Research on small embedding rate of universal steganalysis based on rich model

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Abstract

In order to solve the problem that detection rate will be lower than normal value when the embedding rate is small, this paper proposes a small embedding rate of universal steganalysis method based on rich model. This method is that corresponding feature set is extracted from the noise component model and texture component model. First, some features, which are extracted from wave contour analysis, neighborhood linear prediction and image de-noising analysis, are calibrated so as to reflect variation due to embedding secret information preferably. Finally, use ensemble classifier, which verifies whether the image contains hidden information, to classify. Simultaneously, this paper adds a predictive image in order to remove the characteristic of the image itself. The experimental results show that the correct detection rate exceeds eighty-four percent when the embedded quantity is higher than 1 KB and this method has higher reliability by comparing with the existing literature.

Keywords: universal steganalysis; rich model; ensemble classifier; small embedding rate

1 Introduction

With the rapid development of the Internet and digital media technology, a lot of steganalysis methods also emerged so that people can conveniently use all kind of steganalysis tools. However, these tools abused make network security challenged. Hence, steganalysis has attracted more and more attention. Steganographic analysis is divided into two main categories: specific steganographic analysis [1-4] and general steganographic analysis. Specific steganographic analysis extracts the spectral feature to detect effectively some feature of carrier image change which based on the change specific steganographic process. Therefore, detection rate is higher but is not reasonable. However, the main idea of general steganographic analysis is to seek statistical feature vectors of independent steganographic algorithm according to whether it contains secret information--the change of statistical properties of carrier judges. From a practical point of view, general steganographic algorithm has very good development prospect [5].

Avicibas et al. [6] came up with the concept of universal steganalysis firstly, and he introduced a universal steganalysis method based on IQM (Image Quality Metrics); subsequently, Farid [7] and Shi [8] introduced steganalysis method based on different features, but they researched on only one feature. Lie [9] et al. pointed out the ability of single feature that usually do not distinguish the secret signal from original signal effectively and introduced a blind detection method combining spatial feature with DCT feature. Zhuo Li [10] et al. realized a JPEG image universal steganalysis method which extracts statistical features from multiple domains in order to improve the blind detection rate of image information steganography. Tingli Li [11] introduced universal steganalysis method of small embedding rate based on multiple-domain features according to the different trait of JPEG and BMP image. The method extracts features from spatial domain, DCT domain and DWT domain, integrating features, then, views support vector machine as classifier judges effectively. This method has stronger detection results when embedding quantity is more than 2KB. With the passage of time, single carrier image format has not been satisfied people's demand. Luo [12]et al. who based on Lie, improved spatial feature extraction method combining with the feature of DWT domain, and used the BP neural network classifier to propose a blind detection method, which can simultaneously detect both BMP and JPEG image formats, of image information steganography based on three-domain feature. Jessica Fridrich et al. [13] introduced analysis detection method which can detect secret information of different image formats, particularly which is better for 8-bit GIF image results than chi-square method of attack and the RS method mentioned. Du et al. [14] pointed out that, whether change coefficient of discrete cosine or change the image pixels, JPEG and GIF image was detected based on that the incoming noise would affect the smooth image.

Studies have shown that we can combine with the differences of the different domain features which comprise Rich model as much as possible, and then identify by ensemble classifier. It can effectively improve the detection performance of steganographic analysis algorithm and strong adapt to the new steganography algorithm [15]. Jessica Fridrich et al. introduced a new method about hiding information detection in the literature

