Detection of Double-Compression in JPEG2000 Images

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Abstract

Double image compression might occur if the image has been tampered with or embedded into secret data. It is essential to detect double compression for image forensics and blind steganalysis. This paper analyzes the statistical difference in the sub-band DWT (discrete wavelet transform) coefficient histograms between single and double JPEG 2000 compression; devises a scheme to discriminate between them. The experiments demonstrate that the proposed approach can achieve an effective and accurate detection for double JPEG 2000 compression.

1. Introduction

Double-compression in JPEG, JPEG2000 images occurs when a JPEG or JPEG2000 image is decompressed to the spatial domain and than compressed into a JPEG or JPEG2000 image. There are two reasons why we are interested in detecting double-compressed images. First, detection of double compression is a forensic tool useful for recovery of the processing history. Double-compressed images are also frequently produced during image manipulation. By detecting the traces of recompression in individual image segments, we may be able to identify the tampered region because the non tampered part of the image will exhibit traces of double compression[1-2]. Second, some steganographic algorithms always decompress the cover JPEG, JPEG2000 image into the spatial domain before embedding. During embedding, the image is compressed again. The statistics in double-compressed images may significantly differ from the statistics in single-compressed images. Ignoring the effects of double-compression may lead to extremely inaccurate steganalysis results. Thus, methods for detection of double-compression are essential for design of accurate steganalysis [3].

The past few years have seen much progress in detecting double compressed JPEG images. Popescu et al propose a technique to detect double JPEG compression according to periodic artifacts of DCT (discrete cosine transform) coefficient histograms[2]. The single and double JPEG compression can be discriminated by thresholding the peak of the Fourier transform of the DCT coefficient histogram. In order to obtain an accurate measurement of the peaks' energy, they used a two-parameter generalized Laplace model to remove the interference. The technique needs estimating model parameters. When the ratios between the second and first quantization steps have integer values, the double quantization, i.e., the double compression is undetectable. Moreover, for high first qualities and low second qualities factors, e.g., Q1 = 90 and Q2 = 50, the detection accuracy drops to approximately 50%. T. Pevny and J. Fridrich propose another approach to detect double JPEG compression with artifacts of DCT coefficient histograms[3]. The double-compression detector is implemented using a SSVM (soft-margin support vector machine), whose feature vector consists of DCT coefficient histograms for 9 low frequencies. The dimension of this feature set is 144. The detection accuracies are about 97% for typical compression quality factors used in some steganographic algorithms, but drops sharply for some other quality factors. In the case of Q1 = Q2, the double compression is undetectable, and the algorithm also needs much time to train the SSVM. D. Fu et al propose a method to detect double JPEG compression using the generalized Benford's law[4], but the detection accuracy is only 30.91% by SSVM [3]. Compared with JPEG images, less attention has been paid to JPEG2000 double-compression. JPEG 2000 is a DWT (discrete wavelet transform)-based standard for the compression of still digital images. It was developed to improve on the performance of JPEG.

In this paper, an approach for detecting double JPEG 2000 compression is proposed. The rest of this paper is organized as follows: Section 2 introduces baseline JPEG2000; the approach to discriminate between single and double JPEG2000 compression is presented in Section 3; the experimental results are shown in Section 4 and conclusions are drawn in Section 5.

2. Baseline JPEG2000

A simplified diagram of baseline JPEG2000 compression is illustrated in Fig. 1[5]. As shown in Fig. 1, in the baseline JPEG2000 compression, the original image is first preprocessed. Two-dimensional DWT is then applied to the image. After that, the DWT coefficients are

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quantized, and arithmetic entropy coding is used to encode the quantized coefficients. In the arithmetic coding process, each sub-band is divided into code-blocks of samples which are coded independently. These code-blocks are then coded a bit-plane at a time starting from the most significant bit-plane with a non-zero element to the least significant bit-plane. Each coefficient bit is coded in exactly one of the three coding passes: the significance propagation pass, the amplitude refinement pass and the cleanup pass. Once the entire image has been compressed, a data-ordering operation passes over all the compressed code-blocks and determines the extent to which each code-block's embedded bit-stream should be truncated in order to achieve a particular target bit-rate, distortion bound or other quality metric. More generally, the final bit-stream is composed from a collection of so-called "layers", where each layer has an interpretation in terms of overall image quality. The first, lowest quality layer is formed from the optimally truncated code-block bit-streams in the manner described above. Each subsequent layer is formed by optimally truncating the code-block bit-streams to achieve successively higher target bitrates, distortion bounds or other quality metrics. This kind of rate control strategy is called post-compression rate-distortion optimization. If the bit-stream is truncated, assuming the number of truncated bit-planes is n, this is equal to quantizing the DWT coefficients again with the step size of 2^n. Because coefficient bits are coded in different passes, and the truncation points are possibly within a bit plane, the final quantization step size is usually different to each coefficient, and is difficult to determine.

