LETTER

A Countermeasure against Double Compression Based Image Forensic

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SUMMARY Compressing a JPEG image twice will greatly decrease the values of some of its DCT coefficients. This effect can be easily detected by statistics methods. To defend this forensic method, we establish a model to evaluate the security and image quality influenced by the re-compression. Base on the model, an optimized adjustment of the DCT coefficients is achieved by Genetic Algorithm. Results show that the traces of double compression are removed while preserving image quality.

key words: image forensic, evaluation model, double compression, genetic algorithm

1. Introduction

The conflict between image disguise (also called image tampering or image manipulation) and digital forensic has persisted for more than a decade. With powerful photo editing software, image manipulation has become very common in digital image processing. The target of image forensic is to detect the existence of image tampering based on the traces in the image introduced by the manipulation. With the development of digital forensic techniques, image disguise was severely challenged. Research on countermeasures resistant to the forensic is very important to the development of multimedia security techniques. To deal with tamper detection, some forensic algorithms have been proposed. It is observed in [1] that image interpolation will introduce periodic correlations between pixels. Based on this fact, Popescu et al. proposes to detect the trace of image tampering by evaluating the correlation between neighboring pixels with the aid of the EM (Expectation Maximization) algorithm. The lighting direction is also exploited as a clue for image forensic in [2], as it is difficult to maintain the consistencies in lighting directions of the regions from different source images. However, the lighting direction based scheme is not applied to manipulations where the lighting direction is kept unchanged, such as duplication. The basic detection method of duplication is based on brute-search [3]. In order to enhance the robustness of image forensic against noise and compression, the PCA algorithm is employed to generate a coarse representation of the image [4]. When we tamper with a JPEG image, firstly the JPEG image is decompressed, and then the decompressed image is tampered. If we resave the tampered image in JPEG format, it is re-compressed. For JPEG images, the double compression is a

vulnerability to the digital forensic because of a periodic decrease in or elimination of some DCT coefficients. Fridrich proposed a method to reveal this effect [5].

To enhance the security of image disguise, we established an evaluation model for image disguise to represent the abnormality of the DCT coefficient distribution and the image quality. By adjusting the coefficients, the gaps in the histogram of DCT coefficient are filled. Benefiting from the genetic based optimization method, our algorithm achieves good balance between security and image quality.

2. Double Compression Based Image Forensic

The quantization process transforms the continuous DCT coefficient values to discrete ones. Let S_1 denotes the quantization step used in the JPEG compression, the discrete coefficient values are considered as $N_i = i \times S_1$, where i is the quantized value. In natural image, the distribution of quantized values is considered as Laplacian distribution. In the re-compression process, assume that the quantization step S_2 is chosen. Then $N_i = [i \times S_1 / S_2] \times S_2$, where $[]$ means the rounding operation. If S_1 is multiple of S_2 , $i \times S_1 / S_2$ are discrete integers. It means that the histogram of quantized values is periodic. Some bands disappear and the positions become gaps (shown in Fig. 1). Even S_1 is multiple of S_2 , the distribution of quantized values is much different from Laplacian distribution. In Fridrich's forensic algorithm, the abnormal histogram is compared with the standard distribution and double compression is revealed [5].

3. Proposed Algorithm

In our algorithm, we adjust the DCT coefficients to recover the ordinary distribution. But the image quality will be degraded by the random change of the DCT coefficient values. In this paper, we use optimization method to balance the security and image quality. Firstly, we construct an evalua-

Fig. 1 The distribution of quantized DCT coefficients. (a) The original image, (b) The recompressed image.

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tion model which expresses the security and image quality. Then, the best image quality is achieved through adjusting the DCT coefficients with genetic algorithm.

3.1 The Evaluation Model for Image Disguise

For image disguise, there are two conflicting objectives: security and image quality. Thus, the evaluation model is composed by two parts: the goodness of fit and perceptual distance.