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[15]. The method began with abundant assembly noise component model. Noise component model composed of the residual noise of quantitative image is got by linear and nonlinear high-pass filter. Classifier is viewed as component assembly model because of that ensemble classifier has low computing complexity and effectively trains high dimensional feature space and large feature set. When trained spatial component model, HUGO, edge adaptive and optimal ternary coding algorithm ± 1 are selected. For each algorithm, we can adopt simple submodel method in order to improve the precision of the dimension of each model. The experimental results show that ensemble classifier is faster nearly one hundred times than the G-SVM classification. Jan Kodovsky [16] et al. built Rich model about the DCT coefficients of JPEG image, which captured changes in the cause of the embedding secret information. The model comprises strong dependent spatial adjacent coefficient and joint probability density of submodel of DCT coefficient. Due to its high dimension, the integrated classifier and rich model of this method and rich model build detector based on the six kinds of steganographic algorithm,Six kinds of steganographic methods include F5, MB, YASS, MME, BCH and BCHopt. From the view of accuracy and efficiency, comparing experimental results with high-dimensional or low-dimensional features mentioned currently proposed that whether the single submodel, Descartes proofreading mode or Rich model has advantages. The basic principle of Rich model based on steganalysis is building selective steganography program of submodel firstly. This paper uses the eight kinds of steganography programs, include Jsteg, Jphide, Outguess, PMK, Stools, LSB, EzStego and F5 algorithm, according that trained different submodel does not distinguish image format; the second, other sensitive features because of embedded secret information of carrier image, are extracted. This article extracts residual noise and domain linear prediction statistic feature based on noise feature and local DCT transform convolution template based on local texture feature; the last, the extracted submodel is packaged and trained so as to get a final classified detector by using ensemble classifier, then detecting image is classified accurately, and achieve steganalysis method based on Rich model.

2 Feature extraction

2.1 NOISE COMPONENT MODEL

1) Residual noise statistical characteristic.

In the process of feature extraction, reducing the original image content and noise with gathering image as far as possible because it greatly depends upon whether the extracted features are sensitive to embed secret information. During image de-nosing application, the composition of the image information has a certain structural features, which are consistent with the structure of the atom, but noise doesn't have the same structure feature. Therefore, useful information of image and noise distinguish effectively, and ultimately achieve the purpose of de-noising. It can reconstruct the original image by de-noising method and get the residual noise because the hiding information can be modeled and superimposed with image noise. The residual noise, which enhance signal noise ratio, can extract sensitive features. Hence, adaptive Wiener filtering, which removes the noise of image itself in the high frequency sub-band, improves the extracted sensitivity of features. Wiener (Wiener) filter, also known as the least square filter and is one of the commonly used algorithms to degrade and restore image. Mathematical form as follows:

$$F(u,v)=\frac{1}{H(u,v)}\cdot\frac{|H(u,v)|^2}{|H(u,v)|^2+k}\cdot G(u,v), \tag{1}$$

where k is a constant (compose of the original image power spectrum and noise power spectrum and is commonly 0.5). $H(u,v)$, $G(u,v)$ are defined as filter system function. Firstly, selected 4 $N*N$ neighborhood template is used to calculate the local variance, N={3,5,7,9}.As follows:

$$\delta_N^2(i,j)=\max\left(0,\frac{1}{N^2}\sum_{(i,j)\in N}w^2(i,j)-\frac{1}{2}\right), \tag{2}$$

where $w^2(i,j)$ is square of contour wave coefficient in the neighborhood and the selected minimum

$$\delta^2(i,j)=\min\left(\delta_N^2(i,j)\right), \tag{3}$$

where N={3,5,7,9}.

Using adaptive wiener filtering (AWF) to de-noise, as:

$$Z_{den}(i,j)=Z_m(i,j)\frac{\delta^2(i,j)}{\delta^2(i,j)+0.5}. \tag{4}$$

Calculating the residual, as follows:

$$C_{den}(i,j)=Z_m(i,j)-Z_{den}(i,j). \tag{5}$$

After getting a residual for each sub-band, it calculates mean value, peak and skewness of high frequency sub-band and variance statistical feature.

2) Neighborhood linear prediction statistic feature.

