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Robust HEVC Video Watermarking Scheme Based on Repetition-BCH Syndrome Code

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Abstract

High efficiency video coding (HEVC) was recently introduced two years ago as the new standard for video coding. This new codec will be the most widely prevalent standard. Because of the industry needs for authentication and copyright protection methodologies the robustness of this standard is required to be developed. This paper presents the first robust digital watermarking method for the HEVC based on Repetition-BCH syndrome code technique without intra-frame distortion drift. The objective of this article is to implement a new technique that can offer high robustness against noise channel errors and increase the error detection rate in the HEVC video sequences transmitted over noisy communication channels. The proposed technique does not significantly affect the video quality, nor does it escalate the bitrate. The results show that the proposed technique offers greater robustness against noise channel while preserving good quality for extracted watermark. The proposed technique significantly contributes to the performance of the error detection and correction. In addition, this technique can recover the watermark when the watermarked frames dropping rate is less than 20%.

Keywords: *HEVC, video watermarking, intra error propagation, channel attacks, BCH code, repetition code*

1. Introduction

The HEVC is the latest video coding of the ITU-T and ISO/IEC standard, which was firstly introduced two years ago. According to this standard, the bitrate can be reduced by around 50 % in comparison with the standard H.264 while maintaining the same visual quality [1, 2]. Despite the success of the H.264 video codec for the video coding and video watermarking, the new standard HEVC is poised to replace the existing video coding standards. Furthermore, the HEVC opens a new area of research in distributing digital video data, which requires the copyright protection and authentication methods. For this reason, a new robust video watermarking scheme has been proposed in this paper since the embedded watermark sometimes has errors which cannot be detected at the decoder side. Repetition- BCH (Bose, Chaudhuri, Hocquenghem) code has a powerful random and a burst correcting ability. BCH codes also leave the data in its original form which allows video decoders to perform error correction without extra computation [3]. In addition, the BCH decoder cannot correct a received codeword that has more than (t) errors. For this reason, in this paper a new method is proposed to improve the robustness by repetition of each bit in BCH codes at certain times to recover the errors above t errors. The repetition-BCH code is applied on watermark data before embedding to detect and correct the errors while extracting the watermark. The scheme was tested by frame

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dropping and additive white Gaussian noise while maintaining excellent watermark quality. The rest of the paper is organized as follows. In Section 2, a presentation of related work is given, while Section 3 introduces the proposed scheme. Section 4 presents the results and discussion followed by the conclusion in Section 5.

2. Related Work

According to our previous review, the watermarking methods designed for existing video coding standards cannot be directly applied for the HEVC[2]. The core part of the HEVC is the coding tree unit instead of the macro-block used in the H.264. In addition, the HEVC involves two types of transforms: the integer discrete sine transform (DST) and the integer discrete cosine transform (DCT) while the H.264 involves only an integer DCT [4]. Recently, Swati *et. al.*, proposed a watermarking scheme for the HEVC [5]. In their algorithm the watermark was embedded into the quantized transform coefficients during the encoding process. However, this method requires relatively high computation cost. To cope with this challenge, a new watermarking scheme during the encoding process has been recently introduced and applied before using the entropy code part to get the output bitstream by Ogawa *et. al.*, in [6]. Unfortunately, this technique yields the intra-frame error propagation effect. In order to avoid this problem, the algorithm, which is proposed by Chang *et. al.*, in [7], has been adopted. In this algorithm, the blocks are classified into groups based on intra prediction modes. These groups are used to select specific residual quantized discrete sine transform (RQDST) coefficients of the luma blocks or the residual quantized discrete cosine transform (RQDCT) coefficients for embedding watermarking data with free error intra-coded frames. However, this technique is not robust. It can be corrupted by common types of attack like noise channel or frame dropping. Therefore, this paper presents the first robust digital watermarking method for the HEVC based on Repetition-BCH syndrome code technique without intra-frame distortion drift.

