Simplified Anti-Forensics of JPEG Compression

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***Abstract*—This paper proposes a simplified anti-forensics method for JPEG compression. For a spatial image decompressed from a JPEG file, traces of compression can be tracked by many forensic methods. To conceal these clues of comblike DCT histogram and blocking artifacts, we use the method of image enhancement and filtering. Compared with Stamm's method of introducing noise into the targeting image, the proposed method preserves better quality and works faster. Risks of quantization estimation and global histogram analysis can also be avoided.**

***Index Terms*—Anti-forensics, forensics, gamma correction, JPEG, nonlocal TV filter.**

1. INTRODUCTION

More and more faked images emerge all over the world. As a result, some forensic methods were proposed for image authentication [1], which is different from the image protection methods using data hiding [2,3]. However, most of them hypothesize that a forger possesses little knowledge of forensics. Thus, authentication would fail if forgers hide the tampering traces.

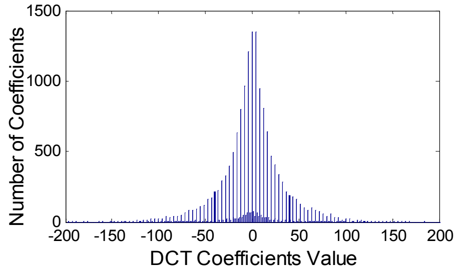
In [4], a method is proposed to erase the fingerprints of resampling. Stamm proposed a novel method of fighting against forensics to JPEG compression history by adding noise to DCT coefficients in [5]. Additionally, an anti-forensic method about videos was proposed in [6].

This paper proposes a novel method of anti-forensics. Different from introducing noises into the images, we try to conceal the traces of JPEG compression by gamma correction, a special kind of image enhancement [16], and image filtering. Comblike DCT histograms and blocking artifacts generated during JPEG compression are concealed. Risks of quantization estimation and global histogram analysis can also be avoided after the anti-forensic processing.

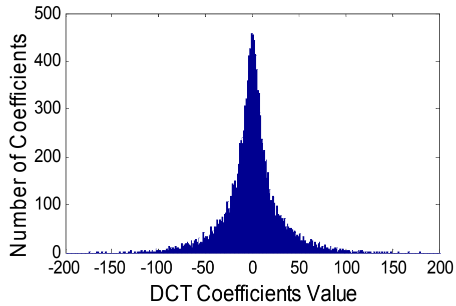
II. ERASION OF JPEG TRACES

To fill the gap bins in the DCT coefficient histogram of each subband, Stamm proposed a noise dithering model in [5]. According to Laplace distribution, possibilities of lost coefficients are calculated and the corresponding gaps are. padded by coefficient dithering. After that, the image is further filtered by a median filter and covered by Gaussian white noises. Fig.1. demonstrates the result of Stamm's method, in which the comblike histogram is concealed.

However, these operations unavoidably degrade the image quality. Instead of introducing noises into the image, we propose a method to conceal these fingerprints by gamma correction and image filtering.



(a)



(b)

Figure 1. Result of Stamm's method, (a) is the histogram of AC coefficients on subband (2, 2) of a decompressed image, (d) the histogram of AC coefficients after anti-forensics.

A. *Anti-forensics Scheme*

For an image **M** decompressed from a JPEG file, we first correct the input image into $\mathbf{M}_o$ using Eq. (1),

$$\mathbf{M}_o(i,j) = round[255 \cdot (\mathbf{M}(i,j)/255)^{\gamma}] \tag{1}$$

where γ is the parameter of gamma correction, and (i, j) the position of pixels in the image.

To preserve visual effect of the output image, we identify the γ value by analyzing the histogram of **M** using Eq. (2) and Eq. (3),

$$B = \sum\nolimits_{x \ge T} h(x), \;\; D = \sum\nolimits_{x \le T} h(x) \tag{2}$$

$$\gamma = \begin{cases} 1+\varepsilon, \text{ if } B \ge D \\ 1-\omega, \text{ if } B < D \end{cases} \tag{3}$$

where $h(x)$ is the global histogram of **M**, and T is a predefined threshold used for identifying the brightness of the whole image. When the bright part B is larger than the dark part D, we set a gamma value larger than one to make the image slightly darker, and vice versa. Generally, we set

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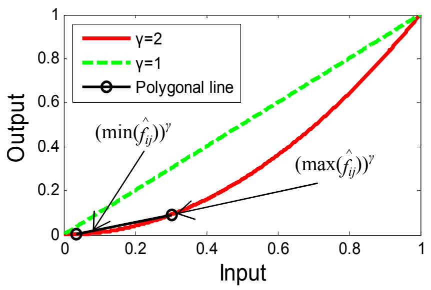
T=128. We use the ε and ω to control the modification. Details of ε and ω selection are discussed in section *C* of this part.

