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EFFECTS OF DOUBLE JPEG COMPRESSION ON STEGANALYSIS

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Abstract:

Double compression is quite common due to image forgery and specific steganographic algorithms. It would notably impact results of steganalysis if not treated properly. This paper discusses the effects of double compression to steganalysis. Then, we evaluate the effect of double compression using L-GEM based RBFNN in comparison to widely adopted SVMs.

Keywords:

Double JPEG compression; L-GEM; Steganalysis

1. INTRODUCTION

Double JPEG compression (DC) means decompressing a JPEG image with its original Quantization Table (QT) and then quantizing it again with another quantization table. The second quantization table could be either the same to the original quantization table or not. Basic idea of double compression is shown in Figure 1. Q1 and Q2 denote the primary quantization matrix and the secondary quantization matrix as in [1], respectively.

Double compression is rather common among JPEG images. On one hand, image forgery usually tampers a JPEG image to disguise it as an authentic image, which would introduce another compression and hence another QT. If double compression can be detected and even restored, image forgery will be identified and located. On the other hand, it is significant for steganalysis to accurately detect double compression. Some famous steganographic algorithms such as JSteg [2], F5 [3] and OutGuess [4] double compress the input JPEG image with designated quality factors. For examples, F5's default quality factor is 80 while OutGuess's is 75. Neglecting the impact of double compression may mislead the steganalysis system and produce notably inaccurate results.

Discrimination between the JPEG images being singly compressed and those being doubly compressed will be discussed in two cases.

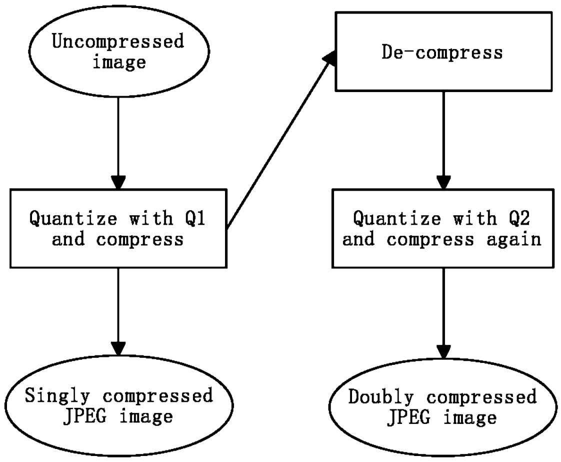

Figure 1. Diagram of Single Compression (SC) and Double Compression (DC).

In the first case, the image is doubly compressed by a secondary QT different from the primary QT ($Q1 \neq Q2$).

Under this circumstance, histogram of DCT coefficients for the JPEG image singly compressed obeys generalized Gaussian distribution, while the JPEG image doubly compressed does not [5]. In [1], T. Pevný et al point out that the histogram of DCT coefficients shows abnormal zeros and double peaks [6, 7], which could be treated as artifacts of DC. Therefore, abnormal zeros could be utilized to help detecting DC. Moreover, T. Pevný proposed three ways to estimate the primary QT.

A.C. Popescu and H. Farid claimed that the histograms of DCT coefficients for double compressed images demonstrate periodic patterns [8], and hence we can decide whether a JPEG image has been doubly compressed using pattern recognition techniques.C. Chen et al [9] improved A.C. Popescu and H. Farid's method and proposed a feature set of 324 elements. From their experiments using SVM as classifier, their algorithm outperforms Popescu's.

D. Fu et al [10] found that first few digits of the JPEG image coefficients obey the generalized Benford's law. Fu's

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experiments proved the reliability of their proposed model in detecting double compression of JPEG images which severely violated generalized Benford's law.

In the second case, the JPEG image is doubly compressed by the same QT （Q1 = Q2）. Although rounding error and quantization error are introduced, the histogram of DCT coefficients still obeys generalized Gaussian distribution. Discrimination between singly compressed images and doubly compressed images is difficult. Fortunately, in steganalysis, the aim is to detect the existence of stego in image instead of detection of double compression.

To the best of our knowledge, it was F. Huang et al that first developed a method to detect double compression by the same QT. They [11] discussed double compression with the same QT and proposed a method based on the random perturbation strategy. According to their experiments, the lower the quality factor is, the less reliable the detection results. On some particular conditions, Huang's algorithm can detect triple compression or even four times compression.

