Embedding Data in Images Using Turbo Coding

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Abstract

A data embedding technique is proposed for embedding a significant amount of data in digital images while retaining high perceptual quality. The scheme employs digital communication techniques to achieve high robustness to standard image processing operations. Information is embedded in the wavelet domain by modifying selected wavelet coefficients of the host image. The embedded data is coded using turbo codes.

1. Introduction

Data hiding can be thought of as a special communication problem, where signature data are the information to be sent from sender to receiver through special channel. The channel is composed of the host signal (image or video) and the noise introduced by signal processing and/or attacks. Imperceptibility, robustness against moderate compression and processing, and the ability to hide many bits are the basic but rather contradictory requirements for many data hiding applications. The traditional way to handle this is to target at a specific capacity-robustness pair. Some approaches choose to robustly embed just one or a few bits [1, 2], while others choose to embed a lot of bits but to tolerate little or no distortion [3]. More recently, it has been pointed out in the literature that similarities between the data hiding problem and digital communication can be utilized to improve the performance of the system [4].

In previous work we have investigated the use of convolutional codes to improve the embedding algorithm [5]. In this paper we investigate the performance of the algorithm with the use of turbo coding.

The use of channel coding in data hiding was proposed independently in [6], where block codes have been implemented in the watermarking process for the spatial domain. Our scheme is different from the above mentioned, firstly, the embedding is implemented in the wavelet domain and not in the spatial domain, secondly, we propose to use new schemes adapted from the area of deep-space communications such as concatenated coding and turbo codes.

2. The Embedding and Extracting Algorithm

The generic embedding principle can be explained by means of the diagram in Figure 1. The signature data is first source-coded either losslessly or lossily depending on the nature of the data, to generate a sequence of symbols. The signature data or watermark could be a binary sequence or an image and may be an encrypted version of the author identification which is used to establish sender credibility or a mixture of the above mentioned types of watermarks. When the hidden data is of image type, vector quantization is implemented to compress the signature data before embedding. The information bits are channel coded using turbo codes before embedding them in the elements of the host. The embedding could be direct or it could depend on a secret key that is known only to copyright owner and to authorized recipient.

The method of embedding involves adding the watermark sequence to the low frequency discrete wavelet transform (DWT) coefficients of the host image. The host signal is transformed into the discrete wavelet domain where its coefficients are grouped into vectors. The embedding process inserts the coded information bits in each coefficient vector of the DWT coefficients of the host signal.

The information symbols are added to the host coefficients after scaling by a factor a to produce a watermarked image that conceals the secret information. At the recipient side, the objective will be to extract this information with the highest possible fidelity. In order to guarantee invisibility, the signature data is inserted into the host with the use of a scaling parameter a , which determines the

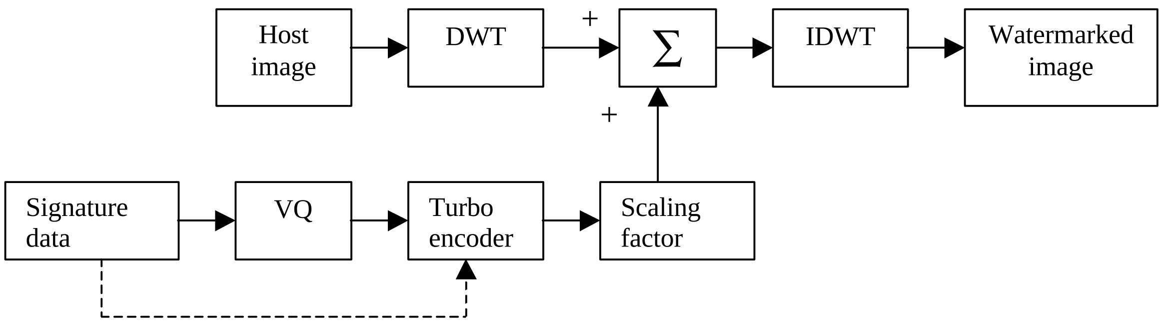

Figure 1. Block diagram of the encoder.

