

2012 International Conference on Future Electrical Power and Energy Systems

The Analysis and Detection of Double JPEG2000 Compression Based on Statistical Characterization of DWT Coefficients

WANG WEI, WANG Rang-ding

Dept. of ckc Ningbo University

Ningbo zhejiang 315211, China

spring.ww@163.com. wangrangding@nbu.edu.cn

Abstract

Detection of double image compression is all the world to the analysis of tampered image and image steganalysis. In order to detect double JPEG2000 compression, through the comparison with JPEG double compression, we analysis the different statistical characterization of DWT coefficients' frequency histogram under single and double compression because of post compression rate distortion optimization(PCRD-opt algorithm)in JPEG2000 codec. We find a new statistical characterization which is different form double JPEG compression. Under certain conditions, experimental results show that such features can be used to detect whether the JPEG2000 image is double compressed or not.

© 2012 Published by Elsevier Ltd. Selection and/or peer-review under responsibility of Hainan University.

Open access under [CC BY-NC-ND license](#).

Keywords - double JPEG2000 compression; DWT coefficients; frequency histogram

1. Introduction

When the natural image is photographed by digital camera, it has been compressed. Thus, steganography or tampering operation inevitably leads to image double compression. Detection of double image compression is important to the analysis of tampered image and image steganalysis. Under the JPEG standard, Farid^[1] thought that the DCT coefficients will have a phenomenon of periodic decrease or disappearance duo to recompression, which can be used to detect the double JPEG format images compression. DAI Meng^[2] use "dithering pattern" to detect recompression of JPEG format image. The distributions of DCT coefficients are changed with the double compression factors: Q1 and Q2. JPEG2000 is a new international standard of compressed images. At low bit rates, the quality of JPEG format image becomes unacceptable. Compared with JPEG format images, the compression ratio of

JPEG2000 format images can be based on the further increase of 10%-30%. And overcome the block-fuzzy-distortion of JPEG standard at low compression ratio. In addition, numerous other features are provided by JPEG2000^[3], including: 1) region of interest coding; 2) progressive recovery of an image by fidelity or resolution; 3) random access to particular regions of an image without needing to decode the entire code stream. Therefore, in the case of bandwidth and storage space are very valuable, JPEG2000 standard will replace JPEG image compression standard and is widely used in Internet and digital cameras. So, the analysis and studying of recompression in JPEG2000 format image will be more meaningful. In this paper, based on the analysis of the DWT coefficients' statistical characteristics between single compression and double compression in JPEG2000 standard, a new detection method of double JPEG2000 compression is proposed.

2. Double JPEG2000 Compression Processing

As shown in Fig. 1, the encoder and decoder of JPEG2000 standard is illustrated.

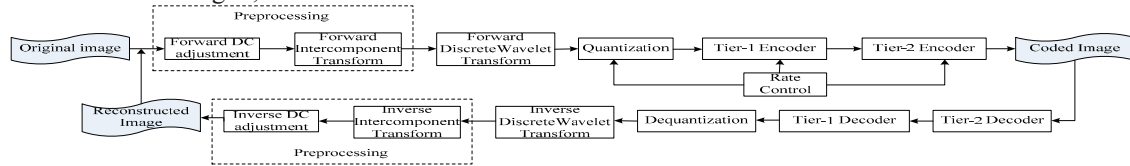


Fig. 1 JPEG2000 Codec

The key processes can be identified: 1) Forward DC adjustment^[4] (Inverse DC adjustment) 2) Forward Intercomponent Transform (Inverse Intercomponent Transform) 3) Forward Discrete Wavelet Transform (Inverse Discrete Wavelet Transform) 4) Quantization (Dequantization) 5) Tier-1 Encoder (Tier-1 Decoder) 6) Tier-2 Encoder (Tier-2 Decoder) 7) Rate Control. On the surface, JPEG2000 codec is similar to JPEG codec. However, it takes a different method in each step. The essential difference between the two is that Discrete Cosine Transform (DCT). In the JPEG2000 standard, after the image preprocessing, the image component will be forward discrete wavelet transformed. After wavelet transform, the image component will be decomposed into multiple-frequency bands (sub-band), and then be quantified for each band. Finally, it is entropy coded and packaged into a code stream. In the JPEG2000 standard, although the quantization step can have different values in each sub-band, but is a fixed value within each sub-band. The compression rate of JPEG2000 image depends not only on quantitation, Tier-1 encoding in Fig. 1 is also playing an important role. They together determine the final compression ratio of the compressed image. Similar to JPEG images, an image is single compressed when it is stored as JPEG2000 format at first, as shown in Fig. 2. When using image processing software to process the image, the image is firstly decompressed into the spatial domain image, and recompressed into JPEG2000 format after the processing. Obviously, this image is double compressed.

