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Image Forgery Detection Based on Quantization Table Estimation

Guo-Shiang Lin
Dept. of Computer Science and Information Engineering, Da-Yeh University, Chang-Hua, Taiwan
khlin@mail.dyu.edu.tw

Min-Kuan Chang
Dept. of Electrical Engineering, National Chung Hsing University, Tai-Chung, Taiwan
minkuanc@dragon.nchu.edu.tw

You-Lin Chen
Dept. of Electrical Engineering, National Chung Hsing University, Tai-Chung, Taiwan
keitaro@wmc.ee.nchu.edu.tw

Abstract

In this paper, we proposed a passive scheme to achieve image forgery. The inconsistent measure of quantization table is characterized to develop the proposed scheme. The proposed scheme is composed of candidate region selection, quantization table estimation, and forgery detection. To select candidate regions for estimating quantization table, a split-and-merge algorithm based on quad-tree decomposition is devised. To estimate the quantization table, we classify the type of PSD and then adjust the estimation algorithm. After quantization table estimation, the variation resulting from the inconsistent of quantization table is utilized to detect tampered regions. The experimental results show that our proposed scheme can not only estimates quantization table correctly but also detect tampered regions well.

1. Introduction

To date, the amount of digital image/video has increased dramatically during the past few years. Since digital images/videos can be copied or duplicated without quality degradation by using digital processing tools, content authentication becomes an important functionality to help receivers to identify the integrity of received data.

Digital watermarking [1] has many applications and one of the most important applications is the authentication of digital images. In [1], a compressed-domain scheme was proposed to achieve dual protection of JPEG images based on informed embedding and two-stage watermark extraction techniques. Though watermark embedding should make the visual quality of the cover media well, the quality degradation is permanent. In addition, most images/videos do not be embedded any digital watermark. That means that in the absence of digital watermarks, other techniques that can help us make statements about the origin, veracity and authenticity of digital images is very necessary. These reasons motive us to develop a non-watermarking scheme for verifying image content and localizing the tampered regions. Compared with watermarking methods that actively embed secret data, non-watermarking schemes passively achieve forgery detection by analyzing digital content.

Some methods [2],[3],[4],[5] for image/video forensics were proposed. For example, a phenomenon [4] that there is a regular symmetrical shape in the blocking artifact characteristics matrix for a JPEG image is analyzed. A method [4] based on this phenomenon was developed to detect cropped and recompressed blocks. In [3], the blocking artifact measure is computed and then utilized to detect digital forgery. However, it seems not clear to explain how to select suspicious regions and then estimate the quantization matrix based on the un-tampered regions. Besides, in digital capture devices, e.g., digital camera, most digital images are stored and transmitted in JPEG format. It implies that the information of quantization table exists in uncompressed images. Therefore, it motives us to develop an image forgery detection scheme based on the information of quantization table.

2. The Proposed Scheme

Quantization is an important process to control image quality and bit rate in JPEG compression standard. After JPEG compression, some phenomena resulting from quantization certainly occur in the resulting image. The important one is that AC coefficients in the low and middle frequency bands often become the multiples of corresponding quantization stepsize after de-quantization. If we gather AC coefficients with the same frequency from all of 8×8 DCT blocks and then plot its histogram, there are several peaks at the multiples of the corresponding quantization stepsize. It is expected that this phenomenon might not exist when some regions in an image were tampered. It implies that this phenomenon can be characterized as a feature for forgery detection. To determine whether this phenomenon exists or not, the variation resulting from the inconsistent of quantization table can be characterized for detecting image forgery. Based on the observation, this proposed scheme is composed of candidate region selection, quantization table estimation, and forgery detection. Figure 1 illustrates the block diagram of the proposed scheme. We elaborate each part in the flowing.

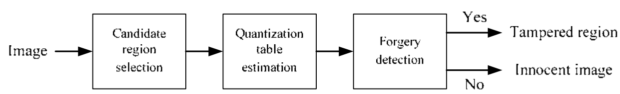


Figure 1. The block diagram of the proposed scheme

2.1 Candidate region selection

In [3], authors did not mention how to remove the suspicious tampered regions for estimating quantization table. Here we adopt a split-and-merge algorithm based on quad-tree decomposition to remove suspicious tampered regions. After removing suspicious regions, the others can be exploited as the candidate region for quantization table estimation. The split-and-merge algorithm of candidate region selection is described as follows.

