Blind Image Data Hiding in the Wavelet Domain

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Abstract. In this paper, we propose a methodology for hiding a gray scale guest image of low resolution into another gray scale host image of higher resolution. The embedding scheme can be used for secure or economic transmission of the low resolution image through the established communication channel for the high resolution image. We encode the guest image by a two-description subband coder. The information of one description is embedded in one frequency subband of the host image, and the other description in the other frequency subbands. We embed the information in those areas of the host image that contains high texture to reduce visibility of the embedded information in the host image. At the receiver, a multiple description decoder combines the information of each description to reconstruct the original guest image. We experiment the proposed scheme by embedding a gray scale guest image of 128*128 pixels in the gray-scale host image of 512*512 pixels, and evaluate the system robustness to various signal processing operations.

1 Introduction

Embedding images into other images and videos has applications in data hiding and digital watermarking. During the last few years, much progress has been made in developing watermarking techniques that are robust to signal processing operations, such as compression [1].

The signature information ranges from pseudo-random sequences to small image icons. In digital watermarking applications, emphasis is put on authentication rather than quantity and quality of the recovered data. It is necessary and satisfactory for the watermarking scheme to be able to prove the ownership, even though the host signal has undergone various signal processing or geometrical attacks. Data hiding has some other types of applications, such as broadcasting. In this application, the goal is to use an already established multimedia transmission channel for transmission of another multimedia signal. In this case, we need to recover the embedded information with high quality. However, in these applications the possibility of active and sever attacks is low. The host multimedia data could only be changed subject to some signal processing operations, such as compression, addition of noise, and down-sampling. As in
digital watermarking, two scenarios are possible at the receiver: (a) referenced detection, where the original host signal is available, and (b) blind detection, where the original host signal is not available. The blind detection has a wider range of applications; however, it is more difficult to implement since the effect of the host signal on the embedded information cannot easily be removed at the receiver [1].

There have been few reports on large capacity data embedding [2],[3],[4], Chae and Manjunath used the discrete wavelet transform (DWT) and lattice code for embedding a signature image/video into another image/video [2]. They further improved their system by using joint source-channel quantizers [3]. However, the channel-optimized quantizer is not suitable in data hiding applications, where intentional or non-intentional manipulations are variable and not known in advance.

In another approach Swanson et. al. [4] designed a method for embedding video in video based on linear projection in the spatial domain. The method is flexible and simple to implement, but like other spatial domain embedding techniques, it is not robust to compression [4].

In our previous work [5], we proposed an image data hiding scheme in the spatial domain. The system uses multiple description coding (MDC) of the guest image and informed data embedding in the spatial domain. In this paper, we propose a new data embedding and recovering scheme that does not need the host image at the receiver. We also use data embedding in the wavelet domain to reduce the visibility distortion. We embed the two descriptions in two independent channels to enjoy more from the potential of multiple description coding.

In case that the host signal is faced signal processing operations, we can retrieve a less corrupted description from the host image and reconstruct the signature image of acceptable quality using the less corrupted description.

After we provide an overview of the proposed image hiding scheme in Section 2, we explain the encoding process of the guest image using multiple description coding in Section 3. Section 4 explains the data embedding and extraction processes, and Section 5 explains the experimental results of the proposed scheme, and finally Section 6 summarizes the paper.

2 Overview of the Proposed Scheme

Fig. 1 shows the overall structure of the proposed scheme for guest image data embedding. We encode the guest image by a two-description subband coder. The two descriptions are represented by $D_1$ and $D_2$. The two portions of the host image are analogous to two communication channels for transmission of the two descriptors. The bitstream of the two descriptions are embedded in the two subbands.

At the receiver, we use only the received host image to recover the two descriptions, and reconstruct the signature image using the multiple description decoder.
3 Multiple Description Coding of the Guest Image

Multiple description coding was originally proposed for speech transmission over a noisy channel [6]. In this paper, we follow a simple but efficient approach of increasing redundancies in important portions of the image. Fig. 2 shows the overall structure of the signature image encoding operation. In the first stage, we decompose the signature image using the Haar wavelet transform, resulting in four subbands, usually referred to as LL, LH, HL, and HH. The lowest frequency subband (LL) contains the most important visual information and it needs more protection compared to high frequency subbands. As Fig. 2 shows, we use MD scalar quantizer for LL [7]. For high frequency subbands, we just split the pixels between the two descriptions.

Except for the lowest frequency subband (LL), the probability density function (PDF) for other subbands can be closely approximated with the Laplacian distribution. The LL does not follow any fixed PDF, but it contains the most
important visual information. We use a phase scrambling operation to change the PDF of this band to a nearly Gaussian shape [8]. The added random phase could be an additional secret key between the transmitter and the registered receiver. We encode the two descriptions of the lowest frequency subband and the high frequency subbands with four state-trellis scalar quantizers. The average encoding bit-rate was 3 bit per sample and we obtained PSNR value over 38 dB for various test images, which is satisfactory in image hiding applications [2].