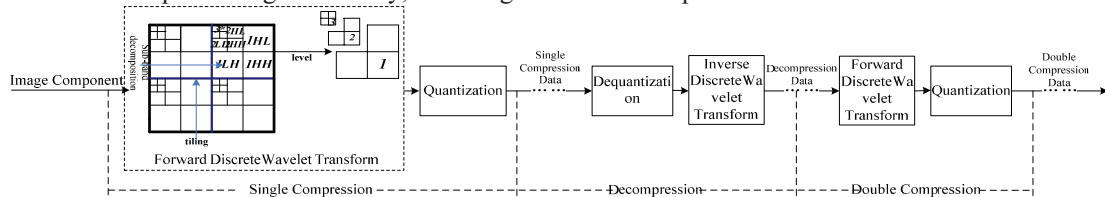


Fig. 2 Single compression and double compression of JPEG2000

3. The Analysis and Detection of Double JPEG2000 Compression

3.1 Difference of double compression feature between JPEG2000 and JPEG

In JPEG compressed standard, the frequency histogram of the discrete cosine transform coefficients (DCT coefficients) have showed different characteristics between single compression and double compression in Fig. 3.

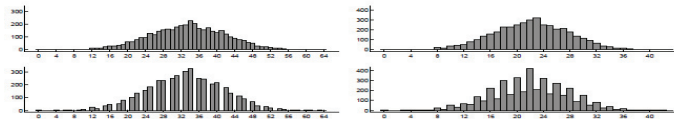


Fig. 3 Frequency histogram of DCT coefficients (Image Source: Literature 6)

Single JPEG compression (top) and double JPEG compression (bottom)

The top row is DCT coefficients histogram of single compression in which the left quantization step size is 2 and the right is 3. The bottom row is its double compression, in which the left quantization step size is 3 followed by 2 and the right is 2 followed by 3. In JPEG compressed standard, the DCT coefficients histogram of single compression is appeared a Gaussianity-nature^[5]. See Fig. 3. But this Gaussianity-nature of the recompression is broken. When the quantization step size of the first compression is larger than the second compression and the ratio of both quantization step sizes are not integer, the statistical characteristics of the DCT coefficients will occur the periodic disappearance (Fig.3, bottom row left). When the quantization step size of the first compression is lower than the second compression and the ratio of both quantization step sizes are not integer, the statistical characteristics of the DCT coefficients will occur the periodic reduction (Fig. 3, bottom row right).

In JPEG format image, this periodic reduction or disappearance characteristic of double compressed of DCT coefficient roots in the quantitative part in JPEG codec. Eq.(1) is the quantitative formula of the JPEG standard. Where “ $\lfloor \cdot \rfloor$ ” is the rounding operation, a is quantization step size, u is the DCT coefficients, $q_a(u)$ is the output quantized values. In the procession of JPEG image recompression, multiplying the quantization step a when the first dequantization, and then divided by the quantization step b (Eq.(2)).

$$q_a(u) = \left\lfloor \frac{u}{a} \right\rfloor \quad (1)$$

$$q_{ab}(u) = \left\lfloor \left\lfloor \frac{u}{a} \right\rfloor \frac{a}{b} \right\rfloor \quad (2)$$

It is precisely because this Quantification-Rounding, the statistical characteristics of the DCT coefficients appear the periodic reduction or disappearance. That is, the frequency of DCT coefficient (The specific reasoning process refers to [5]):

$$n(3k+2) = 3 \left\lfloor \frac{2}{3}(3k+2+1) \right\rfloor - \left\lfloor \frac{2}{3}(3k+2) \right\rfloor = 3(2k+2) - 2k - \left\lfloor \frac{4}{3} \right\rfloor = 0$$

However, in the JPEG2000 standard, we constructed the frequency histogram of the DWT coefficients of image *cats* when it is in single compression and in double compression. Experimental results show that the JPEG2000 format images do not have the characteristics which appeared in JPEG format images at the range of compression rates from 0.9 to 0.3, when double compression. As shown in Fig. 4, the left column (a) is the frequency histogram of DWT coefficients in case of single compression, Department from the top to the end, compression rates are 0.5, 0.7, 0.9, respectively.