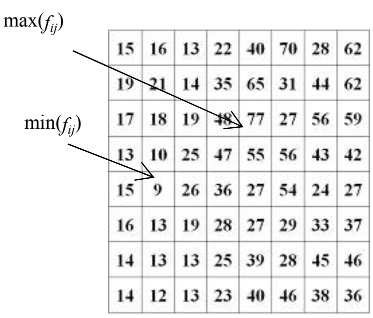
Although gamma correction conceals comblike histogram by perturbing the DCT coefficients, blocking artifacts still exist in $\mathbf{M}_o$. To this end, filters are used to remove the artifacts. Here we use the denoising filter of Nonlocal Total Variation (NLTV) proposed by Bresson in [7], which keeps a better quality of denosing and deblocking than Median filters. According to the algorithm in [7], we choose a 5×5 patch and an 11×11 search window for parameter calculation. After identifying the parameters for Split-Bregman Nonlocal TV, blocking artifacts are finally filtered from the image. Details of NLTV can be found in [7].

B. Perturbation of DCT Coefficients

The modification to pixels using gamma correction affects the histogram of AC coefficients. This impact is realized by perturbation of coefficients.



(a)



15	16	13	22	40	70	28	62
19	21	14	35	65	31	44	62
17	18	19	48	77	27	56	59
13	10	25	47	55	56	43	42
15	9	26	36	27	54	24	27
16	13	19	28	27	29	33	37
14	13	13	25	39	28	45	46
14	12	13	23	40	46	38	36

(b)

Figure 2. An example of approximation for gamma correction, (a) is mapping relationship between the input and output; (b) the dynamic range of an 8×8 block corresponds to the line in (a).

In JPEG, pixels of each 8×8 block are transformed by DCT, which is defined as

$$F_{uv}=\frac{1}{4}C_uC_v\sum_{i=0}^{7}\sum_{j=0}^{7}f_{ij}\cos\frac{(2i+1)u\pi}{16}\cos\frac{(2j+1)v\pi}{16} \quad (4)$$

$$C_u,C_v=\begin{cases}1/\sqrt{2} & \text{for } u,v=0\\ 1 & \text{otherwise}\end{cases} \quad (5)$$

where f_{ij} represents the pixel values, and F_{uv} the DCT coefficients. After gamma correction,

$$F'_{uv}=\frac{255}{4}C_uC_v\sum_{i=0}^{7}\sum_{j=0}^{7}\hat{f}_{ij}^{\,\gamma}\cos\frac{(2i+1)u\pi}{16}\cos\frac{(2j+1)v\pi}{16} \quad (6)$$

where $\hat{f}_{ij}$ is equivalent to $f_{ij}/255$.

Because the curve of gamma correction can be approached by polygonal lines, shown in Fig. 2a, the correction for pixels corresponding to each section, an example of which is shown in Fig. 2b, can be approximately calculated by linear operations,

$$\hat{f}_{ij}^{\,\gamma}\approx k\cdot\hat{f}_{ij}+b,\ \ 0\le i,j\le 7 \quad (7)$$

where

$$k=\frac{(\max(\hat{f}_{ij}))^\gamma-(\min(\hat{f}_{ij}))^\gamma}{\max(\hat{f}_{ij})-\min(\hat{f}_{ij})} \quad (8)$$

$$b=(\min(\hat{f}_{ij}))^\gamma-(\min(\hat{f}_{ij}))\cdot\frac{(\max(\hat{f}_{ij}))^\gamma-(\min(\hat{f}_{ij}))^\gamma}{\max(\hat{f}_{ij})-\min(\hat{f}_{ij})} \quad (9)$$

Thus,

$$F'_{uv}\approx\frac{255}{4}C_uC_v\sum_{i=0}^{7}\sum_{j=0}^{7}(k\cdot\hat{f}_{ij}+b)\cos\frac{(2i+1)u\pi}{16}\cos\frac{(2j+1)v\pi}{16}$$
$$=\begin{cases}k\cdot F_{00}+2040b & \text{for } u,v=0\\ k\cdot F_{uv} & \text{otherwise}\end{cases} \quad (10)$$

According to Eq. (10), coefficient values of each block are dithered by gamma correction to the pixels. For different blocks, we have different k's and b's, which control the degree of perturbation. Fig.3 shows statistical results of the possibilities of different k's from a gamma corrected image. Although it's not completely symmetric corresponding to k=1, perturbations from both sides finally conceal the comblike histogram of AC coefficients on each subband.

