MPEG2 WATERMARKING CHANNEL PROTECTION USING DUO-BINARY TURBO CODES

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ABSTRACT

This paper describes scheme for protection of watermarking channel and its capacity enhancement using state-of-the-art error correction technique - turbo coding. Duo-binary codes were used for protection since they are perform better then classical turbo coders in terms of better convergence for iterative decoding, a large minimum distance and also computational expensiveness. A spread spectrum watermarking technique is used to insert watermark. Proposed pseudo-random watermarking bits spreading, amplitude adjustment in DCT domain based on block classification and bit-rate preserving increased Signal to Noise ratio of the watermarking channel. However, it was essential to introduce an error correction technique in order to achieve high capacity and robustness. In addition, experimental results on robustness to transcoding are presented.

1. INTRODUCTION

A rapid expansion in digital technology, we are witnessing in past two decades, introduced huge benefits both for the industry and for the consumers. However, it also raises a number of questions regarding digital media copyrights. Digital media encryption can provide secure delivery of the content, but once the content is decrypted on a consumer side, it cannot prevent unlimited copping of the material. Digital watermarking, as a technique for embedding secret watermark directly to the digital content, came as possible solution to complement encryption, but also to a range of other interesting applications such as authentication, broadcast monitoring or data embedding. Digital media are mainly transferred and archived in a compressed form. Due to performance constraints in terms of computing efficiency and degradation, re-encoding and watermarking in the pixel domain is not feasible. Hence, it is desirable to embed and detect watermark in compressed domain. Several techniques have been reported in the literature aiming at watermarking in the compressed domain and they are mainly based on spread-spectrum paradigm [1], where a watermark message is transmitted as a narrow-band signal via a video signal, which acts as a wide-band channel.

One of the main requirements in digital watermarking is that the watermark must be embedded in such way that it does not introduce visual artefacts to the host signal. Since the watermark power is bounded by perceptual visibility, watermark bits need to be spread by a large chip-factor in order to have reliable detection, which will decrease a number of watermarking bits that can be put in the same embedding window. Detection reliability can be increased by pseudo-random spreading of the watermarking bits and also perceptual watermarking models can be incorporated to increase the embedding power [2], [3]. In our technique, we used combination of Watson' JND model [4] and improved JND model using block classification proposed by Zhang et al in [3]. In compressed domain watermarking, another limiting factor is that the video bit-rate must remain the same. Embedding in a particular coefficient is not allowed if it increases the bit-rate giving decrease in the power of the watermarked signal. The number of altered coefficients can be increased with an optimized bit-rate preserving scheme on macro-block level.

The watermarking process can be seen as a communication of secret message via a noisy channel, where noise is originated by the video signal and the attacks. Although, above mentioned techniques can increase the watermarking power, the SNR is still low to communicate desirable number of bits with high decoding rate. Hence, it is necessary to introduce some form of error correction coding to boost the capacity and improve the detection rates. In this paper, we are proposing to use duo binary Turbo codes to protect watermarking channel. Turbo codes (TCs) [7] have received great attention since their introduction in 1993. This is due to the extra-ordinary performance at low bit error rates, reasonable complexity, and encoding blocks with various rates and sizes.

2. WATERMARKING CAHNNEL DESCRIPTION

The targeted area of digital watermarking in this work is real-time data embedding and indexing of mpeg2 sequences for applications in professional environment where intentional attacks are not expected, so watermark needs to be robust on typical video editing processes, such as transcoding, logo insertion, cross-fade etc. Hence, focus was given on requirements for high imperceptibility and its trade off with watermark capacity.

A minimum duration of the watermarking video segment from which it will be possible to extract the watermark is often defined as 5 seconds [5]. For the MPEG2 standard for PAL sequences it can be seen as 8 I frames. In this way only 8 frames needs to be processed in watermark decoder. Due to temporal compression embedding space in inter-frames is considerably low, so this can be seen as reasonable trade-off between the capacity and the computational cost.

The principle watermarking scheme based on spread-spectrum is given in Figure 1. Rather than spread bits in bit-by-bit fashion, each of n watermarking bits is repeated 64 times to form 8x8 block and these blocks are then randomly spread through 8 watermarking frames and modulated by pseudo sequence [6]. In that way, every watermark bit has almost the same Signal-to-Noise ratio, since the bits are evenly spread through textured, edge and plain areas. Before embedding the watermark to DCT coefficient, its amplitude is adjusted using the information from corresponding DCT block in the original sequence.

The perceptual adaptation model used in this work tends to exploit three basic types of phenomena: non-uniform frequency response of human eye (contrast sensitivity – threshold t_{CSF}), sensitivity to the different brightness levels (luminance masking - t_l) and sensitivity to one frequency component in the presence of another (contrast or texture masking - t_c):

$$t_{JND}(n_1,n_2,i,j)=t_{CSF}(i,j)\times t_l(n_1,n_2,i,j)\times t_c(n_1,n_2,i,j) \quad (1)$$

where indices n_1 and n_2 show the position of the 8x8 DCT block in the image or the video frame, while i and j represent position of the coefficient in the DCT-block.

