

JPEG Quantization-Distribution Steganalytic Method Attacking JSteg

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Summary

JPEG Image steganalysis has attracted great attention recently. In this paper, JPEG quantization-distribution steganalytic method against JSteg using JPEG Quantization Steps is proposed. By deducing the distribution relation of DCT coefficients before and after quantization in AC channel individually, and investigating the effect of quantization steps on such relation, we present a new method to detect the changes of statistical features derived from JSteg. Experimental results show that our approach can not only estimate the amount of hidden messages exactly, but also achieve a high degree of adaptivity.

Key words:

DCT, coefficient distribution, JPEG, quantization, steganalysis

Introduction

Nowadays, the countermeasure between Steganography and Steganalysis has received significant attention [1][2]. Extensive investigations indicate that the changes of statistical features can be used to detect the existence of secret messages in images. So it is of great importance to study on the statistical features of natural images for the development of steganalytic techniques.

Over the past few years, some achievements have been obtained in data statistical properties research of carrier data. Take those of JPEG images for example, the methods to obtain statistical features of DCT coefficients could be divided into two categories: one is to directly estimate by cropping and recompression [4~6]; the other is to indirectly estimate by constructing the statistical model [7][8]. However, the statistical features of quantized coefficients are derived from natural scene and JPEG compression; here the quantization process of JPEG compression is considered the main factor which can affect statistical features of quantized coefficients greatly. Therefore, there are reasons to believe that a better statistical feature will be achieved if such factor is taken into account.

In this paper, firstly, we deduce the quantization-distribution relationship of each AC channel for JPEG images; then, we investigate the effect of quantization steps on such relation. Based on such relation, JPEG

quantization-distribution (JQD) steganalytic method against JSteg will be proposed. Finally, the conclusion will be given.

2. Distribution of individual AC Channel Coefficients

To make clear what is mainly discussed in this paper, we start with a short description of the JPEG compression algorithm. In JPEG compression, the image is first divided into disjoint blocks of 8×8 pixels. For each block, the discrete cosine transform (DCT) is calculated, producing 64 DCT coefficients, which are distinguished as DC coefficients and AC coefficients. In each block, all 64 coefficients are further quantized to integers using the JPEG quantization matrix Q . Then, quantized coefficients are arranged in a zig-zag manner and compressed using the Huffman coder. The resulting compressed stream together with a header forms the final JPEG file.

During the past two decades, for the goal of image compression, there have been various studies on the statistical distributions of the individual AC coefficients for images. These statistical distribution functions include: Gaussian [9], Laplacian [10~12], Cauchy [13], Generalized Gaussian [14], etc. But the goodness-of-fit of these distributions can be greatly affected by JPEG quantization process. In order to take advantage of JPEG quantization table, we analyze the quantization-distribution relation of AC channels individually in this section. As an example of the implement of our methodology, we will give a detailed description with the Laplacian distribution in this paper.

2.1 Quantization-Distribution Relation

Let I denote the DCT coefficients of raw image, $I_Q = \text{round}(I / Q)$, $I' = I_Q \cdot Q$ denote the quantized and de-quantized value with quantization step Q respectively.

Let us assume that $P_{I,m,n}(x)$, $P_{I_Q,m,n}(x)$, $P_{I',m,n}(x)$ follow the Laplacian distribution with parameter

$\mu_{mn}, U_{mn}, \mu'_{mn}$ respectively, and m, n denote the m -th and n -th AC channel, then we have:

$$P_{I,m,n}(x) = \frac{\mu_{mn}}{2} \cdot e^{-\mu_{mn}|x-\bar{x}|} \quad (1)$$

$$P_{I_Q,m,n}(x) = \frac{U_{mn}}{2} \cdot e^{-U_{mn}|x-\bar{x}|} \quad (2)$$

$$P_{I',m,n}(x) = \frac{\mu'_{mn}}{2} \cdot e^{-\mu'_{mn}|x-\bar{x}|} \quad (3)$$