Pevný and Fridrich [12] proposed a multi-class steganalyzer as shown in Figure 2. The steganalysis system firstly determines whether the image is doubly compressed. If it is a doubly compressed image, its quality factor is estimated and then the image is sent to a multiple classifier corresponding to images with double-compression. Otherwise, the image is sent to a multiple classifier corresponding to images with single-compression.

Ignoring the widespread of doubly compressed images would likely result in disaster for steganalysis and huge risk in security. As shown in Figure 2, inaccurate detection of double compression (misjudge singly compressed images as doubly compressed images, or false positives) would lead to the use of inappropriate steganalysis classifier [12]. In contrast, mistakenly classifying doubly compressed images as singly compressed images may yield a smaller problem.

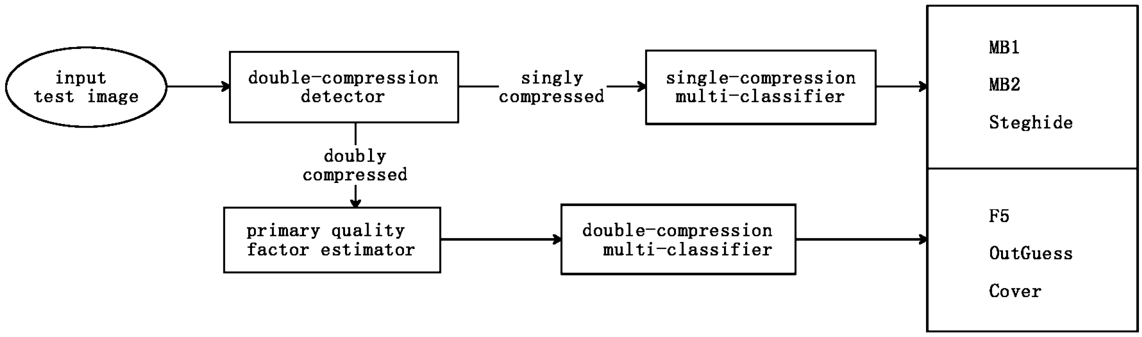

Figure 2. Multi-class steganalyzers in [12]

The rest of this paper is organized as follows. In Section 2, we exhibit the differences among JPEG images compressed once with the quality factor 75, the JPEG images compressed twice with the same quality factor 75, and those compressed first with the quality factor 80 then with the quality factor 75. We will provide a brief on methods being compared in Section 3. Comparison between our method and the others' are shown in Section 4. Section 5 concludes this work.

2. DOUBLE JPEG COMPRESSION

Fundamentals of JPEG format and further explanation of double compression are the main topics of this section.

When we get an raw image, e.g. a TIFF image, we first pre-process it and divide it into 8×8 pixels blocks. Then, apply the discrete cosine transform (DCT) to each block, which is a lossless and reversible transform. The DCT coefficient matrix is divided by a quantization matrix of a selected quality factor. In this work, only standard quantization matrices are studied and each of them is represented by a quality factor. Non-standard quantization matrices are common on the Internet. Our studies in this work could be extended to non-standard quantization matrices directly. In other words, we quantize the image (the quantization process may be lossy). Finally, the processed image will be entropy coded. Figure 3 shows standard procedures of compressing a JPEG image.

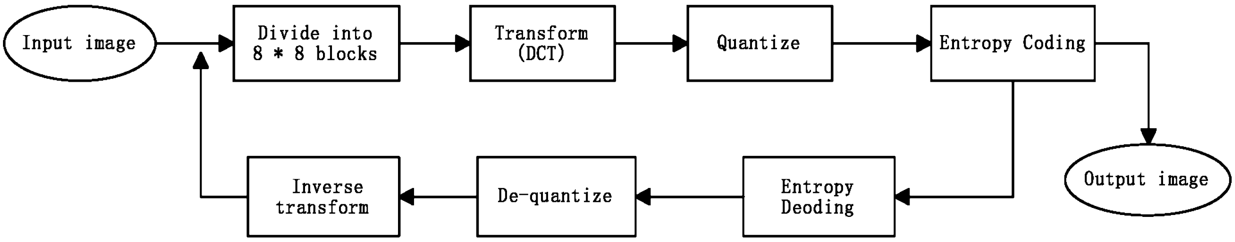

Figure 3. JPEG compression and double compression

The double compression process is to de-quantize the JPEG image back to DCT coefficients and to apply another quantization matrix (either the same or different quantization matrix) for re-compression. Double compression may disturb the distribution of DCT coefficients and introduce slight differences in visual content.