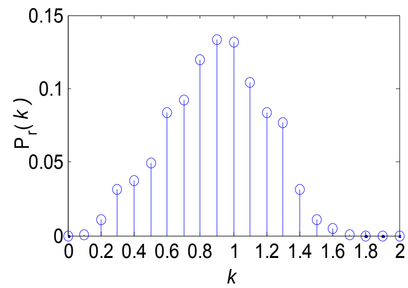


Figure 3. Slope k distribution probability of the image modified by gamma correction.

C. Optimal Gamma Values

In Eq. (3), we define ε and ω for γ selection. To find the optimal γ values, we select 200 original images randomly from the Uncompressed Colour Image Database (UCID) [8] to generate compressed images with different quality factors. We transform the subband histogram of DCT coefficients into DFT spectrum H, and define a criterion in Eq. (11) to evaluate the comblike fingerprint.

$$C=\frac{1}{N-2s}\sum_{i=s}^{N-s}[H(i)-\frac{1}{N-2s}\sum_{i=s}^{N-s}H(i)]^2 \quad (11)$$

In Eq. (11), N is the number of DFT points. We select the high frequency components in H, using a factor s equivalent to 128. With different quality factors, we create 1338 images from UCID. With the criterion, the calculation results are shown in Fig. 4. We find C_T=0.005 is a suitable threshold to distinguish the compressed images from the original images.

After that, we use different γ values for correcting the compressed images. With each γ value, we gather the probability of $\Pr(C>C_T)$ for the compressed images. Accordingly, we find the values are suitable when $\gamma \geq 1.5$ or $\gamma \leq 0.8$. Because the larger γ deviates from 1, the more modification happens for the image, we finally choose the ε from 0.5~0.8, and ω from 0.2~0.5.

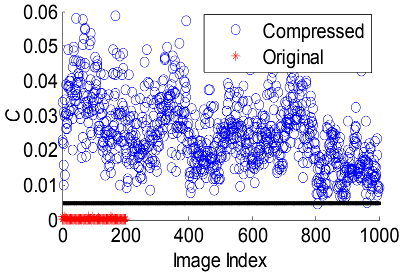


Figure 4. Local variance of images.

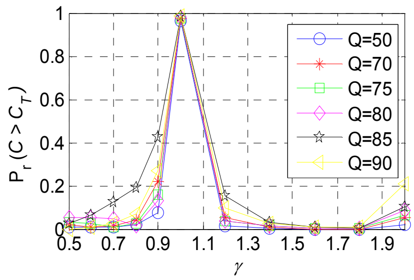


Figure 5. DCT fingerprint detection rate of images.

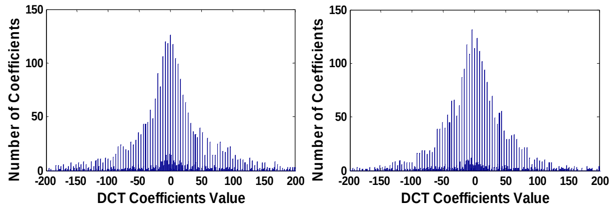
III. Experiments and Analysis

A. Concealment of JPEG Traces

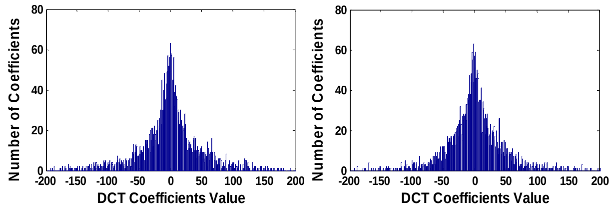
We use the same images as Stamm's to evaluate the proposed scheme. All of them are compressed by JPEG, and then uncompressed into spatial form. The proposed anti-forensics steps are performed to conceal the compression traces. Fig.6 shows two group of experimental results. After anti-forensics, the comblike histograms of AC coefficients at each subband are erased.