The perceptual distance is calculated by the Watson's perceptual error metric [6]. This model is based on DCT coefficient errors. Considering the visual pattern, the errors are revised into the actual perceptual variation, called perceptual distance via (1)

$$D_{wat}(x, x^w) = \left(\sum_{i,j,k} \left| \frac{e_{ijk}}{s_{ijk}} \right|^p \right)^{\frac{1}{p}} \quad (1)$$

where $e_{ijk} = X_{ijk}^w - X_{ijk}$ denotes the DCT coefficient errors between the original image and the degrading image. X_{ijk} denotes the coefficient of frequency i, j in the k -th block. s_{ijk} is the contrast masking threshold calculated with the formula (2)

$$s_{ijk} = \max \left\{ t_{ijk}^L, |X_{ijk}|^{\beta_{ij}} \cdot (t_{ijk}^L)^{1-\beta_{ij}} \right\} \quad (2)$$

where β_{ij} is constant in Watson's Model. For every i, j , β_{ij} is 0.7. t_{ijk}^L is the luminance masking threshold calculated with the formula (3)

$$t_{ijk}^L = t_{ij}(X_{00k}/\bar{X})^{\alpha_T} \quad (3)$$

where X_{00k} is the DCT coefficient in k -th block. $\bar{X}$ denotes the mean value of the image. t_{ij} is the sensitivity of i, j frequency band. α_T is constant in Watson's Model. The value is 0.649.

The other part of the evaluation model measures how well the distribution of the DCT coefficients fits the Laplacian distribution [7] (Eq. (4)).

$$p(x) = \frac{\mu}{2} \exp\{-\mu|x|\} \quad (4)$$

In this paper, we measure the goodness of fit by Pearson's chi-square test. First, we assume the frequency of DCT coefficients have a form of Laplacian distribution (Eq. (4)). Thus, the parameter μ of Laplacian distribution can be estimated by maximum likelihood estimation (Eq. (5)).

$$\mu = \frac{n}{\sum_{i=-n}^n |x_i|} = \frac{n}{\sum_{i=-n}^n |iN_i|} \quad (5)$$

where N_i is the amount of quantized DCT coefficients with the same value.

Secondly, we construct the chi-square statistics to measure the difference between the distribution of DCT coefficients and the Laplacian distribution.

The target of our algorithm is to minimize the parameter D_{wat} in Eq. (1) under the condition that the image disguise is secure ($\chi^2 < \chi^2_{0.05}$). $\chi^2 < \chi^2_{0.05}$ means the confidence is greater than 95%, then DCT coefficients satisfy the Laplacian distribution. According to the conclusion of the previous work [7], the DCT coefficients of natural images comply with the Laplacian distribution. Therefore, an image whose DCT coefficients satisfying the Laplacian distribution is defined as a natural image. If the DCT coefficients of tampered image are adjusted to satisfy the Laplacian distribution, the image is considered a natural image. Then, the evaluation model is defined as follows.

$$\min \left(\left(\sum_{i,j,k} \left| \frac{e_{ijk}}{s_{ijk}} \right|^p \right)^{\frac{1}{p}} \right) \quad (6)$$

s.t. $\chi^2 < \chi^2_{0.05}$

Smaller D_{wat} corresponds to the better quality of image.

So the minimal value of evaluation model indicates the optimal image quality on condition of security.

3.2 Genetic Based Optimization

The genetic algorithm is a series of stochastic search methods which are similar to the process of natural evolution. It is a universal solution in optimization and search problems. The operations used in genetic algorithm, such as inheritance, mutation, selection, and crossover, are simulations of natural evolution.

When the DCT coefficients are adjusted, we use the Genetic Algorithm to achieve the trade-off between the security and image quality. In our algorithm, a group of initial solutions which meet the security requirements is generated by random adjustments. Then we use genetic algorithm to search for optimized adjustment which minimizes the degradation of the image quality.