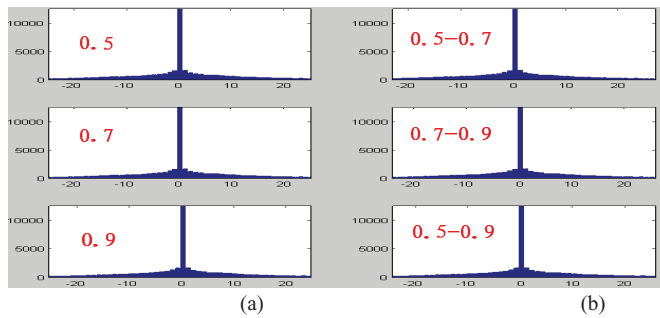


Fig. 4 Frequency histogram of DWT coefficients
Single JPEG2000 compression (a) and double JPEG2000 compression (b)

The right column (b) is the frequency histogram of DWT coefficients in case of double compression, Department from the top to the bottom, compression rates are 0.5&0.7, 0.7&0.9, 0.5&0.9, respectively. As shown in Fig. 4, when JPEG2000 image is recompressed, its frequency histogram of the DWT coefficients do not appear the cyclical characteristics as JPEG images, and its frequency histogram of the DWT coefficients is almost the same. Further experiments showed that no matter how much compression rate is, the quantization step within the same sub-band is the same after the DWT transformation. This is different from the JPEG standard. Although the quantified formula is the same in JPEG2000 and JPEG standard, but because the quantization step size unchanged, also means that $\Delta q_1 = \Delta q_2$.

$$q(u, v) = \left\lfloor \frac{|a(u, v)|}{\Delta q} \right\rfloor \quad (3)$$

$$q_{\Delta q_1 \Delta q_2}(u, v) = \left\lfloor \left\lfloor \frac{a(u, v)}{\Delta q_1} \right\rfloor \frac{\Delta q_1}{\Delta q_2} \right\rfloor \quad (4)$$

So after the recompression, DWT coefficients do not have the frequency characteristics which appeared in JPEG format images. The experimental results shown in Fig.4 are verified this.

3.2 Detection of Double JPEG2000 Compression

In JPEG2000 encoder, the choice of the quantization step size and the selection of the subset of coding passes to include in the code stream are two ways of rate control. Therefore, in addition to quantization part, the part of Tier-1 encoding after the quantization also played an important role in information loss. When the first way is used, quantization step sizes are adjusted in order to control rate. As the step sizes are increased, the rate decreases, But weaknesses have emerged. Every time the quantization step sizes are changed, the quantization indices change, and tier-1 encoding must be performed again. Since tier-1 coding requires a considerable amount of computation, this approach to rate control may not be practical in computationally-constrained encoders. When the second way is employed, the encoder knows the contribution that each coding pass makes to rate, at the same time calculates the distortion reduction associated with each coding passes^[3]. Based on pre-requested rate, the encoder can automatically discard a number of coding pass in order to decrease distortion reduction. Our experiment used the JPEG2000 implementation software: jasper. It controls the rate by the second way.

According to analysis of the previous section, because the encoder does not use the first rate control method, the quantization step size defaults to a constant value. The DWT coefficients will not be the same periodicity as JPEG. However, using the second method which discards a number of coding pass

will allow double JPEG2000 compression performance a new feature. The DWT coefficients disappeared in a cyclical phenomenon just in single compression. According to this analysis, our detection process shown in Fig.5, the DWT coefficients is extracted after the Tier-1 encoding and by the decoder.

