

High Capacity Secure Image Steganography Based on Contourlet Transform

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Abstract

In this paper we propose an image steganography technique which embeds secret data without making explicit modifications to the image. The proposed method simultaneously provides both imperceptibility and undetectability. We decompose image by contourlet transform and determine nonsmooth regions. Embedding data in these regions cause less degradation in image quality. Contourlet sub-bands are divided into 3×3 blocks. Central coefficient of each block is considered for embedding if they belong to edgy regions. Experiments show that this method can achieve high embedding capacity while remains undetectable by Farid's universal steganalysis technique.

Keywords: *Contourlet Transform, Steganalysis, Steganography.*

1. Introduction

Steganography is the art and science of secret communication, which aims to hide a secret data securely in transmission. So, steganography algorithms should hide a message in the media such as audio, image and video in such a way that the very presence of the hidden message remains secret. Contrary to steganography methods, there are steganalysis techniques that try to detect secret communication. The most important requirements of a steganography system is security that include undetectability and imperceptibility. Literature reviews show that there are many steganography methods that use Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) for hiding secret message in images. F5 [1], Outguess [2], Model-based [3], Perturbed Quantization [4] and YASS [5] hide secret message by modification of DCT coefficient. Another steganography methods based on wavelet transform have been proposed. In [6] a wavelet domain steganography algorithm that is compatible with JPEG 2000 was proposed. In this method the secret data embedded in quantized wavelet coefficient.

[7], [8], [9] were proposed another steganography methods based on wavelet.

Recently some research about steganography in contourlet domain has been done. Sajedi in [10] proposed an adaptive steganography method based on contourlet transform that provides large embedding capacity. The contourlet coefficients with larger magnitude that correspond to the edges are selected for embedding. This method is superior to a similar wavelet based approach.

In this paper, we propose a new steganography method that uses contourlet transform for hiding secret data in image. In this method, we first apply contourlet transform on image and then hide secret data in proper contourlet coefficients. The human visual system has been tuned so as to capture the essential information of a natural scene using a least number of visual active cells. So, an efficient image representation should be based on a local, directional and multiresolution expansion. In this method we embed data in non-smooth region of carrier image. So, the visual degradation is minimal. We examine our algorithm by a well-known steganalysis method and we found that it couldn't discriminate between cover and stego images with rate better than random guess.

In section 2, we describe our algorithm. The experiments results are given in section 3. At last, in section 4, we get conclusions.

2. Proposed Approach

2.1 Contourlet Transform

In this paper, we propose a steganography method that find proper place for data embedding within contourlet coefficient in various direction. We achieve high embedding capacity and high degree of security while visual degradation is slight. Note that, in our method we look at secret data as a binary string that produced randomly. The contourlet transform provides a multiscale and multidirectional representation of an image. It consists of a double filter bank structure for obtaining sparse expansions for typical images having smooth contours [11]. In this double filter bank, the Laplacian pyramid (LP) is first used to capture the point discontinuities, and then followed by a directional filter bank (DFB) to link point discontinuities into linear structures. In images some discontinuity points (i.e. edges) are located along contours. So, for images, wavelet that can deal with only 1-D singularity is not a right tool. Contourlet transform was developed for handling 2-D discontinuities like edges. Two key features of contourlet transform that improves over the wavelet transform are directionality and anisotropy. Therefore, the contourlet transform can provide a flexible multi-scale and directional decomposition for images. Because of multi- directional feature of contourlet, manipulating some coefficient in a direction has less effect on relevant coefficient in other directions compared to wavelet.



Fig. 1 Contourlet Decomposition.

2.1 Embedding Process

Fig. 1 shows the block diagram of embedding process of our method. It include following steps:

- 1) Cover image is decomposed into one pyramidal level then decomposed into eight directional subbands (Fig. 3).
- 2) Those 3×3 blocks that belong to non-smooth and noisy regions are suitable for data embedding.
- 3) Location of 3×3 blocks are considered as algorithm key.