1. Divide the test image into four sub-images by using quad-tree decomposition.
2. Perform the quantization table estimation (mentioned later) for each sub-image.
3. Use each estimated quantization table to re-encode and reconstruct the sub-image.
4. Calculate the mean square error (MSE) e^{MSE} of DCT coefficients in the sub-image before and after the recompression as

$$e^{MSE}(X_i) = \frac{1}{|\Omega|} \sum_{B_i \in \Omega} \left(\tilde{Q}^{-1}\left(\tilde{Q}(X_i)\right) - X_i \right)^2, \quad (1)$$

   where X represents DCT blocks and X_{i} represents the i-th DCT block; $|\Omega|$ is the number of 8×8 blocks; $\tilde{Q}$ denotes the estimated quantization table in this sub-image; $\tilde{Q}^{-1}$ is the inverse quantization. Based on Parseval's theorem, e^{MSE} is the same in the spatial and DCT domains.
5. Quad-tree decompose this sub-image if the MSE of any partition is large than one pre-defined threshold or the number that the quantization stepsize is equal to 1 is large than a predefined threshold. Otherwise, this sub-image is determined as un-tampered region.
6. Repeat steps 2-5 until the number of 8×8 blocks within each sub-image is less than a pre-defined threshold T_{B} for estimating quantization table.
7. Combine these un-tampered sub-images as a coarse candidate region for quantization table estimation.

To correctly estimate the quantization table, some misclassified blocks should be re-selected into the candidate region. Therefore, the candidate region for quantization table estimation should be refined. The refined algorithm is described as follows.

1. Obtain the quantization table based on a coarse candidate region.
2. Estimate the quantization table in each suspicious sub-image and compute the mean absolute difference $Diff^{Q}$ of the i-th block as

$$Diff^{Q} = \frac{1}{63} \sum_{i=1}^{63} \left| \tilde{Q}^{C}(i) - \tilde{Q}(i) \right|, \quad (2)$$

   where $\tilde{Q}^{C}$ are the estimated quantization table based on the coarse candidate region and $|.|$ represents the absolute operator.
3. Merge each sub-image whose $Diff^{Q}$ is less than a given threshold (T_{Q}) into the coarse candidate region and then re-perform the quantization table estimation to obtain the refined quantization table $\tilde{Q}^{R}$.

2.2 Quantization table estimation

In [3], the relationship between the quantization stepsize and power spectrum density (PSD) of histogram for each AC coefficient is analyzed. The phenomenon that the numbers of peaks of PSD is equal to the quantization stepsize subtracting 1 is observed. In order to correctly detect peaks of PSD, the smoothed version of the second derivative of PSD is obtained and then the number of its local minimums is calculated for estimating quantization stepsize. Unfortunately, this method [3] is unstable to correctly estimate the quantization step for each AC component due to the local minimum might disappear within the middle range of PSD. Therefore, to improve the drawback, we develop a content-adaptive quantization table estimation algorithm in the proposed scheme.

Before introducing the quantization table estimation algorithm, we define the Fourier transform H_i of histogram h_i of the i-th AC coefficient as

$$H_i = \Psi(h_i), \quad (3)$$

where $\Psi(\cdot)$ represents the Fourier transform. The histogram h_i of the i-th AC coefficient can be obtained by collecting each i-th AC coefficients from each 8×8 DCT block. Then the PSD S_i of the i-th AC coefficient can be obtained as

$$S_i = \left\{ s_k \mid s_k = \mathrm{Re}^2\left(H_i(k)\right) + \mathrm{Im}^2\left(H_i(k)\right), k = 1,2.,...\right\}, \quad (4)$$

where $\mathrm{Re}(\cdot)$ and $\mathrm{Im}(\cdot)$ denote the real and image parts of a complex number, respectively.