As stated above, there exist statistical differences between features of singly compressed JPEG images and doubly compressed JPEG images, even between those compressed with the same quantization matrix. The histograms of DCT coefficients for both kinds of image are calculated and shown in Figure 4.

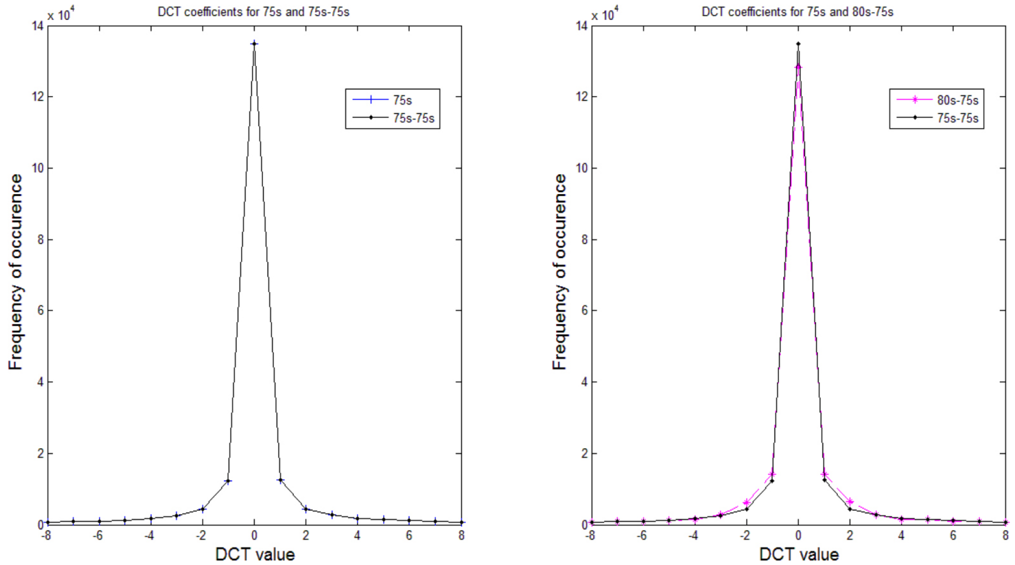

Figure 4. Distribution of DCT coefficients for 75s, 75s-75s and 80s-75s images selected from UCID image database.

From Figure 4, we can find that differences exist and hence they can be extracted as features to detect double compression. Also, we can draw the conclusion that the discrimination between those images doubly compressed with the same quantization matrix is almost imperceptible. It is not easy to distinguish 75s images from 75s-75s images using only histogram distribution shown in Figure 4. According to [11], the number of different DCT coefficients between the two consecutive compressions will monotonically decrease and eventually tend to zero even for repeated compression using the same quantization matrix.

To conclude, patterns will be introduced to the compressed JPEG image even being double compressed with the same quantization matrix. Most steganalysis feature sets and our previously proposed L-GEM based steganalysis method are designed for the detection of single compression, and hence we will test whether they can be applied to detecting stego image of double compression.

3. The Steganalysis METHODs

As stated above, detection of double compression is significant to steganalysis and to recover the trace of image forgery. In this section, we propose our method for analyzing the influences of double JPEG compression on steganalysis.

In this work, we compare widely used Support Vector

Machine (SVM) with the L-GEM based Radial Basis Function Neural Networks (RBFNN) for steganalysis proposed in [17]. SVM [16] is widely adopted by steganalysis methods and Gaussian kernel will be used in this work. Hyper-parameters of SVM are optimized using grid search.

RBFNN is employed as the classifier to classify cover image and stego image. L-GEM (Local Generalization Error Model) [15] is adopted to select the architecture of the RBFNN to improve its generalization capability. The L-GEM provides better results because it selects a proper architecture for RBFNN considering both training error and sensitivity. It is also the goal of steganalysis that we want the classifier to recognize stego and cover images correctly which are similar to the training images. [7] has shown the high performance of steganalysis using L-GEM.