transparency constraint. The watermark sequence bits could be multiplied by a perceptual mask and not a constant scale factor a .
The modified coefficients are then inverse transformed back to form the embedded or watermarked image before transmission or distribution.
Regarding watermark extraction, the schematic block diagram of the decoder is shown in Figure 2. The DWT is applied to the given image and the coefficients are grouped in the same way as in the encoder. The grouping can be done either using the random key or priory knowledge of the watermarked coefficients to determine the location of the embedded watermark bits.
The extraction process uses its knowledge of the original host to extract the watermark bits from its associated wavelet coefficients. A channel decoder is first implemented followed by a source-decoder to obtain the extracted watermark.
The above scheme has two layers of security. The variability of the source and channel codebooks used makes unauthorized retrieval virtually impossible. The knowledge of the algorithm alone is not sufficient to extract the hidden information. The exact source and channel codebooks used for any application must be known. Further, if an encryption key is used in shuffling the transform coefficients before embedding, then additional layer of security is added. Moreover, if we suppose that the attacker knows the exact locations of the hidden coefficients, he cannot retrieve it without knowledge of either the source codebook or the channel codebook. He may be able to destroy the hidden information; but at the same time he cannot do so without significantly degrading the watermarked host.

3. Turbo Coding

Turbo codes are a new class of error correction codes that were introduced along with a practical decoding algorithm. Parallel concatenation of convolutional codes is used to give the codes structure so they can be decoded easily. Pseudo-random interleaving is used to give the codes performance which approaches that for random coding.
The original turbo code is a parallel concatenation of two recursive systematic convolutional (RSC) encoders, while the turbo decoder consists of two concatenated decoder of the component codes separated by the same interleaver. The component decoders are based on a
maximum a posteriori (MAP) probability algorithm or a soft output Viterbi algorithm (SOVA) generating a weighted soft estimate of the input sequence. The iterative process performs information exchange between the two component decoders. The turbo encoder and decoder are discussed in more details in [7].

4. Implementation and Experimental Results

In order to demonstrate the effectiveness of channel coding in the performance of data embedding we have watermarked several images with different types of signature data using the above mentioned codes. We specifically make use of the Haar wavelet transform for all simulations. The implementation is as specified in Section 2 with a scaling parameter $\alpha = 10$.
We perform two classes of tests. We first demonstrate the performance of the proposed method in embedding and recovering watermarks when the watermarked image undergoes distortions. The resulting watermarked signal is distorted (corrupted) using two of the most common distortions (JPEG compression and noise addition separately). The watermark is then extracted and compared with the original watermark sequence to measure robustness and extraction capability of the technique.