Based on MLE expression of Laplacian parameter μ and JPEG quantization process, we can deduce the relationship as follows:

(1) The relationship of μ'_{mn} and μ_{mn} is:

$$\frac{1}{\mu_{mn}} = \int_{-\infty}^{+\infty} |x - \bar{x}| \cdot P_{I,m,n} dx \quad (4)$$

$$\begin{aligned} \frac{1}{\mu'_{mn}} &= \sum_{k=-N}^N \int_{kQ_{mn}-0.5Q_{mn}}^{kQ_{mn}+0.5Q_{mn}} |kQ_{mn} - \bar{k}Q_{mn}| \cdot P_{I,m,n} dx \\ &= \sum_{k=-N}^N \int_{kQ_{mn}-0.5Q_{mn}}^{kQ_{mn}+0.5Q_{mn}} |kQ_{mn} - \bar{k}Q_{mn}| \cdot \frac{\mu_{mn}}{2} \cdot \exp(-\mu_{mn}|x - \bar{x}|) dx \end{aligned} \quad (5)$$

(2) Therefore, the relationship of U_{mn} and μ_{mn} is:

$$\frac{1}{U_{mn}} = \sum_{k=-N}^N \int_{kQ_{mn}-0.5Q_{mn}}^{kQ_{mn}+0.5Q_{mn}} |k - \bar{k}| \cdot \frac{\mu_{mn}}{2} \cdot \exp(-\mu_{mn}|x - \bar{x}|) dx \quad (6)$$

(3) So, we have the relationship of μ_{mn} and U_{mn} :

$$\frac{1}{\mu_{mn}} = \sum_{k=-N}^N |kQ_{mn} - \bar{k}Q_{mn}| \cdot \frac{U_{mn}}{2} \cdot e^{-U_{mn}|k-\bar{k}|} \quad (7)$$

From equation (7) we can see that, we can calculate the relationship of distribution before and after quantization in each AC channel if both set of these DCT coefficients follow Laplacian distribution.

2.2 The Effect on Relation by Quantization Steps

In previous section, we have obtained the quantization-distribution relationship in each AC channel. But we must reemphasize that such relationship only exists when the hypothesis in 2.1 is satisfied. In this section, we study on the very constraint condition under which such hypothesis will be satisfied. In other words, we will investigate the constraint condition of equation (7).

From the deduction above, we can see that the goodness-of-fit of the precise coefficients before quantization and quantized coefficients will affect the

conclusion in 2.1. In order to take these factors into account, we investigate the estimating error caused by different quantization steps while using the equation (7). In detail, we quantize the coefficients in AC channels individually with quantization steps from 1 to 100, and explore the relationship between $|\mu_{mn} - \hat{\mu}_{mn}| / \hat{\mu}_{mn}$ and different quantization steps by statistical experiments.

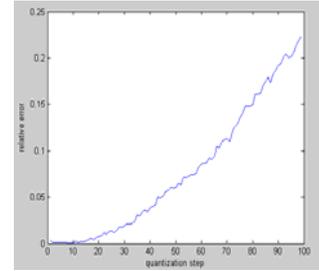


Fig. 1 Relative error of distribution parameter that estimated for (1,2) channel coefficients quantized from 1 to 100.

Fig.1 shows the relationship between the relative error and quantization steps in AC channel (1,2). We can see that the goodness-of-fit of Laplacian to quantized DCT coefficients decreases with increasing quantization step Q . i.e. if Q is restricted within a special range, the conclusion in section 2.1 will come into existence approximately. In this paper, we take the relative error 0.01 as the threshold to determine the Threshold Matrix of Quantization Step.

3. JPEG Quantization-Distribution Method against JSteg

3.1 Detect JSteg Using Quantization-Distribution Relation

Based on the distribution relation above, we can estimate the coefficients distribution of cover image. And now, firstly, we describe the JSteg algorithm proposed by D.Upham [15] briefly. It works by embedding message bits as the LSBs of quantized DCT coefficients. The embedding mechanism skips all coefficients with value of '0' or '1'. There are two embedding ways. One is sequential embedding; the other is random embedding. From the principle of JSteg, we can see that there will leave the "Pairs of Values (PoVs)" in DCT coefficients histogram (see figure 2).