We will perform two tests. Firstly, we train classifiers (both RBFNNs with L-GEM and C-SVM) using singly compressed cover and stego JPEG images, and test on both singly and doubly compressed images. Secondly, we train classifiers using doubly compressed cover and stego JPEG images, but still test on both singly and doubly compressed images. This is to investigate a better approach for steganalysis assuming doubly compressed images occur.

In other words, we train classifiers with singly compressed images and doubly compressed separately, and then test trained classifiers with both singly and doubly compressed images. For example, we train classifier with 75s cover images and 75s MB1 stego images, and then test the classifier with both 75s and 80s-75s images with both cover images and MB1 stego images. 80s-75s denotes double compressed image which is compressed by quality factor 80 and then re-compressed by quality factor 75. After that, we train classifiers with 80s-75s cover images and MB1 stego images, and then test it with 75s and 80s-75s images, both cover images and MB1 stego images. In this way, we could find the differences in performance of L-GEM based RBFNN and SVM when they are trained using either single or double compression JPEG images.

4. EXPERIMENTAL RESULTS

All our images used in both training and testing datasets come from UCID [14]. The steganographic algorithms used in experiments are MB1, MB2 and Steghide. The CHEN features (486 dimensions in total), which are proposed by C. Chen and Y. Q. Shi in [17] are employed to extract features from image datasets.

Before conducting the experiment, we first compress all 1338 UCID images with the quality factor 75 and 80 separately. Secondly, we apply MB1, MB2 and Steghide to half (669) of the singly compressed images, and choose 334 stego images as the training dataset randomly and the rest 335 stego images are used for the testing dataset. Every steganographic algorithm is applied in the same way to obtain 3 different datasets which each consists of cover and stego images. MB1, MB2 and Steghide are performed to JPEG images separately with 0.05 bpnc (bit per non-zero coefficient).

Thirdly, we compress all singly compressed cover images again with quality factor 75. Then we apply MB1, MB2, Steghide to half (669) of the doubly compressed images, and choose 334 stego images as training dataset and 335 stego images as testing dataset.

We use 75s and 80s-75s to denote images compressed once with the quality factor 75 and images compressed twice firstly with the quality factor 80 then with 75.

We conduct two experiments. In the first experiment, we train classifiers using 75s images with both cover images and stego images, and then test the classifier with both 75s and 80s-75s images. In the second experiment, we train classifiers using 80s-75s images, and then test the classifier with both 75s image and 80s-75s images.

TABLE 1. Testing Accuracies OF RBFNN Optimized by L-GEM (Best accuracies are highlighted by Bolded digits)

Test Accuracy (%)		**MB1**	**MB2**	**Steghide**
TRAIN 75s	***TEST 75s***	**77.1642**	81.9403	**95.2239**
	TEST 80s-75s	**55.2239**	**70.1493**	**90.2985**
TRAIN 80s-75s	***TEST 75s***	**55.3731**	**56.2687**	**91.6418**
	TEST 80s-75s	**81.9403**	**85.8209**	**94.0299**

TABLE 2. Testing Accuracies OF SVM (Best accuracies are highlighted by Bolded digits)

Test Accuracy (%)		MB1	MB2	Steghide
TRAIN 75s	***TEST 75s***	75.3731	**82.0896**	94.1791
	TEST 80s-75s	53.7313	62.8358	80.4478
TRAIN 80s-75s	***TEST 75s***	50.1493	50.1493	87.9104
	TEST 80s-75s	80.4478	85.2239	93.7313

Tables 1 and 2 show that the L-GEM based RBFNNs perform better in overall, except the MB2 trained and tested using both 75s. When training and testing images are compressed using different times of compressions, L-GEM based RBFNNs perform better than SVM. If testing and training images are compressed with the same number of compressions, SVM perform only a little bit worse than the RBFNN optimized by the L-GEM. Ignoring singly and doubly compressed JPEG images would greatly affect the performance of the steganalysis.

