DITHERED QUANTIZATION FOR IMAGE DATA HIDING IN THE DCT DOMAIN

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Abstract

In this paper, we propose a robust data hiding scheme to embed a signature image in the host image. We encode the signature image by a fixed rate subband coder and use the coded bitstream as a dither signal in the uniform scalar quantizer of DCT coefficients of the host image. We experiment the proposed scheme for embedding a gray-scale signature image of 256×256 pixels in the DCT domain of a gray-scale host image of 512×512 pixels. Experimental results indicate that high quality embedding is possible with low visible distortions. The signature image can be recovered even when the embedded data is subject to significantly lossy JPEG compression.

Keywords: Data Hiding, Digital Watermarking.

1. Introduction

Various digital data hiding methods are being developed for multimedia services, where a significant amount of signature data is embedded in the host data by the data owner. An important requirement is that an authenticated person should be able to retrieve the hidden data even after the host data undergone some signal processing operations, such as compression [1,2].

In many digital watermarking applications, emphasis is put on authentication rather than quantity and quality of the recovered signature image. In contrast, in perceptual data hiding, we are interested in embedding and recovering high quality multimedia data, such as image, video and audio.

In this paper, we concentrate on hiding a signature image in the host image. The main problem of this method is the large amount of the embedding data that requires a high capacity and robust embedding method. Most of the previous image data hiding schemes have high visible distortions in the host image and have complex implementations [3,4].

In this paper, we suggest a simple and robust image data hiding scheme based on quantization watermarking [5]. We encode the signature image by the subband coder and use its coded bitstream as the dither signal for quantization of the DCT coefficients of the host image. This scheme is simple to implement and can be used in some applications where compression and data embedding need to be done jointly.

In the following sections, after explaining the sig-nature image encoding using the wavelet transform, we explain the proposed system for data embedding and its experimental results.

2. Encoding of the Signature Image

Numerous techniques have been developed for coding still images. However, most of the existing image coders have been developed under the assumption of reliable noise-free transport, which is not valid for image hiding applications. In this paper, we developed a fixed-rate, low complexity subband coder for the signature image encoding. Even for a noisy channel, the decoder can reconstruct the signature image with acceptable quality due to encoding at a fixed-rate, and using the wavelet transform that distributes the signal information among various subbands.

In the first stage for encoding the signature image, we decompose it using the Haar wavelet transform, resulting in four subbands, usually referred to as LL, LH, HL, and HH. Except for the lowest frequency subband (LL), the probability density function (PDF) for other subbands can be closely approximated by the Laplacian distribution. LL does not follow any fixed PDF, but it contains the most important visual information.

We use a phase scrambling operation to change PDF of LL subband to a nearly Gaussian shape [6]. LL subband is transformed by the fast Fourier transform (FFT), and separated into its magnitude and phase components. The phase spectrum of an appropriate reference function is then added to the phase spectrum of the input sequence and an inverse FFT is performed on the resulting sequence. In this way, the performance of a Gaussian-optimized quantizer can be achieved with a board range of source distribution. In addition, the phase scrambling operation provides a more secure bitstream between the encoder and decoder. Fig. 1 shows the effective-ness of phase scrambling in changing PDF of the lowest frequency subband of a sample image (Barbara) to the Gaussian shape. We encode all the subbands of signature image by PDF-optimized scalar quantizer, assuming the Laplacian distribution for high frequency bands and the Gaussian distribution for LL after phase scrambling. In this paper, we have set the encoding bit-rate at three bit per sample (bps), and obtained PSNR value over 32 dB for different test images, which is satisfactory in image hiding applications.

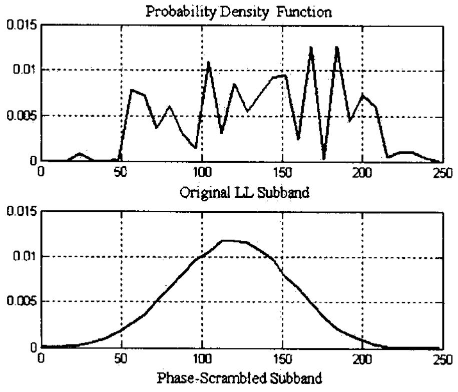

Fig.1. Effect of Phase scrambling on LL subband

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 [7].

3. Data Embedding and Extraction

The process of data embedding is based on dithered quantization [8]. In a dithered quantizer, a signal d[n] is added to the input signal x[n] prior to its quantization. Data embedding and quantization watermarking could be modeled as a non-subtractive dithering [5]. Fig. 2 shows the block schematic of the non-subtractive dithering. The host image x[n] is the input to the quantizer, and the signature signal d[n] is the additive dither.