After contour wave decomposed, coefficient amplitudes with the same direction have a strong correlation that will be affected by the embedded secret information. Select prediction coefficients of four adjacent coefficients in the horizontal and vertical directions, and the coefficients of the other three sub-bands in the same direction at the same deposition.

$$\begin{aligned}|c_n(i,j)|=&\omega_1|c_n(i,j+1)|+\omega_2|c_n(i,j-1)|+\omega_3|c_n(i-1,j)|\\&+\omega_4|c_n(i+1,j)|+\sum_{a=1}^{3}\omega_{a+4}|c_{a(i,j)}|\end{aligned}, \tag{6}$$

where $c_n(i, j)$ is defined as the coefficient amplitude of the position of the subband n and transformed into vector form as follows:

$$C = Q\omega, \tag{7}$$

where C is defined as $c_n(i, j)$ matrix, and Q is defined as amplitudes of adjacent subband coefficients matrix. So mean square deviation is defined as error of the predicted values compared with the original coefficient:

$$E(\omega) = \|C - Q\omega\|^2. \tag{8}$$

Get weight and liner prediction error by derivation, and other sub-band prediction can be got in the same way. The last, calculate mean value, skewness, variance and peak of the error value of the 8 different direction sub-bands.

2.2 TEXTURE COMPONENT MODEL

In the process of image processing, the process of using a series of small size convolution template to convolve, is called local linear transformation. The purpose of this method is counting convolution output of local linear transformation, and these statistical data can well describe the texture characteristics of the image. Local DCT transform is a typical local linear transformation and local DCT transform convolution templates belong to orthogonal template. AVCIBASI et al. confirmed that local DCT transform convolution templates and Gabor filters have the similar characterization characteristic. Therefore, the local DCT transform has good spatial domain and frequency domain characterization capability, and identifies well image texture.

From some universal steganalysis analysis algorithm, feature vectors extracted from the high frequency sub-bands of contour wavelet domain are very effective for steganographic analysis. Because the steganographic algorithm mostly is secret information embedded in the image high-frequency, easier to extract abnormality in the high frequency subb cause of embedding secret information. Meanwhile, from the perspective of image texture, this paper studies the abnormality which is viewed as much random textures due to the appearance of hidden information embedded into high frequency part, so the classification method based on local linear transformation can be very good identification random texture, to discern whether is image hidden secret information. Local linear transform domain will be set to the observed field by steganalysis and the corresponding feature extraction.

In the classification method based on DCT, there are three one-dimensional DCT basis vectors: U1=[1,1,1]T; U2=[1,0,-1]T and U3=[1,-2,1]T U1, U2 and U3 are multiplied to produce a set of mutually independent two-dimensional DCT convolution kernels. Two-dimensional convolution kernel generating method is as follows:

$$V_{i,j} = U_i U_j^T, \tag{9}$$

where $(i.j \in \{1,2,3\})$.

X is defined as being detected image. Firstly, X and $V_{i,j}, (i, j) \in \{(1,3),(2,2),(2,3),(3,1),(3,2),(3,3)\}$, for convolution, denoted output is that:

$$Y_{i,j} = X * V_{i,j}. \tag{10}$$

The output $Y_{i,j}$ is the high frequency DCT transform coefficients, while removing the low frequency coefficients of Y1,1, Y1,2 and Y2,1. It is worth noting that one-dimensional vector W in local DCT transform has a good ability to distinguish in the real application. Therefore, this article introduces four local linear transform convolution kernels for better distinguishing the target image. The convolution kernels are equivalent to the second order gradient operators of the horizontal, vertical, the principal diagonal and the minor diagonal. These second order gradient operators can be a good measure of the correlation between adjacent pixels in all direction. In addition, the second order gradient operator can find the inflection point, so they can detect noise on smooth region and noise on the edge of the ladder. As a result, their features will be effectively detected adaptive steganographic algorithm with data embedding on the edge of the ladder. Let X and $W \downarrow k$ $(k \in \{1,2,3,4\})$ convolution calculation, Z_k is defined as follows:

$$Z_k = X * W_k, \tag{11}$$

where $k \in \{1,2,3,4\}$. Next, to convolute the image, calculate the probability density function of $Y_{i,j}$ and Z_k, where $(i, j) \in \{(1,3),(2,2),(2,3),(3,1),(3,2),(3,3)\}$, $k \in \{1,2,3,4\}$.