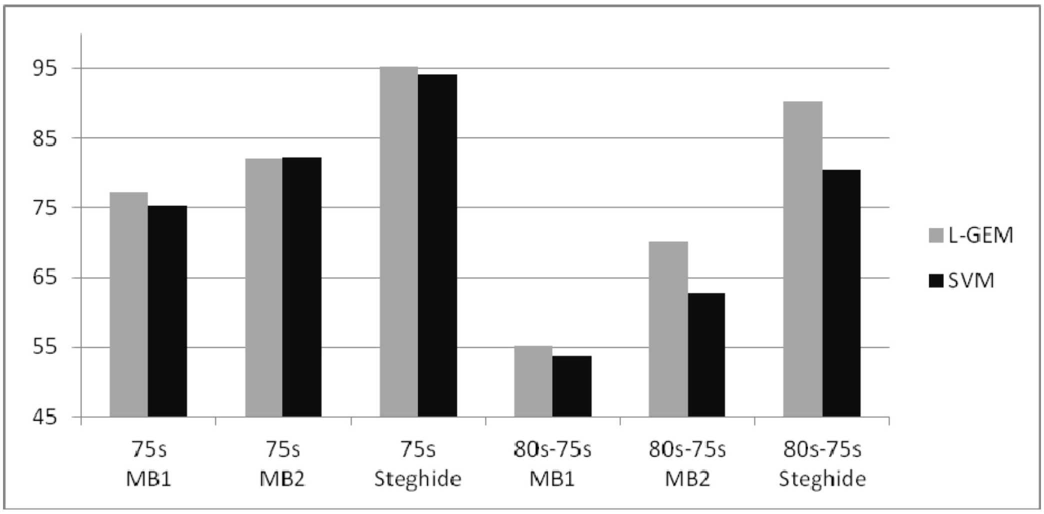

Figure 5. TRAIN with 75S, TEST with 75S AND 80S-75S.

Comparison between results of the RBFNN using L-GEM and SVM. The horizontal axis represents cover images or stego images applied to different steganographic algorithms. The vertical axis represents the percent of test accuracy in different cases.

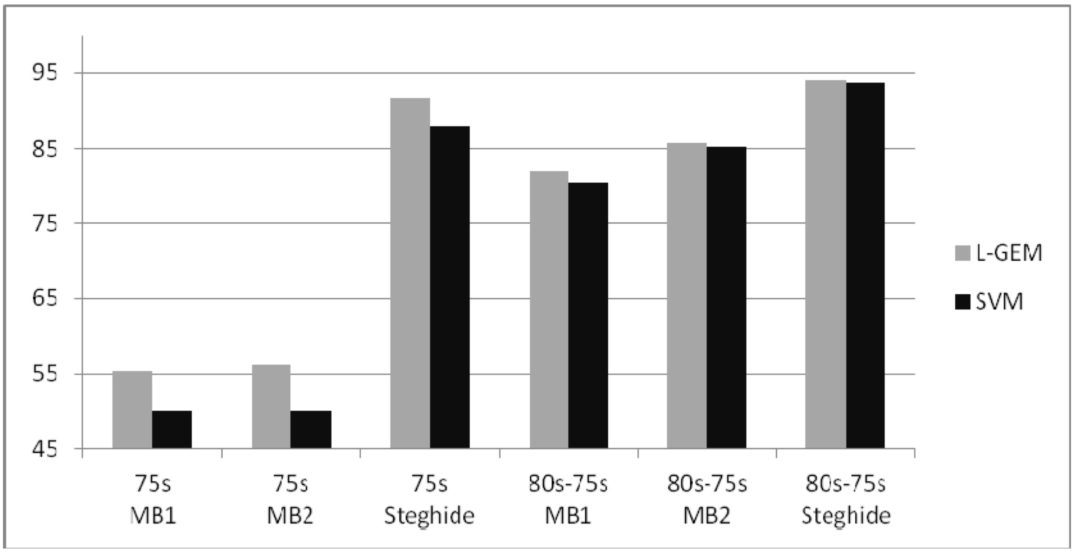

Figure 6. TRAIN with 80S-75S, TEST with 75S AND 80S-75S.

5. Conclusion

Double JPEG compression is rather common among the widely used JPEG images and it would influence steganalysis to a notable extent. A steganalysis system that can detect both single and double compression images accurately is of great use. The RBFNNs optimized by L-GEM with an appropriate choice of feature set yield good generalization capability for both singly and doubly compressed JPEG images in steganalysis. The Accurate detection of double compression would facilitate further research of steganalysis.

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