Since different quantization stepsizes cause different PSDs, it is difficult to estimate each quantization stepsize by using a simple detection method. To adaptively estimate the quantization stepsize, we classify the PSD into different types and then adjust the quantization table estimation algorithm. First, two features are devised to classify the PSD into four categories. One feature f_1 is the local minimum numbers for each PSD. As we know, the local minimum numbers $N_{\min}$ are related to the quantization stepsize. Second, we define a shape factor of PSD as a feature f_2 to evaluate whether the quantization stepsize is large or not. The larger the quantization stepsize is, the larger the shape factor is. To measure the shape factor of a PSD, a bin index can be obtained based on a pre-defined threshold. Figure 2 illustrates the shape factor of PSD. Based on the two features and two pre-defined thresholds (T_1 and T_2), four types of PSD can be determined and shown in Table I. Type I and IV indicate that small and large quantization stepsizes are adopted, respectively.

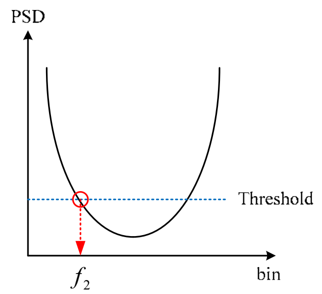


Figure 2. An illustration for the shape factor of PSD

Table 1. Four types of PSD

	f_1	f_2
Type I	0 or T_1	$< T_2$
Type II	$> T_1$	$< T_2$
Type III	$> T_1$	$> T_2$
Type IV	T_1	$> T_2$

After classifying the type of PSD, the quantization stepsize estimation algorithm is described as follows.

1. For Type I, the estimated quantization stepsize is set to 1.
2. For Type IV, the quantization stepsize can not be estimated.
3. For Type II, find the bin index u of the first peak in the PSD and then the quantization stepsize can be calculated via

$$Q(k)=\left[\frac{\max\left\{\mathrm{ceil}\left(\max(X_i(k))-\min(X_i(k))\right),512\right\}}{u}\right], \quad (5)$$

where $[\cdot]$, ceil(), max{}, and min{} denotes the rounding, ceiling, maximum, and minimum operators, respectively.
4. For Type III, the Fourier Transform of PSD is adopted and the index of its first peak is found as the quantization stepsize.

2.3 Forgery detection

After quantization table estimation, we evaluate the variation resulting from the inconsistent of quantization table. The mean absolute error (MAE) of the i-th DCT block is defined as

$$e^{MAE}(X_i)=\sum_{k=1}^{63}\left|X_i(k)-\tilde{Q}^R(k)\cdot\left[\frac{X_i(k)}{\tilde{Q}^R(k)}\right]\right|. \quad (6)$$

It is expected that if one block is an innocent one, a right quantization table can be estimated and then its e^{MAE} is small. If one sub-image was tampered, the wrong quantization table is obtained and then large e^{MAE} occurs after a recompression process with the wrong quantization table. In other words, we can determine whether the 8×8 block is tampered according to e^{MAE} resulting from the recompression process. Therefore, according to the above phenomenon, the decision rule in the forgery detection can be determined: a suspicious 8×8 block is tampered if its corresponding MAE is larger than a given threshold.

3. Experimental Results

Several popular images with size 512×512, such as Lena, Baboon, and F16, are selected for performance evaluation. The threshold T_B and T_Q are 256 and 3, respectively. The parameters, T_1 and T_2, for determining the PSD type are 1 and 100, respectively.

3.1 Quantization table estimation

In order to evaluate the performance of quantization table estimation, we also adopt the mean absolute error (MAE) between the true and estimated quantization table as a measurement. Figure 3 shows the MAE of quantization table estimation under different quality factors. As we can see in Fig. 3, the MAEs are kept small when the quality factor is from 50 to 85. In addition, compared with [3], the MAEs of our proposed scheme are less than those of [3] under different quality factors. The results demonstrate that the quantization table estimation of our proposed scheme can provide a better performance.

3.2 Forgery detection

Here a copy-paste tampering [5] is adopted to evaluate the capability of forgery detection. Since the block mis-matching for generating the tampered image might affect the performance of forgery detection, we also discuss its impact. Figure 4(a) and 4(b) shows two tampered images with and without block mis-matching, respectively. The tampered regions are copied from the original image. As shown in Fig. 4(a) and 4(b), the visual quality of two tampered images remain well. Figure 4(c) and 4(d) illustrate the results for forgery detection. In Figs. 4(c) and 4(d), the white lines indicate the tampered regions. As shown in Figs. 4(c) and 4(d), the tampered regions can be detected well regardless of the existence of block mis-matching.