The steps to obtain distribution of original DCT coefficients from quantized coefficients are: (1) estimate the Laplacian distribution of quantized DCT coefficients using maximum-likelihood (ML); (2) calculate the distribution of original coefficients with formula (7); and

the step to estimate distribution of cover image: (3) recompress the distribution estimated in step 2. These three steps smooth the slight modification like PoVs in coefficients histogram and make use of the information of quantization steps. Therefore these steps can be used to estimate the first-order histogram distribution of cover images. The rest of paper will present the new steganalytic method to attack JSteg with the steps above.

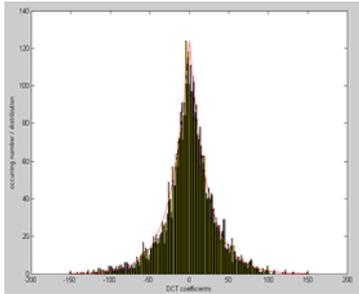


Fig. 2 DCT coefficients (2,1) channel of Jsteg’s stego image and estimated cover image distribution

As the figure show, the steps to obtain distribution of original DCT coefficients from quantized coefficients and recompression can smooth the “PoVs”, so these steps can use the quantization steps information and estimate the distribution of cover images accurately.

3.2 JPEG Quantization-Distribution Method

Based on the discussing above, our method detects the AC channels of an image individually, and we only look at the Channel whose quantization step is below the corresponding quantization step threshold. Here, the quantization step threshold is determined with the given relative error of distribution parameters estimated by formula (7) (in this paper we determine the threshold matrix with relative error 0.01).

Detection algorithm:

1. Estimate the Laplacian distribution parameter u from the quantized DCT coefficients of image AC channels whose quantization step follow the quantization step threshold.
2. Calculate the Laplacian distribution of original DCT coefficients using formula (7), which can be considered as the original coefficients’ distribution estimation of cover image.
3. Recompress the distribution of original DCT coefficients, and then we obtain the quantized coefficients’ distribution estimation of cover image.

4. Let $2p$ be embedding ratio, p be modifying rate, $H_{mn}(2d)$ denotes the histogram value of DCT coefficients in stego image (m,n) channel, and $h_{mn}(2d)$ is that of cover image. So we can get equation from principle of JSteg as follows:

$$H_{mn}(2d) = (1 - p) \times h_{mn}(2d) + p \times h_{mn}(2d + 1) \tag{8}$$

And

$$p = \frac{H_{mn}(2d) - h_{mn}(2d)}{h_{mn}(2d + 1) - h_{mn}(2d)} \tag{9}$$

Modifying ratio p can be estimated as:

$$\hat{p} = \frac{1}{K} \sum_{k=1}^K \hat{p}_k = \frac{1}{K} \sum_{k=1}^K \frac{H_k(2d) - \hat{h}_k(2d)}{\hat{h}_k(2d + 1) - \hat{h}_k(2d)} \tag{10}$$

Here, \hat{p}_k is estimated ratio of k_{th} AC channel which satisfy the quantization step threshold, \hat{h}_k can be estimated indirectly from formula (6)-(7).

4. Experimental results

To evaluate our method, we used 100 JPEG images (resolution 1024×768) recompressed (with ACDSee6.0) with different quality factors from the images taken by Canon camera and embedded random bits message with different capacity, then detect these images with our method. The results are show in tables below.