(a)

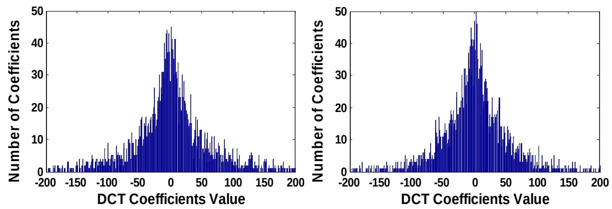
(b)



(c)



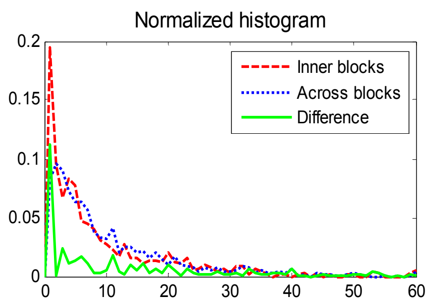
(d)



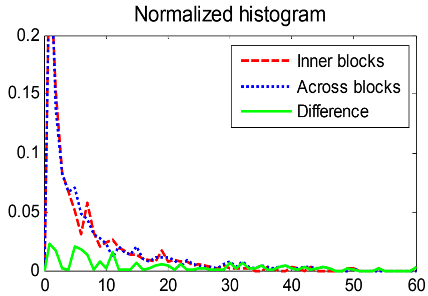
(e)

Figure 6. Results of our method, (a) are images after JPEG compression (QF= 85), (b) the image after anti-forensics to (a), (c) the histograms of AC coefficient on subband (2, 2) of (a), (d) the corresponding histograms of (b), (e) the corresponding histogram of the images using Stamm's method.

Another characteristic of compressed image is the block artifact. A commonly used method of detecting this artifact was proposed by Fan in [9]. Fig.7 shows that, if the image was once compressed, discrepancy of histograms is quite large. After anti-forensics with the proposed method, the discrepancies decrease. Table 1 compares the detection results of the proposed scheme with Stamm's, which shows that the proposed method has a good capability of anti-forensics, in the case of quality factors greater than 50.



(a)



(b)

Figure 7. Red and blue curves show two normalized histograms of inner differences and cross differences. The green curve is the difference between the red and blue curve. (a) corresponds to the compressed image, (b) the anti-forensic image.

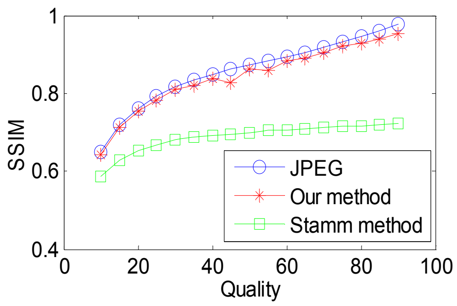
Figure 8.
Block artifact detection rates

Quality Factor	Stamm's method S=2, σ^2=2	Our method
90	0.2%	0.0%
70	0.8%	0.7%
50	1.6%	4.4%
30	24.1%	25.9%
10	95.9%	100%

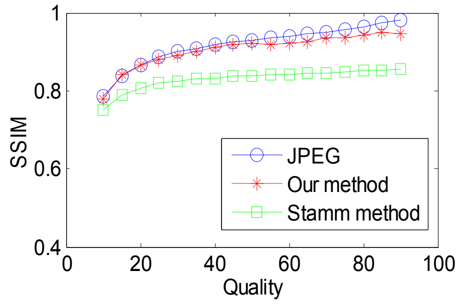
B. Quality Assessment and Computation Efficiency

To evaluate the image quality after anti-forensics, we adopt state-of-the-art Structural Similarity index (SSIM) in [10]. SSIM values range from 0-1 to assess the quality, the larger the better. Fig.8 shows the experimental results of different images corresponding to various compression degrees. The proposed method preserves a better quality than Stamm's method.

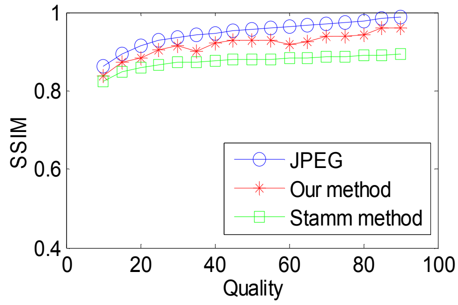
The proposed method also improves the anti-forensic efficiency. Experimental results are generated from the program compiled by Matlab R2010a on PC (Inter Core 2 2.93GHz CPU, 1.96GB memory, and Windows XP operation system). Results show that processing time consumption for our method is about 5 seconds on a given image, but Stamm's method takes about 30 seconds. The proposed method has better efficiency.



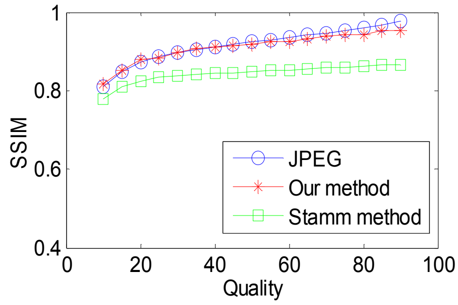
(a) Baboon



(b) Crowd



(c) Columbia



(d) Airplane

Figure 9. In the cases of 17 different quality factors, namely at the interval of 5 from 15 to 90, images get the increasing SSIM scores basically.