The visibility threshold t_{CSF} as a function of spatial frequency response in specific viewing conditions is usually derived by the model presented in [4]. The human visual system's sensitivity to variations in luminance is dependent on the local mean luminance and given by threshold t_l. In this scheme, Zhang luminance adaptation is used [3], since it better models luminance thresholds in very dark and very bright areas.

To incorporate texture masking, a DCT block is first classified according to its energy distribution as textured, edge or plain. In plain and edge areas, we used Watson [4] contrast masking model, since Zhang model tends to underestimate JNDs in edge blocks and gives the low watermark power in edgy sequences. For texture blocks, we used improved Zhang method that basically elevates Watson threshold according to the block texture energy.

As already mention, watermarking or any other process on the compressed video bit-stream must not increase the bit-rate. Concerning the bit-rate preserving, it was proposed in [6] to control difference between a macro-block size in the original and the watermark file. If the watermarked macro-block size is bigger, watermarked AC coefficients with biggest VLC difference are swapped with the original ones till the macro-block size becomes smaller or equal to the original one. In that way, we were able to alter around 50% of non-zero AC coefficients depending on the sequence, compression level and watermark amplitudes [6].

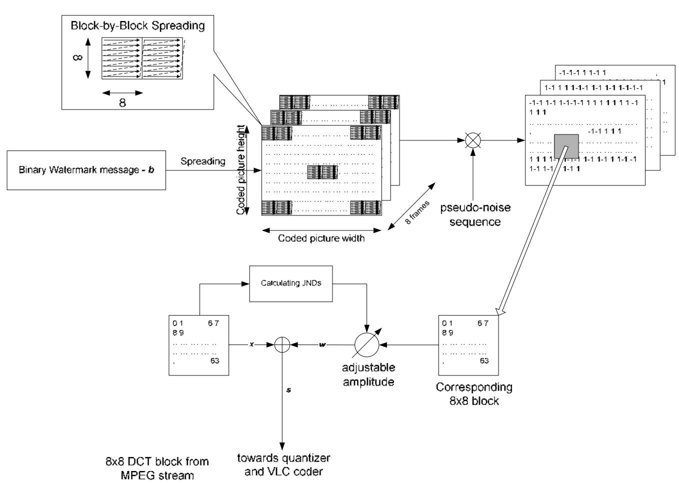

Figure 1. Watermarking embedding scheme

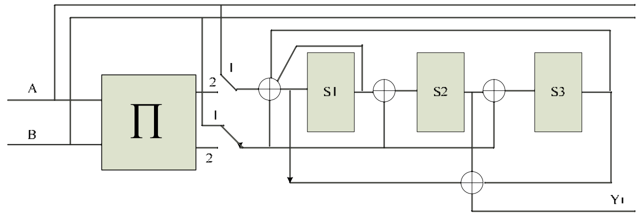

Figure 2. Duo-Binary Turbo Encoder

3. DUO-BINARY TURBO CODES

The watermarking channel has a small signal to noise ratio and a potentially large bit error rate due to noise introduced by the host signal and attacks. Hence, it is essential to protect the watermark message by introducing redundant bits, which will be used for error correction. In our experiments, we were first experimenting with a classical turbo coder with UMTS interleaver [6]. This turbo coder is a parallel concatenation of two binary rate 1/2 Recursive Systematic Convolutional (RSC) encoders that are separated by an interleaver. The overall TC rate is 1/3 without puncturing. We used puncturing mechanism to reduce the number of bits that needs to be embedded in the sequence.

Duo-binary codes were introduced in the domain of TCs by Berrou et al. [8]**.** These codes consist of two binary RSC encoders of rate 2/3 and an interleaver of length *k*. Each binary RSC encoder encodes pair of data bits and produces one redundancy bit, so desired rate 1/2 is the natural rate of the double binary TC.

In this article, we consider the 8-state duo-binary TC with generators in octal notation are (15,13) for Y_1 that has been adopted by the ETSI (European Telecommunications Standards Institute) standards for Digital Video Broadcasting with Return Channel via Satellite (DVB-RCS) and Digital Video Broadcasting with Return Channel via Terrestrial (DVB-RCT) as shown in the Figure 2. The tail-biting [9] technique is used to convert the convolutional code to block code that allow any state of the encoder as the initial state. So there is no need to tail bits to derive the encoders to the all-zero state.

The interleaver design is a critical issue and the performance of the TC depends on how well the information bits scattered by the interleaver to encode the information by second binary RSC encoder.