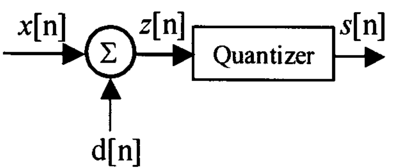

Fig. 2. Non-subtractive dithered quantization

Fig. 3 shows the block diagram of data embedding based on modification of the baseline JPEG compression standard. The image is transformed by an 8×8 block DCT, and DCT coefficients are quantized by uniform scalar quantizers. A quantization table defines the quantizer step sizes for all 64 DCT coefficients. The quantization table is parameterized by a quality factor, where highest visual quality and lowest compression is achieved for Q=100. The embedding scheme uses the signature information to generate the dither signal in the scalar quantizers of DCT coefficients. We select Q=80 for the compression and embedding processes; we can preserve the host image quality and provide satisfactory resistance to further compression attacks with this value. We can have higher resistance for the signature image and lower quality for the host image with selecting smaller values for Q.

In the developed scheme, we assume that the signature image has a quarter size of the host image. Therefore, a 4×4 block of the signature image is embedded into a 8×8 block of DCT coefficients of the host image. Since the signature image is quantized with three bits per pixel, each block of 4×4 signature image generates 48 bits of information, which are embedded in 48 coefficients of middle frequency DCT coefficients of 8×8 host image block.

In order to embed each bit, we generate a bipolar dither and add this dither signal to the 48 selected DCT coefficients. In order to have less visible distortion in the host image, we split the bits of each group into two sub-groups and we use bipolar signal with opposite sign for each of them. We set the energy of dither signal so that PSNR of the host image stays above 34 dB.

At the receiver, we assume the original host image is available. We subtract DCT coefficients of the received host signal from those of the original host image to recover the bipolar dither signal. The sign of each dither signal determines the value of each extracted bit that reconstructs the signature image.

4. Experimental Results

For our experiment, we select a gray-scale host image of 512×512 pixels and signature image of 256×256 pixels. Two images, “Barbara” and “Baboon”, are used as signature images, and the image “Lena” is used as the host image.

In order to evaluate the system performance, we calculate PSNR value and similarity factors. For data hiding for image transmission applications, PSNR values of reconstructed signature images are given.

In order to hide logo images for copyright protection, we should make a binary decision for the presence or absence of the signature image because the presence of the signature is important rather than the quality of reconstructed image. We define the similarity factor between the recovered signature $\hat{s}(m, n)$ and the original signature $s(m, n)$ by

$$\rho = \frac{\sum_{m,n} \hat{s}(m,n)s(m,n)}{\sum_{m,n} (\hat{s}(m,n))^2} \quad (1)$$

Based on the value of ρ, we make a decision on the presence ($\rho = 1$), or absence of the signature image ($\rho = 0$).

We control the strength of data embedding by setting dither signals variance such that the host image PSNR stays above 35 dB for our experiments.

Resistance to JPEG Compression: The JPEG lossy compression algorithm with different quality factors (Q) is tested. Fig. 4 shows the PSNR variation for different Q factors, and Fig. 5 shows the variation of similarity factor (ρ). The PSNR values drop sharply for Q smaller than 70, but the similarity factor (ρ) stays above 0.70 for Q larger than 40.

Robustness to Gaussian Noise: We add a Gaussian noise with a different variance to the normalized host signal after embedding the signature. Fig. 6 shows the PSNR values of signature images for additive noise with different variances. From Fig. 6, we conclude that for certain range of noise, our strategy shows good performance in resisting Gaussian noise for data hiding applications.

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. PSNR values and ρ factors of the recovered signature are listed in Table 1.

5. Conclusion

We have developed an image data hiding scheme based on dithered quantization and a modified baseline JPEG coding scheme. We have minimized the visibility of embed data in the host image by adaptive selection of the dither energy and pseudo-random change of the dither sign. We have tested the system performance by JPEG compression, addition of Gaussian noise, and Gaussian and Median filtering of the host image. Experimental results show high robustness of the system especially when it is used for watermarking purpose. The proposed system can be extended for hiding video in video for broadcast applications.

Acknowledgements

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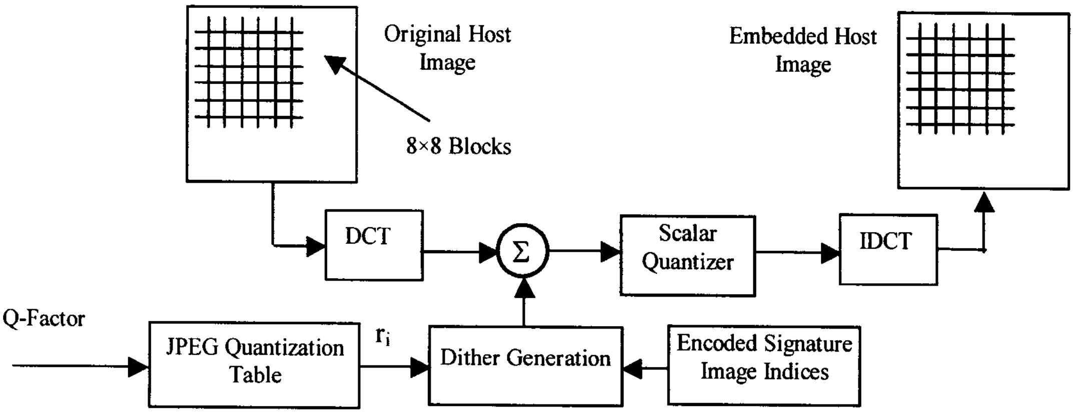