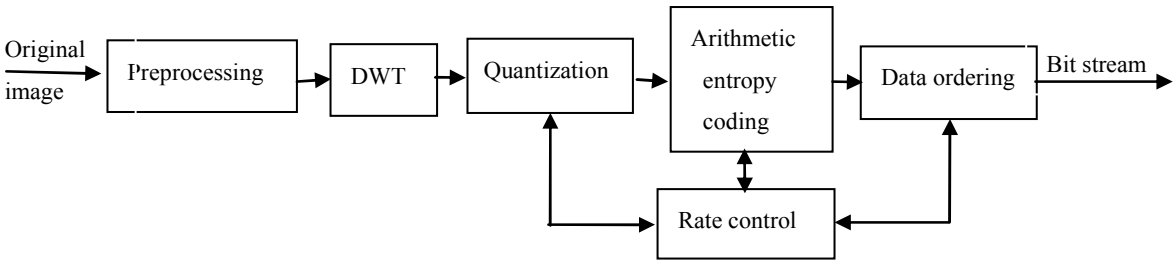
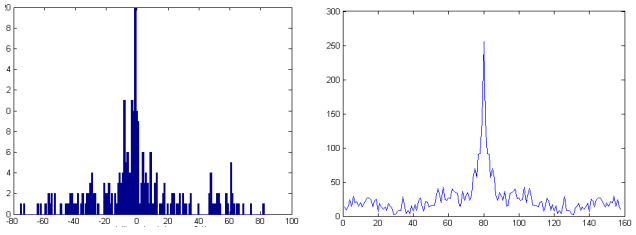


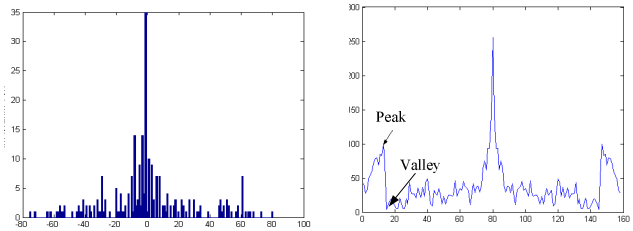
Figure 1 Block diagram of baseline JPEG2000

3. Discriminating between single and double JPEG2000 compression

After DWT, the image energy becomes compact. Most of the coefficients in high frequency sub-bands are quantized to zeros. So we build histograms of DWT coefficients only for low frequency sub-bands, e.g. 5HL, 5LH, 4HL and 4LH. Fig.2 shows the histograms of 5HL sub-band DWT coefficients for the image "Lena". While Fig.3 shows the histograms of 4LH sub-band for the image "Lena".



(a) (b)



(c) (d)

Figure 2 The histogram of 5HL DWT coefficients for the image " Lena": (a) The histogram of single JPEG2000 compression (0.8bpp); (b) the Fourier transform of (a); (c) The histogram of double JPEG2000 compression (first 0.8bpp, second 0.5bpp); (d) the Fourier transform of (b).

As shown in Fig.2 and Fig.3, double JPEG2000 compression does not introduce obvious periodic artifacts, but introduce the more abrupt slopes in the mid and high frequencies, which are likely caused by JPEG2000 particular quantization. By detecting this singularity which can be measured by the range between the peak and the valley, see Fig.2 (d) and Fig.3 (d), we can discriminate between single and double JPEG2000 compressed images. Based on this idea, our approach for detecting double JPEG2000 compression is illustrated in Fig. 4. To a JPEG2000 image, sub-band histograms are built and their FFT (Fast Fourier Transform) is calculated respectively;

then the peak and the valley are extracted and the range between them is obtained. By thresholding the range, we finally make decision if the image has been double JPEG2000 compressed.