The turbo-decoder is composed of two Maximum A Posteriori (MAP) [8] decoders, one for each stream produced by the singular RSC block as shown in Figure 3. The first MAP decoder receive the two distorted systematic bits (A'_k, B'_k) after channel along with the parity y_{k1} for first binary RSC encoder and produce the *extrinsic information* Z_{k1} that is interleaved (∏) and feed to the second MAP decoder as the *a priori* information. The second MAP decoder produces the *extrinsic information* Z_{k2} based on interleaved distorted systematic bits (A'_k , B'_k), distorted parity by second binary RSC encoder and *a priori* information from first MAP decoder. Then Z_{k1} is used as the *a priori* information of the first MAP decoder. After a certain number of iterations usually 3 to 10, the *a posteriori probability* (APP) is taken, deinterleaved (∏') and performed hard decision to get transmitted information.

At low error rates or high signal to noise ratio, the performance of the classical TC fluctuates due to the "error floor". The higher minimum distance can reduce the error floor effect at low error rates. Duo-binary TCs normally has better performance than classical TC due to larger minimum distance. The minimum distance of TC depends on the interleaver design how well it shuffles the information bits. To get better performance for the duo-binary code for watermarking channel, the particular block length is selected that behave better in the low error rates. For this we use the All-zero iterative method [10] to check the performance of the duo-binary TC.

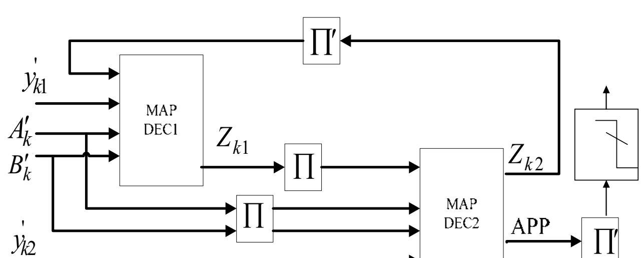

Figure 3 Iterative Turbo Decoding based on MAP algorithm for duo-binary TC

4. EXPERIMENTAL RESULTS

The presented techniques were evaluated using on typical MPEG2 test sequences (Table Tennis, Flower Garden, Mobile and Calendar, Suzy, BBC3 etc). All sequences were 375 frames long, PAL (704x576, 25 fps), with GOP IBBP structure, size 12 and bit-rate 6 mbps. The BBC3 sequence was most difficult to watermark since it is consist of mainly edge and plain blocks. The average SNR of watermarking channel when 256 bits are embedded in the first 8 I frames of this sequence is 7.2 dB. Hence, we focused our experiments on that particular video segment.

The Bit-Error Rate was measured in four different setups: uncoded without attack, uncoded and transcoded to 2 mbps, turbo coded .without attack and turbocoded and transcoded to 2 mbps. We were simulating watermarking with different embedding packet sizes (96-496 bits per 8 I frames). To get meaningful results, we were embedding ~10^5 bits per simulation. Results are given in Figure 4. The iterative nature of the TC shows more than a double gain in the embedded bits for uncoded watermarking messages at 6mbps and after transcoding at 2mbps. A 352-bit watermark message is divided into a pair of 176-bit sequences that are encoded with duo-binary TC and after watermarking channel and turbo decoding, there is no error found. However, in order to resist transcoding watermark message needs to be at most 216 bits long.

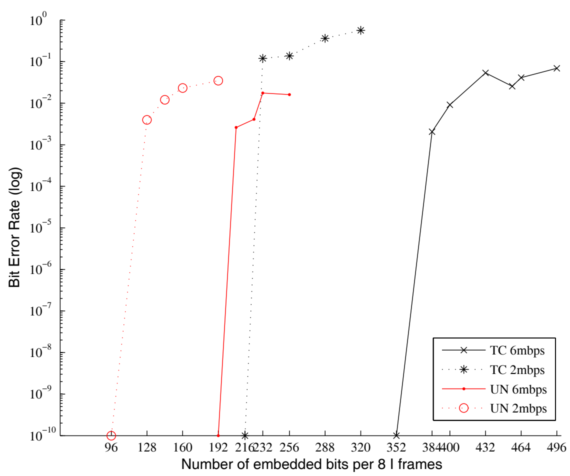

Figure 4. Bit Error Rates for protected (TC) and unprotected (UN) watermark message: no attack – 6mbps and transcoding attack - 2mbps.

5. CONCLUSIONS

Application of the state-of-the-art duo-binary turbo codes in protection of the spread spectrum watermarking technique has been presented. It was shown that duo binary turbo codes can effectively increase the watermark payload. Improvements in the terms of bits spreading, perceptual adjustments and bit-rate preserving fulfilled capacity requirements for the typical indexing application (64 bits in 5 seconds) and with implementation of turbo coding capacity is doubled.

Duo- binary codes perform better then classical turbo coders in protection of watermarking channel, since they have natural rate of ½ and no puncturing is needed. Above that they are computationally less expensive, show better convergence for iterative decoding and have a large minimum distance.

6. REFERENCES

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