Figure 5(a) and 5(b) show a test image and its forgery version. As shown in Fig. 5(b), it is difficult to decide whether this image is tampered or not. Figure 5(c) illustrates the result of forgery detection. Compared with Figs. 5(a), 5(b), and 5(c), the detection result demonstrates that our proposed scheme can identify the tampered region well.

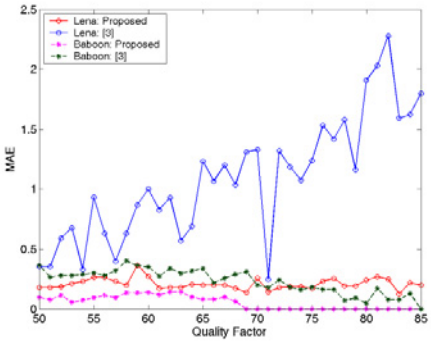
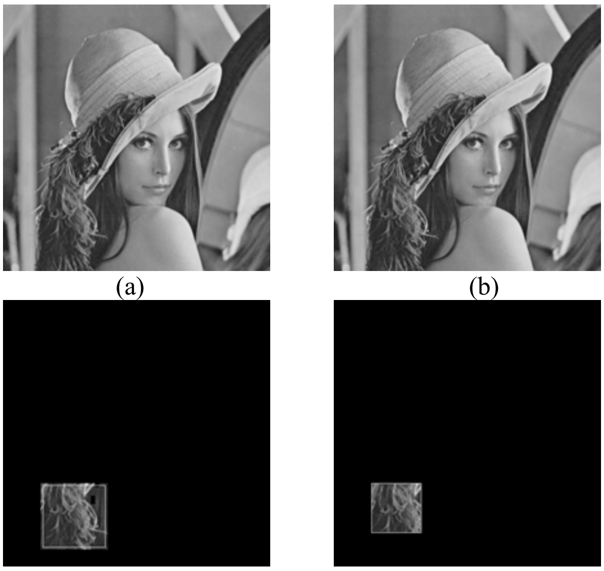


Figure 3. The MAE of quantization table estimation

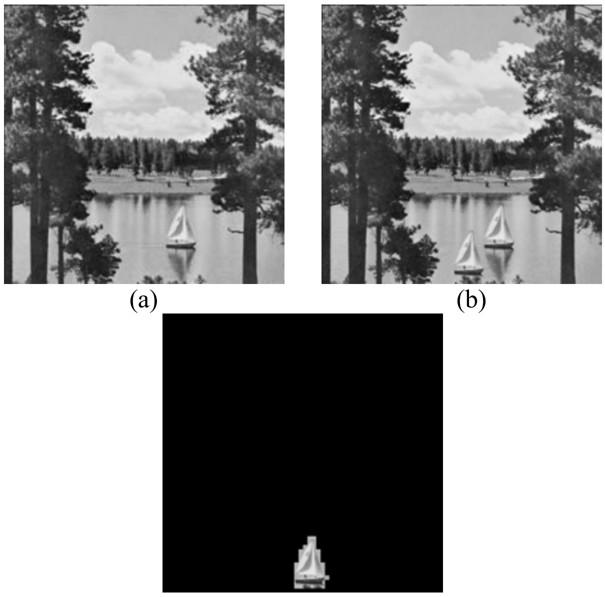


(a) (b) (c) (d)

Figure 4. Tampered images: (a) block mis-matching, (b) block matching; forgery detection: (c) block mis-matching, (d) block matching

4. Conclusion

In this article, a passive scheme to achieve forgery detection is developed for uncompressed images. The inconsistent measure of quantization table is characterized as a feature in the proposed scheme. The proposed scheme is composed of candidate region selection, quantization table estimation, and forgery detection. To select candidate regions for estimating quantization table, a split-and-merge algorithm based on quad-tree decomposition is devised. To estimate the quantization table, we classify the type of PSD and then adjust the estimation algorithm. After quantization table estimation, the variation resulting from the inconsistent of quantization table is utilized to detect tampered regions. The experimental results show that the performance of quantization table estimation in our proposed scheme is better than that of [3]. In addition, our proposed scheme can detect tampered regions well.



(a) (b) (c)

Figure 5. (a) original image, (b) tampered version, and (c) forgery detection

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