C. Risk Analysis

(1) Quantization Estimation

One risk of anti-forensics to JPEG compression is the estimation of quantization table. In [11], Ye proposed an efficient estimation scheme. We compress an original image using the defined steps in Fig.9 (a). After uncompression, the steps are estimated with Ye's method, which are shown in (b). After anti-forensics with the proposed method, Ye's method fails, results of which is shown in (c).

Another quantization estimation scheme is proposed by Farid [12]. Quality factor of JPEG compression can be extracted by Mean Squared Error (MSE) distortion analysis. Fig.10 shows the comparison of quality factor detection. With the proposed method, we are able to defeat the quantization analysis.

5	3	3	5	7	12	15	18
4	4	4	6	8	17	18	17
4	4	5	7	12	17	21	17
4	5	7	9	15	26	24	19
5	7	11	17	20	33	31	23
7	11	17	19	24	31	34	28
5	19	23	26	31	36	36	30
22	28	29	29	34	30	31	30

(a)

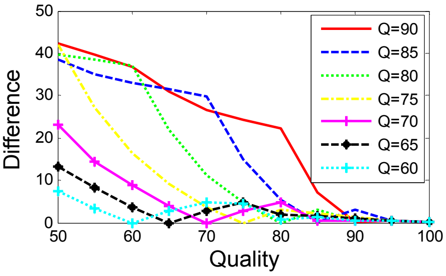
0	3	4	5	7	12	15	18
4	5	4	6	8	17	18	17
3	4	5	7	12	17	21	17
4	5	7	9	15	26	24	19
5	7	11	17	20	33	31	23
7	11	17	19	24	31	34	28
15	19	23	26	31	36	36	30
22	28	29	29	34	30	31	30

(b)

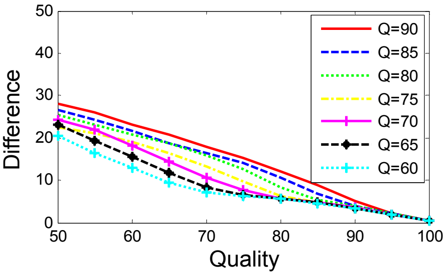
0	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1

(c)

Figure 10. Quantization table.



(a)

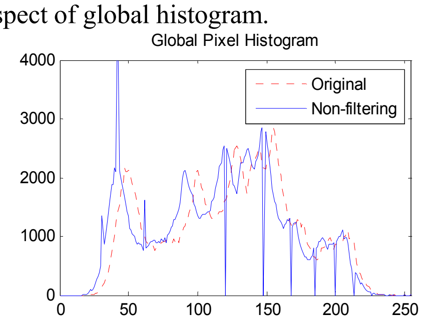


(b)

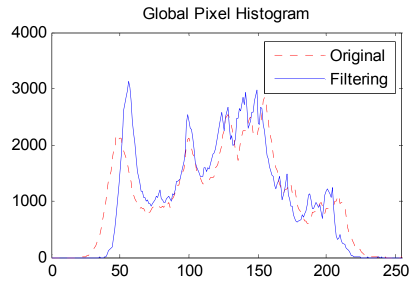
Figure 11. MSE distortion of the same image with different quality factors.

(2) Impact on Global Histogram

As anti-forensic operations may generate new fingerprints, we have to avoid the traces reflected on global histogram which is commonly analyzed in forensics. Fig.11 (a) shows the global histograms before and after anti-forensics. When gamma correction is used on the test image, some obvious peaks and gaps appear which can be used as forensic traces [13]. However, these peaks and gaps are removed after NLTV filtering, shown in Fig.11 (b). Although the proposed method changes the contrast and pixel histogram slightly, an investigator has no original images for comparison. Thus, the proposed scheme is safe on the aspect of global histogram.



(a)



(b)

Figure 12. In (a), the red curve displays an unprocessed image histogram, and the blue shows the histogram after gamma correction without filtering. Similarly, in (b), the blue curve is the histogram of the same JPEG image using gamma correction with filtering.

IV. Conclusions

This paper proposes a new method of concealing JPEG compression forensics. Different from the method of introducing noises into the image, we use the joint operations of image enhancement and filtering to conceal the compression traces. As a result, structure and quality of the image are well preserved. Besides, the anti-forensic scheme has a better working speed.

In recent works, some countering anti-forensic methods have been proposed in [14] and [15]. However, no anti-forensic method is perfect as traces are everywhere. Anti-forensics also improves the development of forensic technology from the reverse side.

Acknowledgement

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