If an adjustment of the coefficients is considered as a chromosome $C_j = \{Q_0^j, Q_1^j, \dots, Q_n^j\}$, the gene in the chromosome is a quadruplet $Q_i^j = \{O_i, S_i, M_i, P_i^j\}$, which maps some coefficients from a value to another. In the quadruplet, O_i denotes the original value of coefficients, S_i denotes the coefficient value after adjusting, M_i denotes the number of coefficients changed from value O_i to S_i , and the list P_i^j denotes the position of the changed coefficients. For example, $Q = \{1, 2, 200, P\}$ means that select 200 coefficients whose value is 1, change them to 2, the positions of the 200 coefficients are P .

The algorithm includes following steps:

- (1) In the original image, estimate the parameters μ of the Laplacian distribution which the DCT coefficients obey by maximum likelihood estimation (Eq. (5)).
- (2) Compare the histograms of the original one and disguised. According to μ , calculate the amount of coefficients which should be adjusted to fill the gaps in the histogram (Fig. 2). In this step, the parameters O_i , S_i , and M_i are determined.

- (3) According to O_i , S_i , and M_i , generate the initial solutions $C_1, C_2, \dots, C_m$. Select the coefficients randomly and adjust them to meet the security requirements. Save the positions of the changed coefficients in P_i^j . In different solution C_1 and C_k , the O_i , S_i , and M_i are identical, but $P_i^j \neq P_k^j$. Figure 3 shows an example to illustrate the generation of different P_i^j , where $O_i = 0$, $S_i = 1$, $M_i = 3$.
- (4) Evaluate fitness of the solutions. Reserve 50% solutions with high fitness value.
- (5) Each solution generates the next generation by the fol-

Fig. 2 The result of DCT coefficients transforming.

Fig. 3 An example of initial solution creation.

Fig. 4 An example of crossover used in our algorithm.

lowing method: For every solution pair, select 50% chromosome randomly and exchange their positions (Shown as Fig. 4). Repeat the solution generation process once, then the solution of the current generation derives two solutions of the next generation.

- (6) Repeat step 4-5 until reach the maximum iteration times.

4. Experimental Results

In our experiments, 10000 initial solutions are generated each time. The termination condition is 3000 times iteration.

The “walkbridge” image is used to test the proposed algorithm. The sample is a 512×512 gray image. In the experiment, it is compressed separately with quality factor 20 and 90. In the DCT coefficient matrixes, the coefficients of positions (1, 2), (2, 1) and (2, 2) are adjusted to evaluate the algorithm.

The experimental results are shown in Fig. 5. The histograms of DCT coefficients in re-compressed image become periodically. The parameter μ of the histograms of position (1, 2), (2, 1) and (2, 2) are 0.75, 0.65 and 1.46, re-

Fig. 5 The column shows respectively (a) the original image, (b) re-compressed image with 1st compression at quality factor = 20, and 2nd one at 90, and (c) the optimized image by Genetic Algorithm. The following columns show the corresponding histograms of DCT coefficient of each image.

spectively. When the coefficients are adjusted, it is easy to find that the abnormality in the histograms is eliminate. The perceptual distance D is 69 between the original and decompressed image and 98 between the original and adjusted image. PSNR values are separately 37.1 dB and 34.3 dB.

Most of the optimization algorithms include Genetic Algorithm may fall into the local optimum solution during the searching of the best solution. Genetic Algorithm involves methods such as increase the number of initial solution and the rate of mutation to improve the result. But we found the phenomenon that the relation between image visual quality and perceptual distance D_{wat} is not linear. The visual quality changes slow when D_{wat} is decreased to 100. The analysis of our experiments shows that the fine results can be achieved without mutation operation when the number of initial solution is enough.

5. Conclusions

Re-compression is a common operation in image disguise. To eliminate the statistical characteristics that make the disguise insecure, this paper proposed an evaluation model for image disguise aims at the JPEG recompression detection and calculated the optimal parameters μ and D by Genetic Algorithm. By this method, the security of image disguise can be enhanced while maintaining good visual quality. The experimental results show our method may disguises an im-

age more securely and effectively. In future, more works should be devoted to improve the stability of this algorithm.

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