3 Integrated classifier design

Integrated classification was first proposed by Hansen and Salamon [17] in an unintentional experiment. In the experiment, they used a neural network to solve related problems and tried to combine with the neural network to solve by domino voting method. On the surface its performance should be between the best and the worst, but the end result is better than the best individual neural network. Since then, the integration technology in many other fields has achieved excellent results.

Integrated classifier is mutually independent decision-making ability between two or more classifiers combination. It turns out to be that the prediction ability of integrated classifier is much better than the prediction ability of single classifier. Integrated classifier can solve the hypothetically little space, small amount of training data and local optimal problems for single classifier.

Assuming the training data set to T, including {(xi, yi) i=1,2,…,*N*}, y is a classification label. For the steganographic analysis, y only has two values which

represent the image carrier or the carrier secret images. For Forecast function of F(x,T), the classification is given by the value of x and y values obtained by predicting the function process. And the structure of the integrated classifier informs prediction function set Fm(x,D) by the way of using integrated learning.

Predictor variable vector X are obtained to generate prediction values {0,1} by feature extraction, classifier $f(x)$, then acquire the error rate on the training sample image:

$$\varepsilon = \frac{1}{N}\sum_{i=1}^{N} I(y_i \neq f(x_i)). \tag{12}$$

To produce a series of classifier by using the method of Boosting $f_m(x)$, with m=1,2,…,M. Then, each classifier is weighted and merged, to get the final result:

$$f(x) = sign(\sum_{m=1}^{M} \varphi_m f_m(x)), \tag{13}$$

φ_m whose role is to weight for $f_m(x)$ in order to improve the influence of classification accuracy of classifiers, is obtained by Boosting algorithm. The main idea of the training integrated classifier is: First of all, a sampling weight of all samples (under normal circumstances, at the beginning of the same weight), trains a classifier classifies to sample on this sample to get the error rate of classifier. Then, re-assigned a weight according to the error rate, this misclassification increased sampling weights, and so it will focus on the wrong sample when the next classifier trains, iteration in turn. Finally, the classifier is a weighted sum of the multiple classifiers.

4 Experimental results and analysis

All the experimental data are obtained in this article under the Core Duo CPU 2GHz, 2GB RAM, WINDOWS7 operating environment with MATLAB2012b and SVM (support vector machine) classifier, and experimental images are selected from standard image library of NRCS, UCID and USC-SIPI. JPEG images use 1004 of the NRCS gallery and 24 of the standard image library, BMP images use 1014 of the NRCS Gallery sinks and 24 of the standard image library, and GIF images use1338 TIFF format image of the UCID image library. Matlab program with a disturbance transform them into GIF images. Image content which covers range is a very wide, including natural scenery (such as, trees, mountains, rivers, flowers, etc.), artificial facilities (such as buildings, bridges, streets, cars, etc.), as well as human portrait and animal close-up and so on. For the convenience of calculation and testing, all forms of image are cut into 512×512 format according to the center.

For the image of different formats, the existing steganographic algorithm is more. As a result of the limitation of space, the paper selects several typical steganographic methods to test. The three relatively popular steganography methods selected, include Jsteg, Jphide, Outguess are regarded as detection object for the carrier of JPEG format; the three common steganography methods Selected, include PMK, Stools and LSB, are regarded as detection object for the carrier of BMP format; For the GIF image format, select EzStego and F5 steganographic algorithm to implement the embedment of secret information to get steganographic images. 100 images are randomly selected as test images each group and the remaining images are supported to train vector machine. Taking into account the error in the selection of a test image, this paper takes 10 times test average to reduce error of the selection of a test image form.

Experiment is divided into two main parts: individual training and testing, comprehensive training and testing. Individual training and testing refers to a specific format of the carrier which takes advantage of part of the original image and steganographic image to train and test steganographic image that use different steganographic methods to achieve; comprehensive training and testing refers to use some of the original image and the three different formats of the carrier images by the different steganographic to generate generated steganographic image which is to train together, and test the corresponding to the other steganographic image.