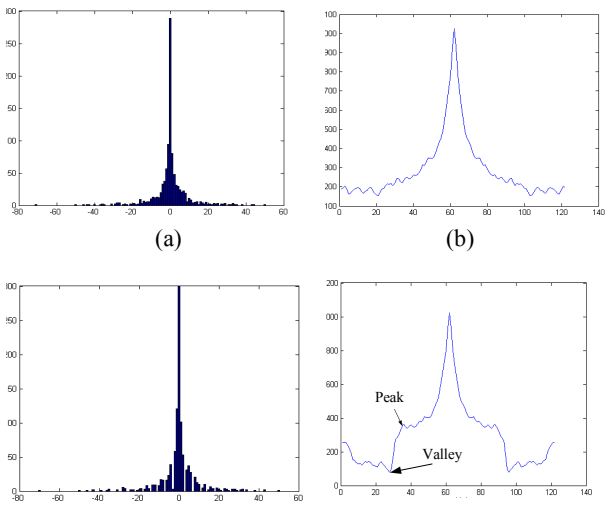


Figure 3 The histogram of 4LH DWT coefficients for the image " Lena": (a) The histogram of single JPEG2000 compression(0.8bpp); (b) the Fourier transform of (a); (c) The histogram of double JPEG2000 compression(first 0.8bpp,second 0.5bpp); (d) the Fourier transform of (b).

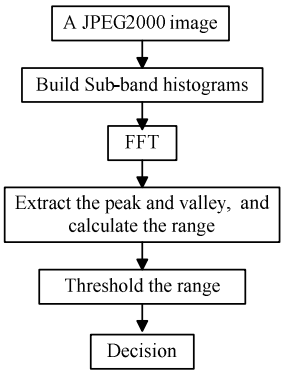


Figure 4 The work flow of our approach

As shown in Fig.2 (d) and Fig.3 (d), the valley can be extracted by computing the minimal amplitude of the Fourier transform, but the peak can not be extracted easily. We design the following scheme to extract the peak:

(1) Extracting amplitude extrema of the Fourier transform

Due to the central symmetry of the Fourier transform, we only use the left half of the FFT amplitudes. Assuming the amplitude sequence

$$A = \{a_i\}_{i=1,2,\cdots,n} \tag{1}$$

The difference sequence B is calculated as follows:

$$B = \left\{ \Delta a_k \,\middle|\, \Delta a_k = a_k - a_{k-1} \right\}_{k=2,3,\cdots,n} \tag{2}$$

If $\Delta a_{k-1} = a_k - a_{k-1} \geq 0$ and $\Delta a_k = a_{k+1} - a_k < 0$, then $a_k (2 \leq k < n)$ is extracted as an amplitude extremum.

Because a_n corresponds to the DC (direct current) component, denoting the number of the DWT coefficients in the sub-band, it is the same in single and double JPEG2000 compression and is not the peak to be extracted, we need not consider it. But a_1 is possibly the peak, we should not omit it. So we modify the difference sequence B to B':

$$B' = \{\Delta a_k\}_{k=1,2,\cdots,n-1} = \{0, a_2 - a_1, \cdots, a_i - a_{i-1}, \cdots, a_n - a_{n-1}\} \tag{3}$$

Then all the amplitude extrema are extracted using the method described above.

(2) Screening out small amplitude extrema

Let $C = \{C_i\}_{i=1,2,\cdots,m}$ denotes the extremum sequence; we screen out small extrema by selecting the extremum which satisfies:

$$C_i > \bar{C} = \frac{1}{m} \sum_{j=1}^{m} C_j, \quad i = 1, 2, \cdots, m \tag{4}$$

The remaining extrema constitute the new extremum sequence $D = \{D_i\}_{i=1,2,\cdots,l}$.

(3) Appling one-dimensional DWT to the sequence D

We use DWT to locate the peak. The extremum sequence D is transformed into scale coefficients (also called approximation coefficients) and wavelet coefficients (also called detail coefficients) by one-dimensional DWT. We find the maximum amplitude value of the wavelet coefficients just corresponds to the peak to be extracted (See Fig.5), then the peak amplitude a_{pk} can be extracted.