Table 1: The mean and variance of detect results for Canon images with 80 quality factor compression

Message Length	Mean	Variance
20%(*max)	23.74%	0.0106
50%(*max)	48.51%	0.0061
80%(*max)	78.60%	0.0030
100%(*max)	97.80%	0.0012

Table 2: The mean and variance of detect results for Canon images with 50 quality factor compression

Message Length	Mean	Variance
20%(*max)	29.88%	0.0236
50%(*max)	51.39%	0.0171
80%(*max)	80.24%	0.0075
100%(*max)	97.41%	0.0015

Table 3: The mean and variance of detect results for Canon images with 30 quality factor compression

<i>Message Length</i>	<i>Mean</i>	Variance
20%(*max)	25.81%	0.0255
50%(*max)	51.25%	0.0201
80%(*max)	80.95%	0.0077
100%(*max)	96.19%	0.0029

As the tables show, the performance of our method proposed is reliable and accurate. Especially, our method can adapt to images with different quantization table.

5. Conclusions

In this paper, we deduce the Laplacian quantization-distribution relation of DCT coefficients in AC channel individually, and investigate effect of quantization steps on it. Based on such investigation, JPEG quantization-distribution steganalytic method against JSteg is presented. Experimental results show that our approach can not only estimate the amount of hidden messages exactly, but also achieve a high degree of adaptivity.

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References

- [1] Information Hiding, 1st~6th International Workshop, Springer, (1996~2005)
- [2] Cachin C. An information-theoretic model for steganography. Information Hiding: Second International Workshop, vol. 1525 of Lecture Notes in Computer Science, Portland, Oregon, U.S.A., 1998. Springer-Verlag, Berlin
- [3] Xiangwei Kong, Chang Liu Xingang You, and Yanqing Guo. A New Steganographic Method Resisting Statistical Attack. The 7th International Conference of Signal Processing, Sep 2004, pp1092—1095
- [4] J. Fridrich, M. Goljan and D. Hoge. Steganalysis of JPEG Images: Breaking the F5 Algorithm. Proceeding of 5th Information Hiding Workshop. 2002. page(s):310-323
- [5] J. Fridrich, M. Goljan and D. Hoge. Attacking the OutGuess. Proc. of the ACM Workshop on Multimedia and Security 2002, Juan-les-Pins, France, Dec 6, 2002
- [6] J. Fridrich, M. Goljan and D. Hoge. New Methodology for Breaking Steganographic Techniques for JPEG Images. In Proceeding EI SPIE Santa Clara, CA, Jan 2003
- [7] Xiaoyi Yu, Yunhong Wang, Tieniu Tan, "On Estimation of Secret Message Length in JSteg-like Steganography", Pattern Recognition, 2004. ICPR 2004. Proceedings of the 17th International Conference on, Volume: 4, pp.673- 676. Aug. 23-26, 2004
- [8] Sallee, P.: Model-based methods for steganography and steganalysis. Submitted to International Journal of Image and Graphics. Special issue on Image Data Hiding (2004)
- [9] W. K. Pratt. Digital Image Processing. New York: Wiley-interscience, 1978. ch. 10
- [10] Randall C. Reiningek and Jerry D. Gibson. Distributions of the Two-Dimensional DCT Coefficients for Image. IEEE TRANSACTIONS ON COMMUNICATIONS, vol. com-31, no. 6, June 1983
- [11] Bellifemine. F. Capellino. A. Chimienti. A. Picco. R. and Ponti. R. Statistical analysis of the 2D-DCT coefficients of the differential signal of images. Image Communication. 1992, 4, pp.477-488
- [12] Edmund Y. Lam and Joseph W. Goodman. A Mathematical Analysis of the DCT Coefficient Distributions for Images. IEEE TRANSACTIONS ON IMAGE PROCESSING, VOL. 9, NO. 10, October 2000
- [13] Eggerton J. D. and Srinath M. D. Statistical distribution of image DCT coefficients. Comput.&Elect. Eng., vol. 12, pp 137-145, 1986
- [14] F. Muller. Distribution shape of two-dimensional DCT coefficients of natural images. ELECTRONICS LETTERS 28th October 1993 Vol. 29 No. 22
- [15] JPEG-JSteg-V4, <http://www.funet.fi/pub/crypt/steganography/jpeg-Jsteg-v4.diff.gz>



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