First, to individual training and testing, the results are shown in Table 1. Table 1 shows test result for different format carriers alone, which is slightly lower than the general steganographic analysis method due to its general characteristics, but also achieves a better detection.

TABLE 1 The test result of the universal steganalysis performance of three image formats

Carrier formats	Steganographic methods	Detection rate（%）		
		TPR	TNR	ACC
JPEG	Jsteg	92.3	93.1	92.60
JPEG	Jphide	89.6	93.0	91.30
JPEG	Outguess	86.9	90.4	88.65
BMP	PMK	92.4	85.7	89.05
BMP	Stools	88.4	87.2	87.80
BMP	LSB	90.0	83.9	87.05
GIF	EzStego	72.4	79.8	76.10
GIF	F5	88.5	91.6	90.05

Contrast separately test with small embedding rate of single format documents in this article to these effects in the following Table 2:

TABLE 2 Algorithm testing results compared with the literature [11]

Carrier formats	**Embedded quantity (KB)**	**Detection rate（%）**	
		literature [11]	this article
JPEG	1	95	86.68
JPEG	2	98	90.85
BMP	1	62	82.13
BMP	2	84.5	87.97
GIF	1	-	79.20
GIF	2	-	83.08
Average Detection rate		73.25	84.99

From the experimental data in Table 2, when compared with the literature [11], it can be seen that a single JPEG image format is no high detection rate than literature [11] in the case of two different embedding quantity, but this article algorithm has absolute advantage on the average detection rate, and using a method to detect three image formats, at the same time, the method of literature [11] is carried out by the corresponding detection methods. The reason why the detective effect of a single JPEG format has no good than literature [11] is that: the literature [11] extracts the feature set for JPEG image format and more easily captures the change caused by embedding information, however this paper is based on multi-carrier, and also takes into account the BMP and GIF image formats while thinking about JPEG format.

Overall analysis: in this paper, the method is better than the accuracy of the detection in literature [11]. Literature [11] analyses only one image format and extracts the statistical characteristics due to the embedded information changed in the corresponding format, while this paper find out the common features due to the embedded information changed by deeply researching the internal structure of all kinds of formats of the images. For example, it has noise features and texture features for any image.

TABLE 3 The comprehensive testing results compared with the literature [12]

Carrier formats	**Embedded quantity (KB)**	**Detection rate（%）**	
		literature [12]	this article
JPEG	1	-	79.4
JPEG	2	52.4	87.2
BMP	1	51.8	72.7
BMP	2	59.7	86.8
GIF	1	-	72
GIF	2	-	78.4
Average Detection rate		54.63	84.13

This article chooses a different embedded quantity for comprehensive training and testing, respectively 1KB and 2KB, and compares with the literature [12] which can detect two kinds of formats image. The results are shown in Table 3.

From the experimental results of the comprehensive test shows: the algorithm in this paper can effectively detect JPEG, BMP, GIF, three different storage format images of the carrier, and has a higher detection rate when embedded quantity is smaller. In comparison with the literature [12], all the effect of testing results are better than the literature [12], especially effective in detection of GIF images, but the method of literature [12] almost fails to the detection of a small embedded quantity of the steganography. The reason is that: literature [12] is decomposed into three dimensions by wavelet packet transform and counts high-order moments of the histogram feature function from time-frequency sub-band. When embedded quantity is a small amount, high-order moments of the histogram feature function is not affected. In this paper, the outline of the wavelet transform has time-frequency local features of the small wavelet transform and multi-resolution features, at the same time, also has the very strong anisotropy and directional selectivity in order to better express the image characteristics and has the congenital advantage; because the hidden information can be superimposed on the image noise modeling, so you can take advantage of de-noising method to reconstruct the original image, and to obtain the residual noise, which captures changes caused by embedding secret information.

