A Robust Method for Data Hiding in Color Images

Mohsen Ashourian[1], Peyman Moallem[1], and Yo-Sung Ho[2]

[1] Faculty of Engineering, Isfahan University,
Isfahan, Iran
mohsena@yahoo.com
[2] Gwangju Institute of Science and Technology,
1 Oryong-dong Puk-gu, Gwangju, 500-712, Korea
hoyo@gist.ac.kr

Abstract. In this paper, we propose a methodology for embedding watermark image data into color images. At the transmitter, the signature image is encoded by a multiple description encoder. The information of the two descriptions are embedded in the host image in the spatial domain in the red and blue components. Furthermore, this scheme requires no knowledge of the original image for the recovery of the signature image, yet yields high signal-to-noise ratios for the recovered output. At the receiver, the multiple description decoder combines the information of each description and reconstructs the original signature image. We experiment the proposed scheme for embedding a gray-scale signature image of 128×128 pixels size in the spatial domain of a color host image of 512×512 pixels. Simulation results show that data embedding based on multiple description coding has low visible distortions in the host image and robustness to various signal processing and geometrical attacks, such as addition of noise, quantization, cropping and down-sampling.

1 Introduction

Various digital data hiding methods have been developed for multimedia services, where a significant amount of signature data is embedded in the host signal. The hidden data should be recoverable even after the host data has undergone some signal processing operations, such as image compression. It should also be retrieved only by those authorized [1, 2, 3, 4].

The main problem of image hiding in another host image is a large amount of data that requires a special data embedding method with high capacity as well as transparency and robustness. Chae and Manjunath used the discrete wavelet transform (DWT) for embedding a signature image into another image, which has high visible distortion in the smooth area of the host image [2]. It is possible to improve their scheme by employing the human visual system (HVS) model in the process of information embedding [3,4]; however, exact adjustment of the HVS model is not easy in many applications. As another approach for improving the robustness of data embedding, Mukherjee et. al. [5] designed a joint source-channel coding scheme for hiding a signature video in a video sequence. However, the channel optimized quantizer is not suitable in image hiding applications, where intentional or non-intentional manipulations, are variable and not known in advance.

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In this paper, we suggest to use a multiple description subband coder for encoding the signature image [7,8,9]. The two descriptions are embedded in different part of the host image in red and blue component which are analogies to two communication channel. The algorithm can be used for watermarking color images and has a low complexity compare to many of the color image watermarking schemes [Figure 1 shows the block diagram of the overall system. At the receiver, the multiple description decoder combines the information of each description and reconstructs the original signal. It can decode only one channel, when data on the other channel is highly corrupted; otherwise, it can combine the received information from both channels.

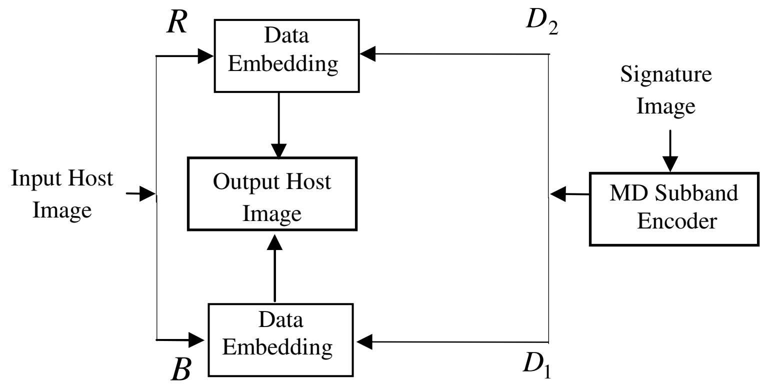

Fig. 1. Overview of the Proposed Scheme

The main advantage of encoding the signature image by two descriptions and embedding these descriptors in the host signal is that with an appropriate strategy, we can reconstruct a good approximation of the signature signal, even when the host signal is severely attacked.

In Section 2, we explain the data embedding and extraction, and in Section 3 we describe encoding and decoding process of the signature image using MDC. In Section 4 the experiments and results of different tests are provided, and finally section 5 summarize the paper.

2 Data Embedding and Extraction

The data embedding in the host image could be in the spatial or frequency domain [10, 11, 12, 13, 14, 15]. While data embedding in the spatial domain is more robust to geometrical attacks, such as cropping and down-sampling, data embedding in the frequency domain usually has more robustness to signal processing attacks, such as addition of noise, compression and lowpass filtering. In this paper, we use data embedding in the spatial domain using the proposed algorithm in [16].

Te data are embedded in one color component of the image based on its luminance. Since human eye is less sensitive to change in blue color, the method suggests modification of the blue component [16]. However the method fails when the image has very low density of blue component. We use MDC and embed in both red and blue components, so that it can survive even for images with low density of blue component. We expect that high resilience of MDC coding of the signature signal can help the data embedding scheme to survive the signal processing attacks.

In order to embed output indices of the signature image into pixel values at point (x, y) of the host image, we scramble and arrange these indices as a binary sequence: $D = d_1, d_2, \cdots, d_n$, where d_k is a binary variable.