Fig. 3. Block diagram of the overall embedding system

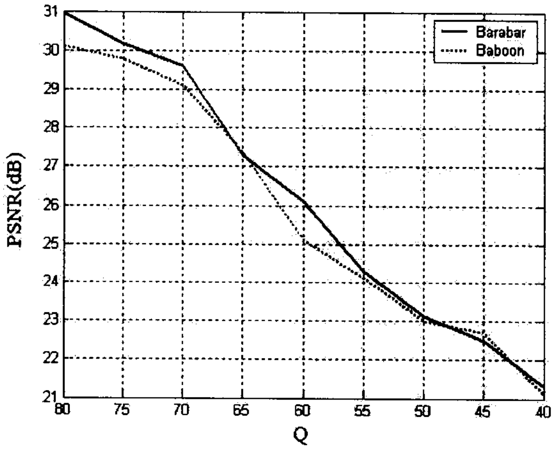

Fig.4. PSNR variation of recovered signature image due to JPEG compression

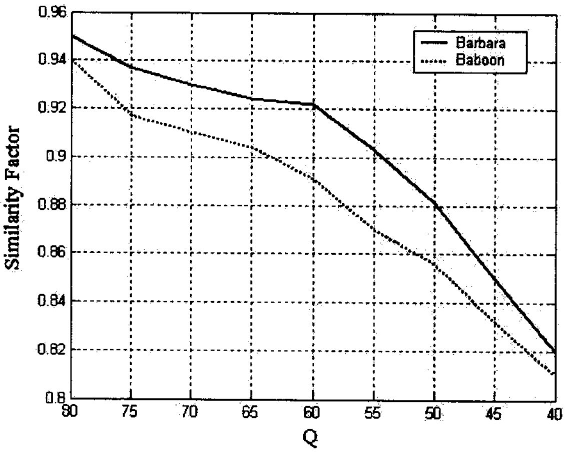

Fig. 5. Similarity factor variation due to JPEG compression

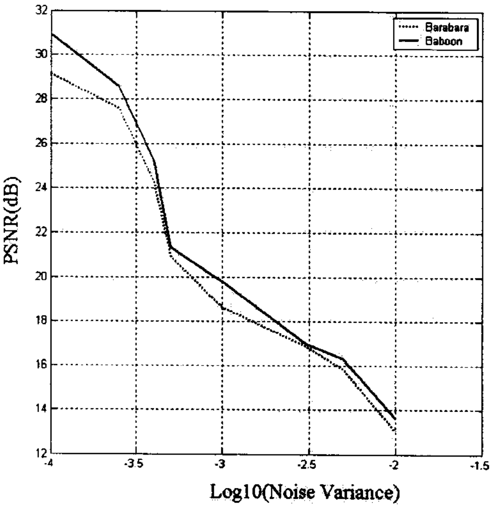

Fig.6. PSNR variation of recovered signature images due to additive Gaussian noises

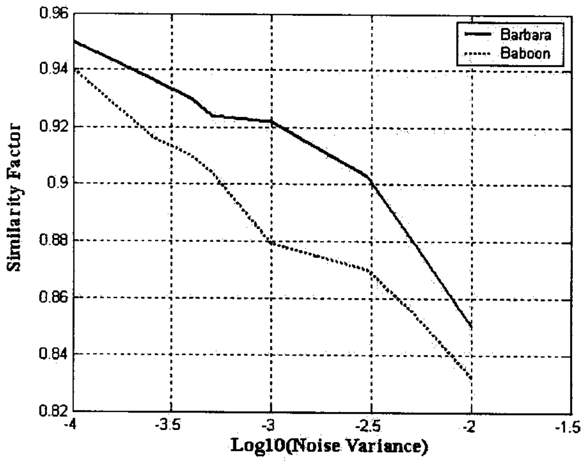

Fig. 7. Similarity factor variation due to additive Gaussian noises

Table 1. PSNR (dB) values of the recovered signature images after median and Gaussian filtering

	Filter Type	*PSNR*	ρ
Barbara	Gaussian	24.80	0.87
	Median	21.82	0.81
Baboon	Gaussian	23.73	0.88
	Median	23.2	0.80