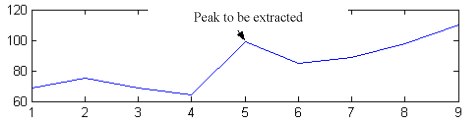
The valley amplitude a_{vy} is extracted by:

$$a_{vy} = \min\{a_i\}_{i=1,2,\cdots,n} \tag{5}$$

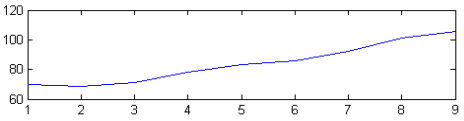
Then the range rg is calculated:

$$rg = a_{pk} - a_{vy} \tag{6}$$

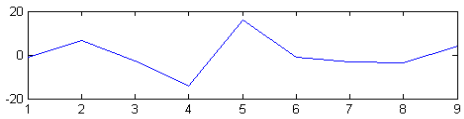
By thresholding rg, the single or double JPEG2000 compression can be finally identified.



(a) The extremum sequence D



(b) Approximation coefficients of D



(c) Detail coefficients of D

Figure 5 Locating the peak

4. Experimental results

In our experiments, 512×512 PGM images are adopted. The original PGM images are first JPEG2000 compressed with bit rate b_1, then decoded and second JPEG2000 compressed with bit rate b_2. Table 1 and Table 2 show the *rg* values of single and double JPEG2000 compression for three different images. We set the threshold $TRG_{5LH} = TRG_{5HL} = 50$, $TRG_{4LH} = TRG_{4HL} = 100$, if at least three of the four sub-bands (5HL, 5LH, 4HL and 4LH) are labeled as double compressed, then the image is classified as double JPEG2000 compressed. Table 3 shows the detection accuracies of our method when applied to 18 standard test images which are single and double JPEG2000 compressed. As seen in Table 3, The detection accuracies are good even in the case of $b_1 = b_2$. Compared to the methods in [2] and [3], our algorithm is easily implemented and the performance is satisfactory.

5. Conclusions

In this paper we have proposed a novel technique for detecting double JPEG2000 compression automatically and effectively. This technique exploits the facts that double JPEG2000 compression amounts to particular double quantization of the sub-band DWT coefficients, which introduces specific artifacts visible in the histograms of these coefficients. We have devised a quantitative measure for these artifacts, and employed this measure to discriminate between single and double JPEG2000 compressed images. The experiments demonstrate that the proposed technique can detect double JPEG 2000 compression accurately.

Our future work will proceed to research on digital image forensics and steganalysis based on this detecting technique.

Table 1 the *RG* value in single JPEG2000 compression

Image	Bit rate	Sub-band			
		5HL	5LH	4HL	4LH
Lena	0.5bpp	39.817	36.185	94.068	90.234
Lena	0.9bpp	26.669	31.732	91.953	91.953
Pepper	0.5bpp	38.804	35.386	91.625	113.59
Pepper	0.9bpp	37.498	33.268	91.625	75.42
Girl	0.9bpp	39.204	38.126	51.078	107.49
Girl	0.9bpp	23.919	38.126	80.891	108.11

Table 2 the *RG* value in Double JPEG2000 compression

Image	b_1	b_2	Sub-band			
			5HL	5LH	4HL	4LH
Lena	0.5bpp	0.9bpp	50.904	72.44	139.66	115.81
Lena	0.9bpp	0.5bpp	96.261	105.57	202.81	282.13
Pepper	0.5bpp	0.9bpp	54.59	47.549	113.51	136.24
Pepper	0.9bpp	0.5bpp	70.336	67.173	172.08	166.04
Girl	0.5bpp	0.9bpp	70.134	90.803	130.19	163.69
Girl	0.9bpp	0.5bpp	86.616	91.911	204.44	204.91

Table 3 detection accuracy for double JPEG2000 compression

b_1	b_2					
	0.5 bpp	0.6 bpp	0.7 bpp	0.8 bpp	0.9 bpp	1.0 bpp
0.5 bpp	94%	94%	94%	94%	94%	94%
0.6 bpp	100%	100%	100%	100%	100%	100%
0.7 bpp	100%	94%	94%	94%	94%	94%
0.8 bpp	94%	94%	94%	94%	94%	94%
0.9 bpp	100%	100%	100%	100%	100%	100%
1.0 bpp	100%	100%	100%	100%	100%	100%

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