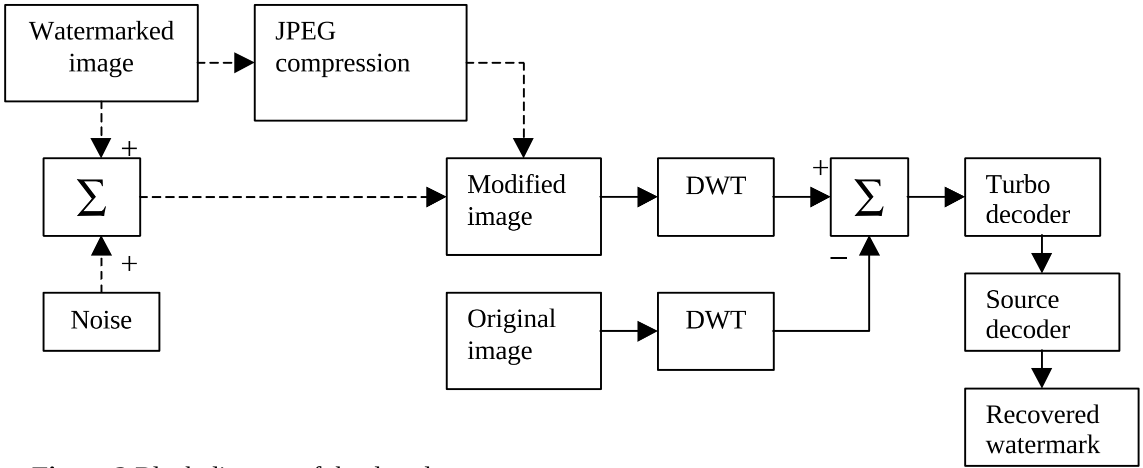

Figure 2 Block diagram of the decoder

In the next set of tests we demonstrate the improved performance of using channel coded watermarks over uncoded watermarks. In this test, the watermark sequence is left uncoded before embedding it in the host coefficients.
Finally, for using turbo codes in encoding the signature data, the DWT coefficients of the host image of *Lena* is modified to enable hiding the encoded message data. A random message of length 1000 bits was turbo coded using two parallel convolutional encoders of rate ½ with transfer function = [07,05] in octal form. Punctured encoding resulting in a rate of ½ for the turbo code while unpunctured code gives a rate of 1/3. The decoder uses logmap decoding with 5 iterations and the results were obtained over 80 frames. Results are shown in Figure 3 and Figure 4 for the bit error versus JPEG compression and noise addition respectively. The difference in bit error between the coded and uncoded messages is quite significant especially for lossless recovery (bit error = zero). However, little difference noticed between punctured and unpunctured codes. Though, the number of bits hidden in the case of punctured codes will be smaller than unpunctured code.
To compare the results of turbo coding to convolutional codes of similar rate, the same watermark is coded with convolutional code of rate ½ and the recovered data were obtained using Viterbi soft decoding algorithm. The results are shown in Figure 5 for the bit error versus JPEG compression for turbo coding and convolutional code and uncoded case. Similarly, Figure 6 shows the bit error of the recovered watermark against the PSNR of the host *Lena* image for the noise addition attack for the two different codes and uncoded watermark. From these figures one can see the improvement of turbo codes over convolutional codes and uncoded case. Notice also that at high compression ratio and low PSNR the three graphs seems to be close but at this point the host image is of no commercial value and therefore the high bit error is not of much concern.

5. Conclusions and Discussions

In this chapter we have given an outline of the advantages that channel coding using turbo codes brings about in data embedding applications, while the similarities with the detection problem in digital communication have also been pointed out. We have chosen the bit error probability as the reference quality measure. Comparison with uncoded case shows gains of up to 5 dB for simple codes. Note that a coding gain of 3 dB allows doubling the number of hidden information bits for the same probability of error.
In this work we have shown the benefits of turbo coding. However, the major disadvantages of turbo codes are its long decoding delays, due to the large block lengths and iterative decoding, and its weaker performance at lower bit errors, due to its low free distance. In spite of that, its performance was superior to convolutional codes with similar rates. Moreover, the encoding complexity and long delays in the case of turbo codes are not an issue, especially if the encoding and decoding is not to be implemented on real time, which is the case for most image watermarking applications. It is worth noting here that the codes used here were chosen for simplicity of implementation and to obtain a qualitative comparison rather than extreme coding gains. Our best scheme (turbo code) can be further improved by using much longer codes.

References:

[1] J. Cox, J. Kilian, T. Lieghton, and T. Shamoon, "A Secure, Robust Watermark for Multimedia", Workshop on Information Hiding, Newton Institute, Univ. of Cambridge, May 1996.

[2] M. Barni, F. Bartolini, V. Cappellini, and A. Piva, “A DCT-Domain System for Robust Image Watermarking”, Signal Processing (Special Issue on Watermarking), vol. 66, no. 3, 1998, pp. 357-372.

[3] Stego Dos, Blocl Wolf's Picture Encoder v0.9B, ftp://ftp.csua.berkely.edu/pub/cypherpunks/steganography/stegodos.zip.

[4] M. Ramkumar and A. N. Akansu, "Information Theoretic Bounds for Data Hiding in Compressed Images," Proceedings of IEEE Signal processing Society 1998 Workshop on Multimedia Signal Processing, December 7-9, 1998, Los Angeles, California, USA.

[5] N. Abdulaziz and K. K. Pang, "Coding Techniques for Data Hiding in Images", Sixth InternationalSymposium on Signal Processing and its Applications ISSPA 2001, 13-16 August 2001, Kuala-Lumpur, Malaysia, pp. 170-173.