The primary purpose is to effectively distinguish right between carrier image and carrier density image for steganalysis algorithm of image. Since steganalysis algorithm is unlikely to reach 100% accurate detection, and the detected carrier density image and the actual carrier density image is different, so we need to introduce a metrics of the accuracy of the analytical performance of steganography detection. The true positive rate and the

false positive rate are plotted as a curve, namely the ROC curves [18] (Receiver Operating Characteristic Curve) which measures the right rate of the carrier detection.

In order to more clearly see the advantages of this algorithm, and Figure 1 shows two different embedding quantity of ROC curve of the JPEG images in the case of a single test, and Figure 2 and Figure 3 show contrastive ROC curve which are in literature [11] and [12].

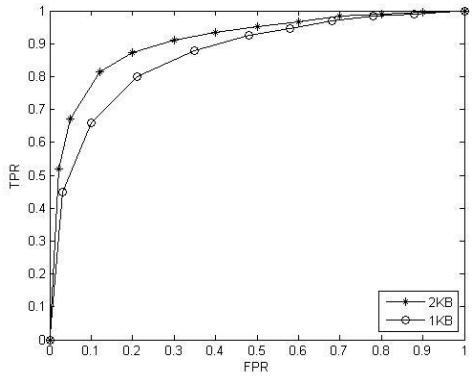

FIGURE 1 Two different embedding quantity of ROC curve based on JPEG image separate test

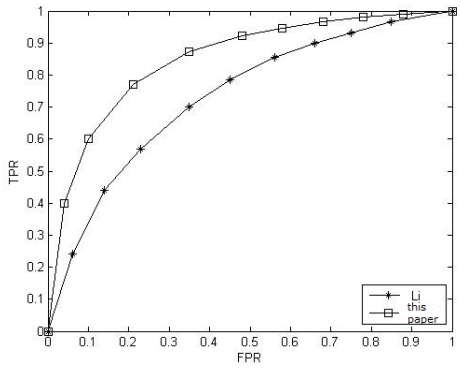

FIGURE 2 ROC curve of contrasting with literature [11]

1) It can be seen from Figure 1 that detective rate will reach to about 90% when embedding quantity is 1KB or 2KB for the Jpeg format images. Compared with a single steganalysis method, it is more similar.

2) We did a lot of experiments for the three different formats of images, and the average test result keeps stable at 85%, so you can consider this algorithm has good stability.

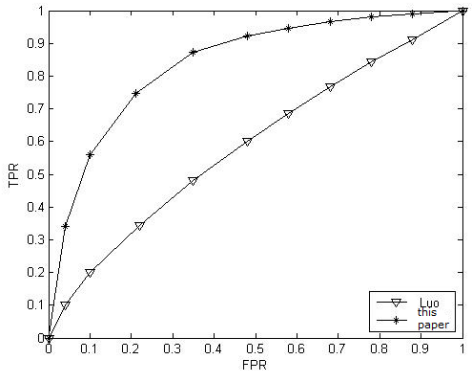

FIGURE 3 ROC curve that comprehensive test contrast with literature [12]

3) As shown in Figure 2 and 3, either the effective steganalysis method of a single format or detecting two formats of steganalysis method, the paper has a higher detection rate, which is 11% higher than the literature [11], and nearly 30% higher than the literature [12]. Therefore, we can consider this algorithm has good versatility.

5 Conclusion

In order to solve the problem that when the embedded rate is small based on multi-vector steganalysis algorithm for the current literature, this paper proposes a small embedding rate of universal steganalysis method that based on rich model. This method is that corresponding feature set is extracted from the noise component model and texture component model. First, some features are extracted from wave contour analysis, neighborhood linear prediction and image de-noising analysis and informed to features are calibrated, and inform feature set. Finally, use integrated classifier to classify. The experimental results show that compared with the existing literature, the correct detection rate is over 84% when embedding quantity is higher than 1 KB, moreover the method has higher reliability and can detect the embedded method so as to estimate the embedding rate and to eventually achieve ideal result of extracting secret information.

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