Coefficient (w,w)

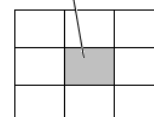


Fig. 2 3×3 block.

- 4) We embed secret bit at the coefficient which placed in center of 3×3 non-smooth block (Fig. 4). This coefficient is suitable for embedding if 4 of adjacent coefficient belong to higher coefficient set. For each subband we define $avg = (min+max)/2$ where min is minimum value of coefficients and max is maximum value of coefficients of that subband.

In this step we act according table 1.

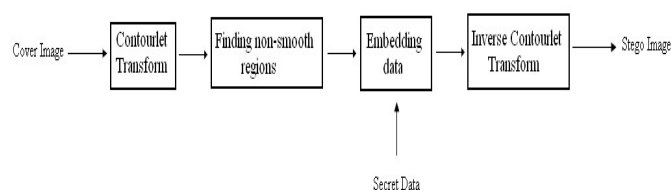


Fig. 3 Embedding process.

After embedding all of bits of secret data, we apply inverse contourlet transform on image and get stego image.

Table 1 : Embedding Process

Secret bit = 0	If $Coefficient(w,w) \geq avg$ then do nothing end
	If $Coefficient(w,w) < avg$ then $Coefficient(w,w) = avg + 1$ End
Secret bit = 1	If $Coefficient(w,w) \geq avg$ then $Coefficient(w,w) = avg - 1$ End
	If $Coefficient(w,w) < avg$ then do nothing end

2.2 Extraction Process

- 1) Decompose stego image with a one level contourlet transform into eight directional subbands.

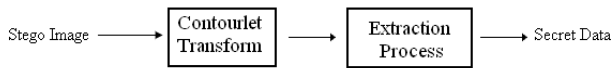


Fig. 4 Extraction process.

- 2) Determine block position using key.
- 3) Extract embedded data such as table 2.

Table 2: Extraction process

$Coefficient(w,w) \geq avg$	Embedded bit = 1
$Coefficient(w,w) < avg$	Embedded bit = 0

3. Experimental Result

Here 250 images, each of 512×512 gray images, with tiff format, were selected randomly from Washington University image database. We first investigate imperceptibility and undetectability of proposed algorithm.

3.1 Image Quality

We evaluate imperceptibility of our algorithm by peak signal to noise ratio (PSNR):

$$PSNR = 10 \times \log_{10} \left(\frac{255^2}{MSE} \right) \quad (1)$$

Where MSE shows the mean square error between cover image C and stego image S.

$$MSE = \left(\frac{1}{M \times N} \right) \sum_{i=1}^M \sum_{j=1}^N (C_{ij} - S_{ij})^2 \quad (2)$$

Via proposed method, we embed the secret data of size 1000 bit. Average PSNR for 250 images is 56.05 dB. The Results of Embedding secret data of different size in popular image Lena of size 512×512 are shown in table 3.

Table 3: The quality factor of stego image.

Secret data size (bit)	1000	3000	6000	12000
PSNR (dB)	60.44	50.17	43.06	42.01

3.2 Steganalysis Result

We evaluate the security of our method by the well-known Farid's universal steganalysis technique. Farid's method uses Support Vector Machine for discriminate between clean and stego images [12]. We have 500 images in database (250 clean and 250 stego). We use 60% of image for training and the rest are used for testing. The detection accuracy is shown in table 4.

According to achieved results, our method has better results over previous wavelet-based and DCT-based steganography methods.

Table 4: Detection accuracy of steganalysis method

Secret data size (bit)	1000	3000	6000	12000
Detection Accuracy	51.5%	52.68%	54.1%	62%

4. Conclusions

An algorithm for embedding a message into gray images represented by means of contourlet decomposition. It embeds a secret data in non-smooth and edgy regions of an image. So, the proposed method provides high image quality.

The security of the scheme has been tested against a general purpose steganalysis method, showing the validity of the proposed approach.

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