[6] J. R. Hernandez, F. Perez-Gonzalez and J. M. Rodriguez, "The Impact of Channel Coding on the performance of Spatial Watermarking for Copyright Protection," Proceddings of International Conference on Acoustics, Speech, and Signal Processing ICASSP'98, Seattle, Washington, USA, May 1998, vol. 5, pp. 2973-2976.

[7] B. Vucetic, and J. Yuan, Turbo Codes: Principles and Applications, Kluwer Academic Publishers, MA, USA, 2000.

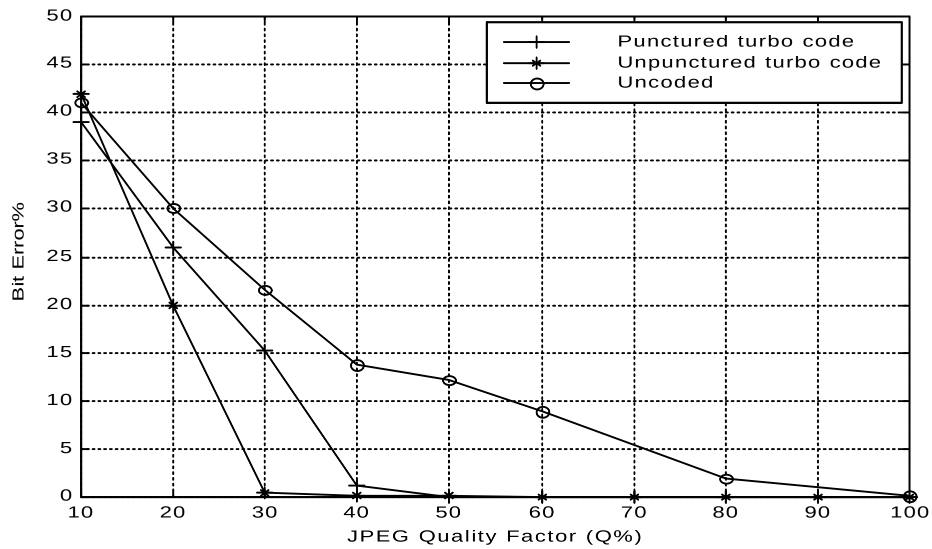

Figure 3 Bit error rate versus JPEG compression for turbo codes and uncoded messages.

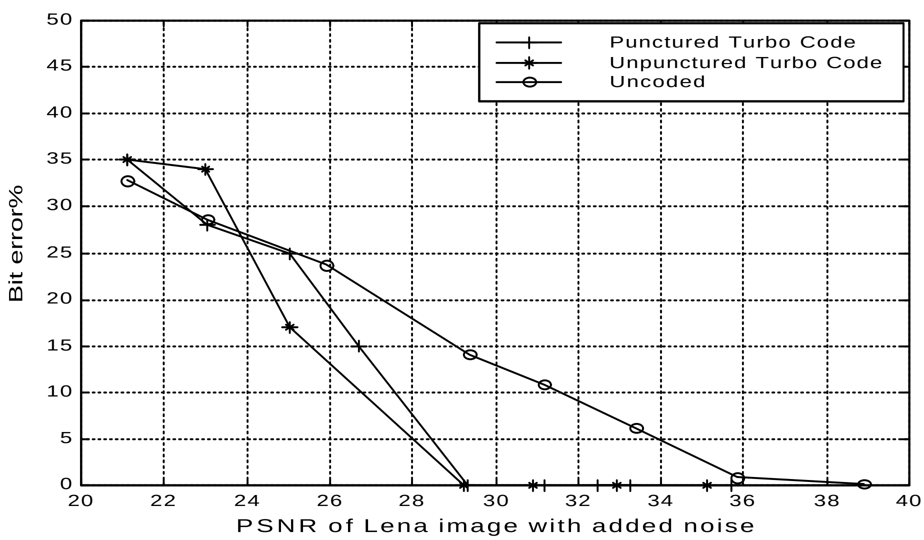

Figure 4 Bit error rate versus noise addition attack for turbo coded and uncoded messages.