3. Proposed Scheme

In order to improve the robustness of our approach, the watermarked data is encoded by repetition-BCH code before embedding process. In this proposal, a random set of I-frames is selected to embed the secure data watermark, to produce a good video quality with a few time spent for embedding process with an acceptable increase in bitrate. The encoded watermark information is embedded in the quantized DCT/DST residuals of I-frames for different TUs sizes which they meet the conditions of free intra-frame error propagation which is proposed by Chang *et. al.*, in [7]. The watermark data is extracted from the same set of I-frames on the decoding side.

3.1. Encoded Watermarking Pre-Process

Binary BCH code is capable of correcting all random patterns of t errors [8]. For any positive integer number $m \geq 3$ there exists a binary BCH code, BCH (n, k, t) with the following properties [8]:

n = $2^m - 1$: The maximum codeword length

$k \geq n - mt$: The number of information bits in the codeword or called code dimension.

The BCH codes leave the data in its original form that allows the decoder to error correction without high computation [3]. However, the BCH decoder cannot correct a received codeword that has more than (t) errors. Therefore, in this paper proposed method to improve the robustness by the R-BCH algorithm. This algorithm repeats each bit in the codeword of BCH codes (R) times in order to detect more errors in the output of BCH code technique. The original binary watermark (W) is encoded by repetition-BCH codes to produce a watermark codeword (W_c).

3.2. Embedding Process

This proposed technique divides the watermark code W_c into blocks and embed these blocks inside the selected I-frames. The set of I-frames was selected randomly while the others leaves un-watermarked, which gives good results in terms of PSNR and complexity of the scheme. Figure 1 shows the embedding framework of the proposed scheme.

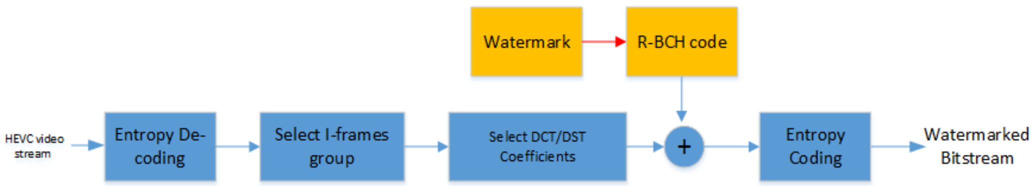


Figure 1. The Basic Framework of the Embedding Proposed Scheme at Encoder Side

The intra-frame error propagation problem arose because we embed watermark data in I-frames. In order to tackle the intra-frame error propagation problem, a free intra-frame error algorithm for HEVC has been proposed in [7]. The algorithm classifies the pixels to groups based on five cases along horizontal,vertical, and diagonal to protect a particular pixel set against intra-frame error effects. This set called protected pixel group as shown in Table 1.

Table 1. Truth Table of Error Propagation Relationships [7]

Case	Error propagation pattern			Protected pixel group
	H	V	D	
1	T	F	T or F	$\{R_{i,N}\} i = 1,2 \ldots., N$
2	F	T	T or F	$\{R_{N,i}\} i = 1,2 \ldots., N$
3	F	F	T	$\{R_{N,N}\}$
4	F	F	F	None
5	T	T	T or F	$\{R_{i,N}\} \cup \{R_{N,i}\}$ $i = 1,2,3, \ldots\ldots, N$

H: Horizontal, V: Vertical, D: Diagonal, T: True, and F: False, $R_{x,y}$ *protected pixels along directions*

The non-zero values of residual QDCTs or QDST coefficients within the different size of TUs are modified based on both the categories of the intra-frame error propagation and the W_c will be embedded in these non-zero coefficients in order to keep the bit average rate almost constant, and the video watermarked quality will not be affected by embedding process [9]. The following Figure 2 illustrates the pseudo code of embedding process algorithm.