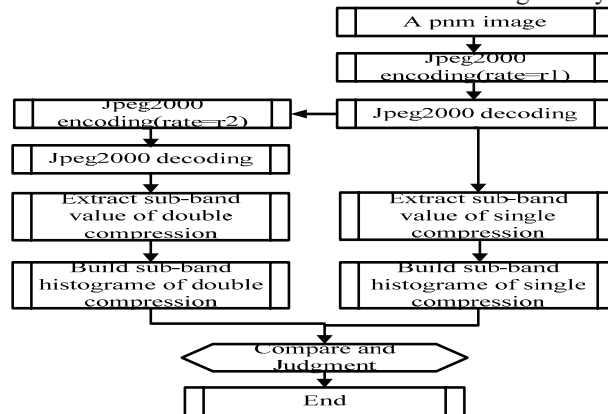


Fig. 5 Flow chart of detection of double JPEG2000 compression

The realization of this experiment using the JPEG2000 software Jasper developed by M D. Adams, and in VC ++ 6.0 experimental environment. In Fig. 5, an original image is first compressed into a JPEG2000 format images by pre-requested rate, extracting the DWT coefficients of sub-band In the process of decompression, and then constructing the DWT coefficients histogram. The decompressed image is compressed by another rate at the second time. Getting the recompressed JPEG2000 image, then we extract the DWT coefficients of sub-band and construct the frequency histogram. Finally we compare the two histograms to judge whether the JPEG2000 image is double compressed. When rate r_1 equals to 0.1, a image cats of pnm format are JPEG2000 compressed. We extract the DWT coefficients of high frequency sub-band 4HL and build histogram, as shown in Fig.6(a). The decompression image is recompressed, the default compression rate r_2 equals to 0.3, extracting the DWT coefficients of high frequency sub-band 4HL and building histogram, as shown in Fig.6(b). We clearly see that the double compression characteristics and the single compression characteristics of the DWT coefficients of the same image is different.

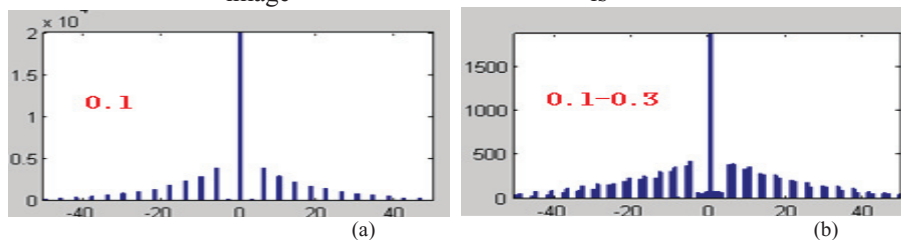


Fig. 6 Frequency histogram of 4HL sub-band DWT coefficients
Single JPEG2000 compression (a) and double JPEG2000 compression (b)

4. The Analysis of Experimental Results

In a case of the compression ratio is less than 0.2, the characteristics shown in Fig.6 is obvious. "0" value is most, away from it the "0" value decreases. But unlike JPEG images, the frequency value of the DWT coefficients in JPEG2000 image compression is obviously equal to "0" value just at single

compression. These "0" value increases when double compression. That is the DWT coefficients of single compression appearing periodic disappearance while the DWT coefficients of double compression is added increasing. Such characteristics is duo to the post compression rate distortion optimization(PCRD-opt algorithm) closely. As shown in Fig.7, the first line (a) is the DWT coefficients and the second line (b) is the frequency of the DWT coefficients.

(a)	-22	-21	-20	-19	-18	-17	-16	-15	-14	-13	-12	-11	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	434	0	0	0	475	475	0	0	541	0	0	0	675	0	0	806	0	0	0	124	0	0	14378	0	0	140	0	0	0	787	0	0	0	706	0	0	572	0	0	506	0	0	0	0	413
(b)	200	234	1	0	221	254	0	232	308	1	2	307	355	12	1	378	428	1	69	55	79	14202	83	0	74	7	385	394	1	2	340	361	3	289	274	5	4	266	231	7	5	212	192		

Fig. 7 The value of DWT coefficients and the corresponding specific frequency of JPEG2000

((a): $r_1 = 0.1$, single compression; (b): $r_1 = 0.1$ $r_2 = 0.3$, double compression)