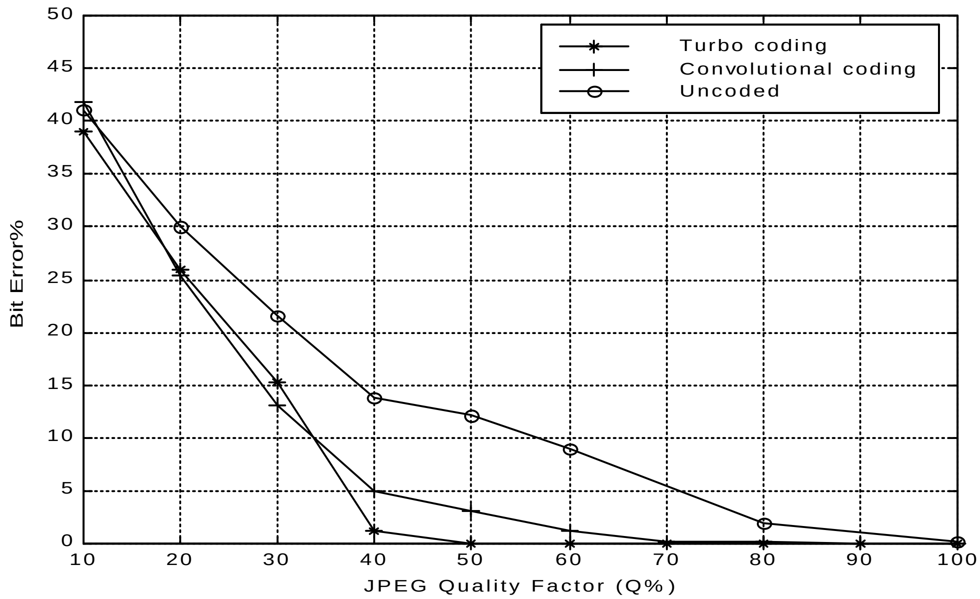

Figure 5 Bit error rate versus JPEG compression for turbo codes, convolutional code, and uncoded messsages.

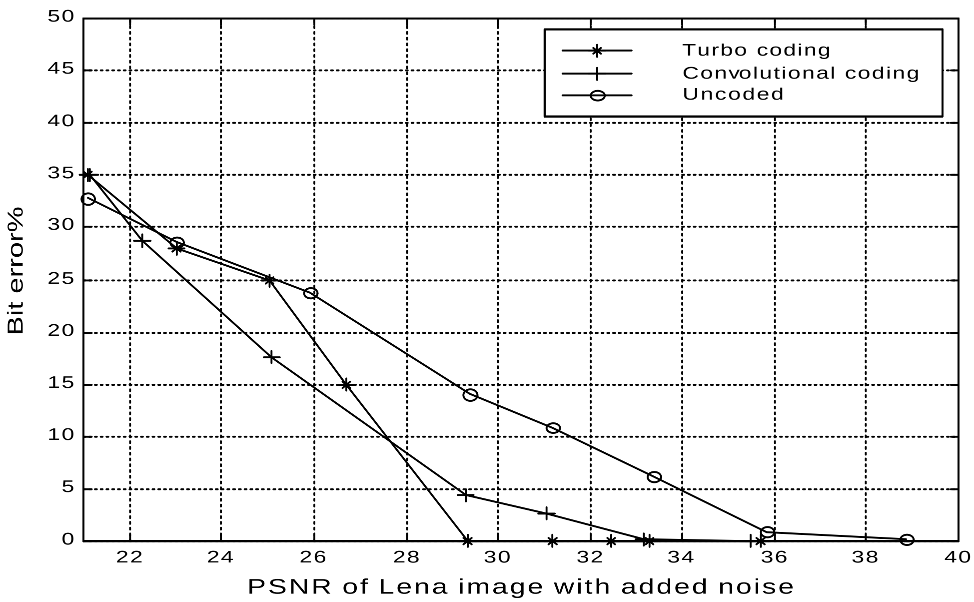

Figure 6 Bit error rate versus noise addition attack for turbo coded, convolutional code and uncoded messages.