We calculate the luminance value of a pixel at (x,y) using its three color components r(x,y), g(x,y) and b(x,y) as

$$l(x, y) = 0.299r(x, y) + 0.587g(x, y) + 0.114b(x, y) \tag{1}$$

We select a group of pixel with higher value of blue components, and change the blue color component using this equation:

$$b'(x, y) = \begin{cases} b(x, y) + \alpha.l(x, y) & \text{if} \quad d_i = 0 \\ b(x, y) - \alpha.l(x, y) & \text{if} \quad d_i = 1 \end{cases} \tag{2}$$

Where α is the embedding modulation factor. We do a similar process for embedding value in red component of the pixels in the red dominated area of the host image.

For data extraction, we do not need the original host image. For the data embedded in blue components, at first we calculate an estimate of the blue component of the modified pixel using its neighboring pixels in a window size of 3 by 3 pixels (C=1).

$$\hat{b}''(x, y) = \frac{1}{4C}\left(-2b''(x, y) + \sum_{i=-C}^{+C} b''(x+i, y) + \sum_{i=-C}^{+C} b''(x, y+i) \right) \tag{3}$$

Here we use of 3 by 3 pixels (C=1) around each pixel. Now assuming that we embed each bit M times, we can estimate the average of difference using

$$\sigma''_k = \frac{1}{M}\sum_{l=1}^{M}[\hat{b}''(x_l, y_l) - b''(x_l, y_l)] \tag{4}$$

The bit value is determined by looking at the sign of the difference between the pixel under inspection and the estimated original. In order to increase robustness, each signature bit is embedded several times, and to extract the embedded bit the sign of the sum of all differences is used.

We do a similar process for embedding value in red component of the pixels in the red dominated area of the host image.

3 Encoding and Reconstruction of the Signature Image

We decompose the signature image using the Haar wavelet transform, resulting in four subbands usually referred to as LL, LH, HL and HH. Fig. 2 shows the decomposition scheme.

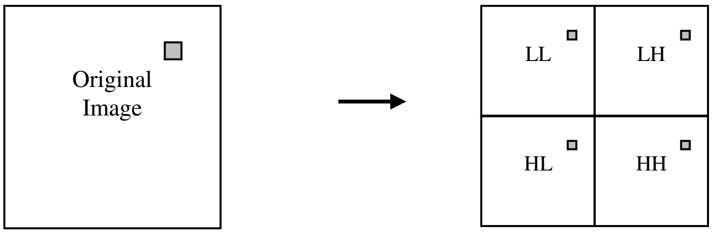

Fig. 2. The wavelet decomposition of the signature image

We use a phase scrambling operation to change the PDF of the lowest frequency subband (LL) to a nearly Gaussian shape [17]. The added random phase could be considered as an additional secret key between the transmitter and the registered receiver.

We encode the subbands using a PDF-optimized two-description scalar quantizer [18,19], assuming the Laplacian distribution for high frequency bands and the Gaussian distribution for the LL subband after phase scrambling. In this paper, we have set the encoding bit-rate at three bit per sample (bps), and obtained PSNR value over 31 dB for different tested images, which is satisfactory in image hiding applications. We use an integer bit-allocation among subbands based on their energies. The information of subband energies (15 bits) can be sent as side information or it can be encoded with a highly robust error correction method and embedded in the host image. We use the folded binary code (FBC) for representing output indices of quantizer to have higher error resilience.

Fig. 3. Host Image- Bird

4 Experimental Results and Analysis

We use a host image of 512×512 pixels and signature image of 128×128 pixels size. The "Cameraman" image is used as signature images, and the two images "Birds" and "Boat" which are shown in Fig. 3 and Fig. 4 are used as the host images.

We set the embedding factors such that their PSNR values stays above 34 dB after data embedding. Fig. 3 shows a sample of reconstructed signature image.

In order to evaluate the system performance, we calculate PSNR values of the reconstructed signature images. The system can be applied to applications such as hiding logo images for copyright protection, where the presence or absence of the signature is important more than the quality of the reconstructed image. In these applications, we usually set a threshold to decide on the amount of the cross correlation between the recovered signature and the original signature [1]. However, in this paper, we concentrate only on image hiding applications and provide PSNR values of reconstructed images.

Fig. 4. Host Image - Boat

Resistance to Baseline-JPEG Compression: The JPEG lossy compression algorithm with different quality factors (Q) is tested. Fig. 5 and Fig. 6 show the recovered signature image before and after JPEG compression of the host image. Fig. 7 shows the PSNR variation for different Q factors. As shown in Fig. 7, the PSNR values drop sharply for Q smaller than 50.

Resistance to JPEG2000 Compression: The JPEG2000 lossy compression algorithm with different output bit rates is tested on the host image. Fig. 8 shows sample of reconstructed image after JPEG-2000 compression of the host image. Fig. 9 shows the PSNR variation of the recovered signature images.

Resistance to Median and Gaussian filtering: Median and Gaussian filters of 3×3 mask size are implemented on the host image after embedding the signature. The PSNR of recovered signature are shown in Table 1. Fig. 10 and Fig. 11 show samples of reconstructed image after Median and Gaussian filtering of the host image.