Input: Secure Watermarking codeword w_c, and I-frames

Output: The watermarked residual QDCTs / QDST coefficients $x'_{i,j}$

Initialize size of TU block to 4×4 (size=4)
Initialize put the map of coefficients positions, Coeff._position to zero
Count the binary elements of w_c and put the maximum number in constant: wmax
Select a set of I-frames in order to embed the watermark and save the indexes in array: index_IF
Count the frames in the set and put the maximum number in constant: Imax
While element number of w_c < wmax **do**
While index_IF < = Imax **do**
size=4
While size ≠32 **do**
While Coeff._position <= (size*size) **do**
Read the selected residual QDCT/QDST coefficient $x'_{i,j}$ inside the block of frame based on the cases in table 1.
If ($X_{ij} \neq 0$) **then**
If (($|X_{ij}|$mod2==0 and W_c==1) or ($|X_{ij}|$mod2==1 and W_c==0))
If ($X_{ij} > 0$) **then**
Increment X_{ij} by 1 (to produce the output X'_{ij})
else
Decrement X_{ij} by 1 (to produce the output X'_{ij})
Endif ; Endif ; Endif
End while; End while; End while; End while

Figure 2. Pseudo Code of Embedding Process Algorithm

3.3. Extraction Process

For extraction, the detection process is accomplished after the HEVC video stream was entropy decoded as shown in Figure 3. The embeddable I-frames are determined according to our selection and blocks of those frames also determined based on the cases of the intra-frame error propagation that used at the encoder side. By identifying the locations of these coefficients, the synchronization will never be lost, and watermark bits can be extracted correctly. If $x'_{i,j} \neq 0$, the watermark bit can be detected by

$$w = \begin{cases} 1, \text{ if } & x'_{i,j} \text{ is odd,} \\ 0, \text{ if } & x'_{i,j} \text{ is even} \end{cases}$$

In order to extract the corrected watermark data, the watermark bits correct by the R-BCH code with same keys parameters n, k, t and (R) that used before to encoder side.

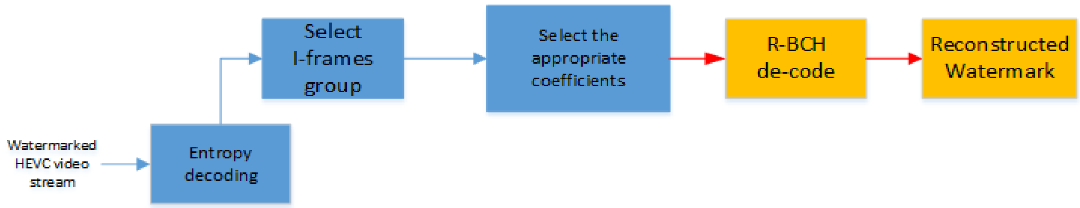


Figure 3. The Basic Framework of the Extracting Proposed Scheme at Decoder Side

4. Results and Discussion

In order to validate the performance of the proposed scheme, the method was implemented with Visual C++, HEVC HM-10.0 reference software [10], with different videos test sequences[11]. The main software configuration parameters are shown in Table 2.

Table 2. Configuration Parameters of the HM Software

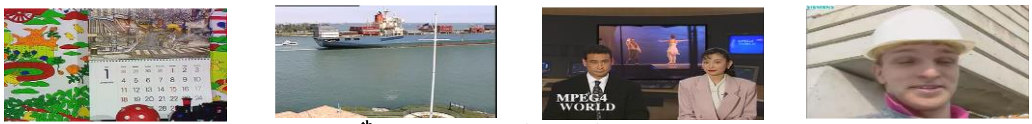
Parameters	Value
Frame rate	30fps
Frame to be encoded	96
Intra Period	4
GOP size	4
RDOQTS	1

The size of W is 64×64 . The W encoded by repetition-BCH with repetition factor (R). In this paper, the BCH (19, 511, 119) at same value of (R =3) have been tested in terms of error correction capability, watermarking capacity and visual quality.