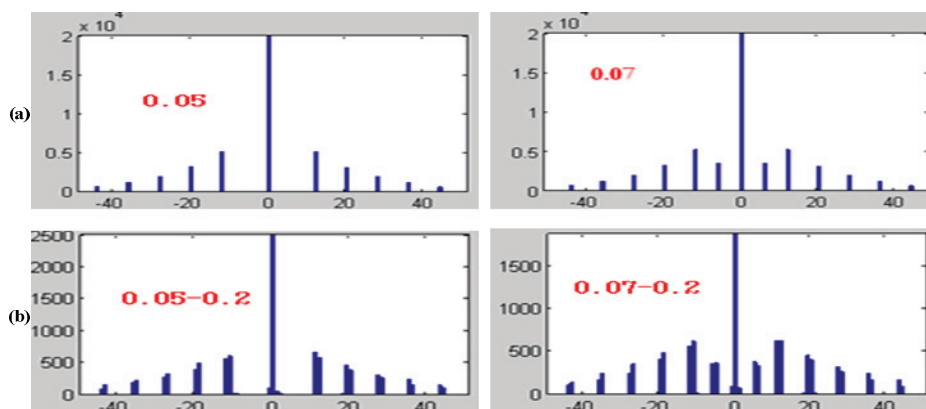


Fig. 8 Frequency histogram of 4HL sub-band of DWT coefficients

Single JPEG2000 compression (a) and double JPEG2000 compression (b)

As shown in Fig.8, in the case of $r_1 = 0.07 \& 0.05$ in single compression and $r_2 = 0.2 \& 0.2$ in double compression, the result of the experiments have the same feature. Detection method of the JPEG2000 double compression features described in this article is limited to two conditions: 1, the rate of single compression is lower than 0.2. It has been analyzed previously, at the compression ratio as described in Section 3.1, the difference feature between single compression and double compression is not obvious. 2, the compression rate of double compression is greater than the single compression.

5. Conclusions

JPEG2000 standard image has not been widely used. Fewer valuable results of research about double JPEG2000 compression is published. But because of the great superiority of the JPEG2000 standard, JPEG2000 standard is bound to replace the JPEG standard and is widely used in the near future. This paper is just a useful exploration about double JPEG2000 compression within the current technical conditions in the domestic. At appropriate compression rate, this paper presents a distinction between single JPEG2000 compression and double JPEG2000 compression in DWT statistical characteristics. But because of the methods described in this article limits to the compression rate, so this approach also needs further study in practical terms.

Acknowledgment

This work is supported by the National Natural Science Foundation of China (NSFC: 60873220), Zhejiang natural science foundation of China (ZJNSF: Y1080221, Y1090285), Ningbo Natural Science (2009A610085) and Ningbo Science & Technology Project of China (2009B10003), and Scientific Research Foundation of Zhejiang Provincial Education Department (20070974) .

References

- [1]Hany Farid. Digital Image Ballistics from JPEG Quantization Technical Report, TR2006-583, Dartmouth College, Computer Science, 2006.
- [2]DAI Meng, ZHAO Xue-zhou. The Analysis and Detection of Double JPEG Compression. *Journal of Image and Graphics*, 2009,12 (14) :2599-2602.
- [3]M.D. Adams. The JPEG-2000 still image compression standard, ISO/IEC JTC 1/SC 29/WG 1, Document N2412, September 2001.
- [4](Japan)Sadayasu Ono, Junji Suzuki. *JPEG2000 Technology*. Beijing: Science Press, April 2004.
- [5]ZHOU Lin-na. Digital image forensics technology: Ph.D. thesis, Beijing: Beijing University of Posts and Telecommunications, 2007.
- [6]Alin C.Popescu, Hany Farid. Statistical Tools for Digital Forensics. In *Proceedings of the 6th Information Hiding Workshop*, May 2004.
- [7]M.D. Adams,Faouzi Kossentini.Jasper:A Software-Based JPEG2000 Codec Implementation. *ICIP.2000*. vol.2. 53-56.
- [8]Mikhail Sizintsev, Konstantinos G. Derpanis, Andrew Hogue. Histogram-based Search: A Comparative Study.: *IEEE Conference on CVPR 2008* June. 23-28.