4 Data Embedding and Extraction in the DWT Domain

For our experiments, we select a gray-scale host image of $512\times 512$ pixels and guest image of $128\times 128$ pixels size. We embed the information in the host image area with high texture content to be less visible. In order to evaluate the texture content of a block, we apply single-level Haar wavelet decomposition on each of the two portions of the host image [9]. As depicted in Fig. 3, each block $k$ with $8\times 8$ pixel size in the image is mapped to 4 blocks with $4\times 4$ pixel size in the wavelet domain. We define a normalized measure for the energy of high frequency bands by

$$\mu_k = \left| \frac{e_H}{e_L} \right|$$

(1)

where $e_H$ is the average of the absolute value of the high frequency bands (LH, HL, HH), and $e_L$ is the absolute value of the lowest frequency band (LL) of the corresponding block. $\mu_k$ characterizes the given block texture energy. Higher value of shows the block has strong high frequency component or high texture. We consider these blocks good candidate for data embedding and replace some DCT or wavelet coefficients with embed data. In the following sections, we explain in more details the process of embedding in each domain.

![Fig. 3. The wavelet decomposition of the host image for texture measurement](image)

We split the candidate blocks of the host image into two groups, and embed one description of the guest image in LH and the other in the HL band. For data embedding, we replace some wavelet coefficients in the selected blocks with the quantized value of the signature image description ($D_1$) after proper weighting by a defined modulation factor ($\alpha$). Since the signature image size is lower than the host image size, we can select only part of the blocks using the texture measurement criterion derived in previous section, and replace some pixels of the total 64 pixels of the wavelet coefficients of a block with signature image quantized values.
At the receiver, we first reconstruct the lowest frequency subband of the guest image from the extracted indices in each portion of the host image, and recombine the two reconstructed bands. As the lowest frequency band is a blurred version of the original image, we can estimate the corrupted pixels from the over-sampled guest image using various error detection and concealment methods. In developed system, we follow a simple scheme based on comparison of each pixel with its neighboring pixel average value. Each pixel has four neighboring pixels from its own description and four neighboring pixels from the other description.

For the pixel with intensity value \( x_{i,j} \) first we calculate the average value of neighboring pixels in the first descriptions: \( m_1 \), and the second description: \( m_2 \); and then we calculate,

\[
\lambda_1 = \left| \frac{x_{i,j} - m_1}{m_1} \right| \quad (2)
\]

\[
\lambda_2 = \left| \frac{x_{i,j} - m_2}{m_2} \right| \quad (3)
\]

High value of \( \lambda_1 \) or \( \lambda_2 \) suggests possibility of corruption of the pixel. In this case we can replace the pixel \( x_{i,j} \) with \( m_1 \) or \( m_2 \). If the receiver can gain some knowledge of the type of attack the host image undergone, it can estimate which description has been more corrupted and adjust the or more efficiently.

For high frequency subbands, we can simply recombine the two independent descriptions. On the other hand, if based on evaluation from the lowest frequency subband we estimate that one of the two descriptions is highly corrupted, we can replace that description with the less corrupted description.

5 Experimental Results and Analysis

For our experiments, two images, ‘F16’ and ‘Einstein’, are used as signature images, and the ‘Shipping Boat’ image is used as the host images.

In order to control distortion resulted form data embedding in the host image; we can change the embedding factor in the wavelet domain. We set the modulation factor such that the host images PSNR stays above 38.5 dB for our further experiments. Fig. 4 shows samples of signature image recovered from the host images (‘Shipping Boat’) without any attacks.

As the goal of developed system has been image hiding for broadcasting application, we evaluate the system performance by calculating PSNR values of the reconstructed guest 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 more important 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 \([2]\). However; in this paper, we concentrate only on image hiding applications and provide the reconstructed images PSNR values after the host image undergone some signal processing and geometric operations that could be the result of transmission or format exchange.
Table 2 shows PSNR values when some parts of the host image corners are filled with the cropped image. Fig. 6 shows samples of host image corners filled with cropped images. The experiments were performed in our experience. We cropped parts of the host image corners and Gaussian filters on the host image corners. Table 1. PSNR (dB) value of the recovered signature images after implementing the algorithm. The PSNR of recovered signature images are shown in Table 1. Aliens of 3 x 3 masks were embedded on the host image after embedding the signature. Recovery of Median and Gaussian Filter: Median and Gaussian Filter, PSNR of recovered signature images due to baseline-JPEG compression.

Fig. 3. PSNR of recovered signature images due to baseline-JPEG compression.

Drop sharply for a smaller than 50 PSNR variation for different Q-factors as shown in Fig. 3. The PSNR values shown alterations with different quality factors (Q) is listed. Fig. 5 shows the resistance to baseline-JPEG compression. The JPEG lossy compress.

Fig. 4. Samples of reconstructed signature images of.
cropped. 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 partly in the cropped area from the available descriptor in the non-cropped area.

**Fig. 6.** Sample of the host image after 20% cropping

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

<table>
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<tr>
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<th>5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
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<tbody>
<tr>
<td>F16</td>
<td>26.78</td>
<td>25.83</td>
<td>22.40</td>
<td>21.65</td>
</tr>
<tr>
<td>Einstein</td>
<td>25.26</td>
<td>24.44</td>
<td>23.30</td>
<td>20.01</td>
</tr>
</tbody>
</table>

**Resistance to JPEG2000 Compression:** The JPEG2000 lossy compression algorithm with different output bit rates is tested on the host image. Fig. 7 shows the PSNR variation of the recovered signature images.

**Fig. 7.** PSNR variation of recovered signature images due to JPEG-2000 compression
9. Communication Codecs: JPEG 2000, MP3, MP4, WMA, AAC, etc. These codecs are designed for efficient and lossless compression of multimedia data.


15. Multimedia Storage and Retrieval: Techniques for efficient storage and retrieval of multimedia data.


17. Multimedia Applications: Video conferencing, multimedia databases, multimedia retrieval systems.

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References

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