In order to detect the watermark correctly at decoder side the enough numbers of I-frames are selected to insert all the blocks inside those frames. For example, when BCH (19, 511, 119), R=3, size of frame is 352x288 and, the size of watermark is 64×64, the numbers of watermarked I-frames are 15 I-frames out of 24 I-frames in video test sequence based on the configuration parameters in Table 2. Therefore, the selected I-frames have been used as a key for decrypting the original watermarked data. According to Figure 4, the first row is the decompressed of 8th I-frame index before embedding data watermark, and the second row is the eight I-watermarked frames index at QP=32. This approach investigates invisible watermark with lower the visual degradation, a human cannot note this degradation by eyes. In Figure 5, plots the bitrates vs. PSNR, bitrate vs. embedding capacity, and QP vs. PSNR of the mobile test sequence. In addition, the proposed technique preserves video quality, and the capacity is increased when the number of none zero coefficients increase at high bitrate.

Table 3 gives the objective video quality in terms of PSNR and Bitrate at four different QP values of the three test sequences. The PSNR is inversely proportional to the QP value, for the two video sequences, the original and watermarked one. For the tested video sequence samples, the relationship is almost linear. Similar behavior is observed for both the watermarked and unwater marked video. However, at low QP values, the PSNRs of the video are considerably different from each other; but the watermarked video sequence quality is still acceptable.

(a) 8th I-frames before embedding



(b) 8th I-watermarked frame after embedding

Figure 4. Subjective Performance Evaluation of 8th I-frames before and after Embedding a Watermark with QP=22

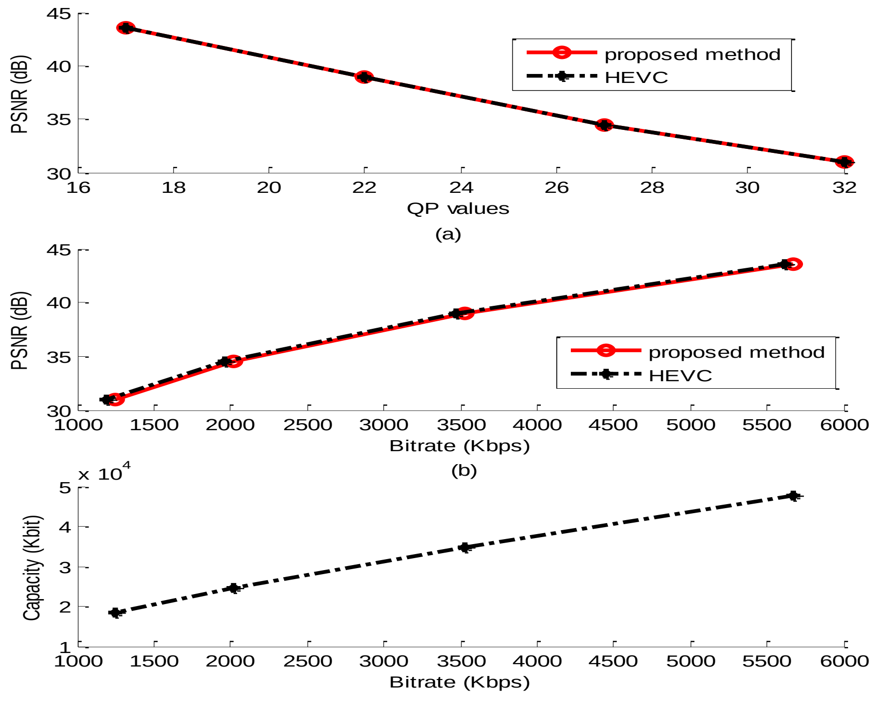


Figure 5. Objective Assessment with a) QP vs. PSNR, b) Bitrates vs. PSNR, and c) Bitrate vs. Embedding Capacity of the Mobile Video

