bit stream N'_i into N_i by K .

4. Decompose N_i into n bit streams N_1 through N_n for the n to-be-constructed tile images Q_1 through Q_n in T , respectively.

5. Decode M_i for each tile image Q_i to obtain the following data items: 1) the index j_i of the block A_{ji} in D corresponding to Q_i ; 2) the optimal rotation angle of Q_i ; 3) the means of Q_i and A_{ji} and the related standard deviation quotients of all color channels; and 4) the overflow/underflow residual values in Q_i decoded by the Huffman table HT.

Stage 2: recovering the secret image.

6. Recover one by one in a raster-scan order the tile images Q_i , $i=1$ through n , of the desired secret image T by the following steps: 1) rotate in the reverse direction the block indexed by j_i , namely A_{ji} , in D through the optimal angle and fit the resulting block content into Q_i to form an initial tile image Q_i ; 2) use the extracted means and related standard deviation quotients to recover the original pixel values in Q_i according to (4); 3) use the extracted means, standard deviation quotients, and (5) to compute the two parameters c_s and c_L ; 4) scan Q_i to find out pixels with values 255 or 0 which indicate that overflows

or underflows, respectively, have occurred there; 5) add respectively the values c_L or c_s to the corresponding residual values of the found pixels; 6) take the results as the final pixel values, resulting in a final tile image Q_i .

7. Compose all the final tile images to form the required secret image T as output.

3 Performance evaluation

In this section, we numerically examine the performance of our proposed method. In our experiments, an electric environment is provided for our experiments, and the sizes of target images is 1024×768 . To show that the created mosaic image looks like the preselected target image, the quality metric of root mean square error (RMSE) is adopted, which is considered as the square root of the mean square difference between the pixel values of the two images.

Fig. 1. Experimental results.

Figure 1 shows the experimental results of the proposed method and the method of [13]. Figure 1 (a) is the input secret image; Figure 1 (b) is the selected target image; Figure 1 (c) is the mosaic image according to the method of [10] with $RMSE=50$; Figure 1 (d) is the mosaic image according to the proposed method with $RMSE=40$. It can be obtained from these results that the mosaic image generated by the proposed method has a smaller RMSE value with respect to the target image, and it is more similar to the target image. According

to the experimental results, the proposed method is better than the method in [10]. For privacy, users can select specific images as target images.

4 Conclusion

In this paper, a novel image transmission method based on mosaic image creation and secret image recovery is proposed for the security of image transmission. According to the proposed method, images can be transmitted safely, and the original secret images can be recovered nearly losslessly from the created mosaic images. Experimental results show that the proposed method has better feasibility. Therefore, the proposed method will be further improved for image transmission of electric power security.

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