Fig. 5. Samples of reconstructed signature images

Fig. 6. Samples of reconstructed signature images after JPEG compression of the host image with Q=55

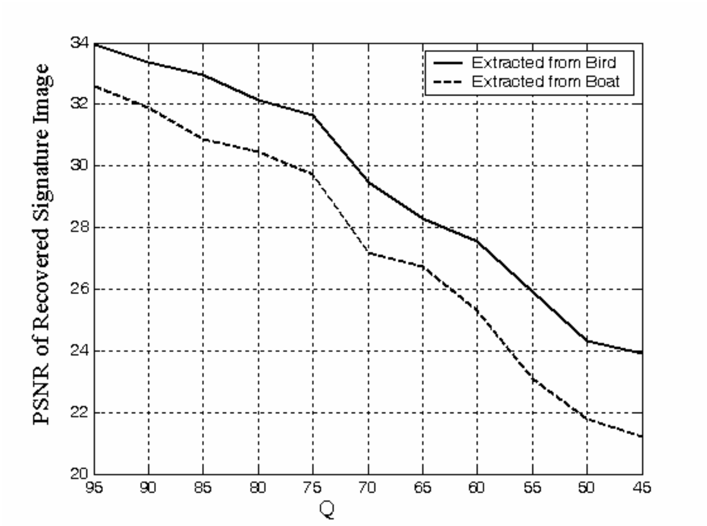

Fig. 7. PSNR variation of recovered signature image due to JPEG-compression of the host image

Fig. 8. Samples of reconstructed signature images after JPEG-2000 compression of the host image at 0.2bps

Table 1. PSNR (dB) values of the recovered signature images after implementing median and Gaussian filters on the host image

	Median Filter	Gaussian Filter
Extracted from Bird Image	20.65	25.80
Extracted from Boat Image	21.65	24.43

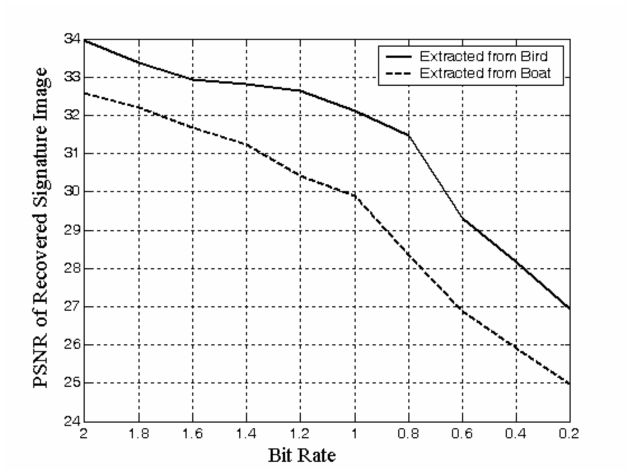

Fig. 9. PSNR variation of recovered signature image due to JPEG2000 compression of the host image

Fig. 10. Samples of reconstructed signature images after Median filtering

Resistance to Cropping: Table 2 shows PSNR values when some parts of the host image corners are cropped. Fig. 12 shows the host image after 10% cropping. Considerably good resistance is due to the existence of two descriptors in the image and scrambling of embedded information, which makes it possible to reconstruct the signature image information in the cropped area from the available descriptor in the non-cropped area. Fig. 13 shows sample of reconstructed image after 10% cropping of the host image.

Fig. 11. Samples of reconstructed signature images after Gaussian filtering the host image

Fig. 12. Sample of the host image after 10% cropping

Table 2. PSNR (dB) values of the recovered signature image for different percentage of cropping the host image

	5%	10%	15%	20%
Extracted from Bird Image	23.48	21.52	20.60	19.82
Extracted from Boat Image	26.25	23.65	20.20	20.70

Table 3. PSNR (dB) values of the recovered signature image after different amount of down-sampling the host image

	1/2	1/4	1/8
Extracted from Bird Image	23.18	19.15	18.27
Extracted from Boat Image	24.33	17.44	16.75

Fig. 13. Samples of reconstructed signature images after cropping the host image

Fig. 14. Samples of reconstructed signature images after down-sampling the host image

Resistance to Down-sampling: Due to loss of information in the down-sampling process, the host image cannot be recovered perfectly after up-sampling. However, it is possible to recover the signature image from those pixels available in the host image, as the two descriptions of the signature image information are scrambled and distributed in the host image. Table 3 lists PSNR values after several down-sampling processes. Fig. 14 shows sample of reconstructed image after down-sampling by 2 of the host image.

5 Conclusions

We have presented a new scheme for embedding a gray-scale image into a color host image. The signature encoding is based on multiple description subband image coding, and the embedding process is performed the spatial domain. The proposed system does not need the original host image for recovering the signature at the receiver. Since the system uses embedding in both red and blue components, it can works well for variety of images with different distribution of colors. We evaluate the reconstructed signature image quality when the host undergone various signal processing and geometrical attacks. The results show the system has good robustness. The developed system has low implementation complexity and can be extended for embedding video in video in real time.

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