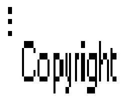
Table 3. Effects of Watermarking Embedding on Video Sequences at R-BCH Code Parameters (n=19, k=511, t=119, R=3)

Sequences	*Δ PSNR / ΔBitrate*	*QP=17*	*QP=22*	*QP=27*
Mobile 352x288	*ΔPSNR (dB)*	0.00	0.01	0.00
	ΔBitrate (%)	1.1%	1.7%	2.8%
Container 352x288	*ΔPSNR (dB)*	0.01	0.01	0.01
	ΔBitrate (%)	*2.6%*	*4.2%*	*5.02%*
News 352x288	*ΔPSNR (dB)*	0.00	0.01	0.00
	ΔBitrate (%)	*3.6%*	5.1%	*5.3%*

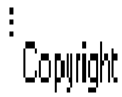
In order to evaluate the watermarked video quality and robust of our scheme, we use peak signal to noise ratio (PSNR) [12], the normalized cross-correlation (NCC) [13] and subjective measures[14]. The robustness of the proposed technique was evaluated according to the common communication channel attacking types into two cases: additive white Gaussian noise (AWGN) and the frame dropping rate (FDR) which is the numbers of watermarked frames divided by the dropped watermarked frames. In case I, the DCT/DST coefficients of watermarked video (mobile sequence with QP=22) at decoder side are attacked by AWGN with a zero mean and standard deviation=1. Table 4 shows the NCC of the proposed scheme against (AWGN) with different BER values. When the probability of errors in the channel is less than 0.12, the entire NCC values in table 4 approach to 1 and the complete watermark extraction can be recovered with good subjective performance as shown in Figure 6.

Table 4. Extraction Performance with Different BER Values at R-BCH Code Parameters (n=19, k=511, t=119, R=3) for Mobile Video against (AWGN)

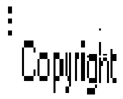
BER	NCC	subjective
0.01	1.00	excellent
0.12	0.93	good
0.15	0.89	fair



AWGN a) BER=2×10^{-5}, NCC=1



AWGN b) BER=3×10^{-2}, NCC=1



AWGN c) BER=9×10^{-2}, NCC=0.96

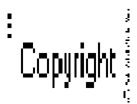
AWGN d) BER=0.15, NCC=0.89

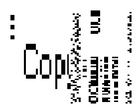
Figure 6. Reconstructed Watermark after Attacking by AWGN Noise for Watermarked Mobile Sequence Test

Case II is the (FDR), which is applied to 15 watermarked frames. Table 5 gives the extraction performance of the mobile sequence test when BCH code (n=19, k=511, t=119, R=3). The proposed technique recovers the watermark data until approximately 20% of watermarked frames loss as shown in Figure 7.

Table 5. Extraction Performance with Different Watermarked Frame Dropping Rate Values at R-BCH Code Parameters (n=19, k=511, t=119), R=3 for Mobile Video Against Frame Dropping.

Watermarked frame dropping rate	NCC	subjective
6.66% (1/15)	1.00	excellent
13.33%(2/15)	0.98	good
20%(3/15)	0.68	Unsatisfactory





b) FDR=6.66% (1/15), NCC=1.0 a) FDR=13.33% (2/15), NCC=0.98 c) FDR=20% (3/15), NCC=0.67

Figure 7. Reconstructed Watermark after Dropping Frames from the Watermarked Mobile Sequence using Different FDR Values

5. Conclusion

In this article, a new robust digital watermarking method for HEVC based on Repetition-BCH syndrome code technique without intra-frame propagation errors has been developed. The experimental results show that this technique is invisible and robust. Overall, the average PSNR decreased by 0.01dB while the bitrate is slightly increased by 5%, on average at low bitrates. The proposed technique significantly contributes to the performance of the error detection and correction when the channel error probability is around 0.15. In addition, this technique can recover the watermark when the watermarked frames dropping rate is less than 20%. In our future work, we will try to evaluate the performances of the system against other attacks.

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