Robustness of SVD Watermarks in Video Sequences Encoded with H.264/AVC

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Abstract – **This paper analyzes the robustness of watermarks based on SVD transformation in order to protect the copyright of H.264 encoded video. The robustness of the CSP watermark has been tested with algorithm which performs extracting and thresholding of the watermark. A comparative results analysis, using the PSNR as a measure of quality, has been shown that robustness increase in the function of the number sampled bits in video sequence. The results indicate that the CSP algorithm can be successfully applied in professional video profiles defined H.264/AVC standard.**

Keywords **– Singular value decomposition, Digital watermark, H.264/AVC codec, Multimedia.**

I. Introduction

The development of modern digital telecommunications networks and systems has led to a dramatic increase of the volume multimedia traffic [1]. Today's customers are particularly interested for new multimedia services such as VoIP (Voice over Internet Protocol), VoD (Video on Demand), IPTV (Internet Protocol Television), videoconferencing, etc. Viewing and sharing of digital video content in a wireless environment is extremely demanding services and require significant network resources [2]. For efficient use of video on the network, as well as its storage, it is necessary to apply specialized compression algorithms [3]. The latest ITU-T recommendations relating to the use of H.264 compression standards include both current as well as future video applications [4]. Recent application of this standard include HD video resolution and different sampling format. For professional application uses a larger number of bits per samples as well as higher resolution of sampling color. For the purposes of this, standard H.264/AVC has been expanded with new coding tools that are called the FRExt [5].

The global availability of multimedia contents over the Internet is resulted in the increase of their illegal use. Protection from illegal use that are based on hardware or software techniques have not bring satisfactory results. Many companies that are owners of video materials giving up on technical ways to protect and turning to legislation which regulates copyrights. In order to prove copyright over the video material, owners use algorithms to inserting invisible marks (watermarks) in video [6]. Algorithm for inserting the watermark should not cause visible degradation of the image, and it should be allow extracting of the watermark satisfactory quality. The most common in use are the algorithms based on the transformation techniques such as DCT (Discrete Cosine Transform), FFT (Fast Fourier Transform) or SVD (Singular Value Decomposition). SVD is a transformation technique for inserting a watermark in the video, which is often used. This paper analyzes the robustness of CSP algorithms, [7] which belongs to the class of very robust SVD algorithms. Pursuant to the advanced capabilities H.264/AVC standard, is analyzed the robustness of encoded video sequences in function of number of bits per samples. The analysis was conducted with the video content which is sampled with 8 and 10-bits per samples and coded in accordance with the H.264/AVC standard. Extracted watermark and his binarized (thresholded) version are analyzed. The robustness of extracted and binarized watermark are evaluated by objective PSNR parameters. Higher PSNR value means that extracted watermark is a better quality, and the greater robustness of the CSP algorithm.

This paper is organized as follows. In Section II describes FRExt profiles of H.264 standard. In Section III is presented an algorithm for testing of the robustness of the watermark, while in section IV presents the results of experiments and comparative analysis of the results. In Section V, some conclusions about the robustness of CSP algorithm and avenues for further research are done.

II. FRExt profiles of H.264/AVC standard

H.264 video compression algorithms are based on removing redundant information from the videos, with the methods of prediction in time (temporal, inter) and space (spatial, intra). Powerful mechanism for research redundancy in the current picture and/or images that precede, or follow, is the basis of superior compression characteristics of H.264 encoder [3], [4]. Anticipating the content of some parts of the image based on the observed similarity, it is possible to form a residual frame with much less data. The consequence of this approach may be the neglecting of fine detail in the image, which will have a negative effect on the video quality. In addition to the negative effect on the video, neglecting fine detail reflects negatively on the quality of the injected watermark. In addition to the standard application of H.264/AVC encoder on the Internet, for professional applications this standard provides profiles that support more than 8 bits for sampling (10-14 bits). Also, this standard supports higher resolution for color representation (4:2:2 or 4:4:4). These profiles are known as FRExt. The influence of the number of bits in a video sample on the quality of the extracted and binarized watermark is discussed. On Fig. 1 is presented relationship between profiles of the H.264/AVC. standard.

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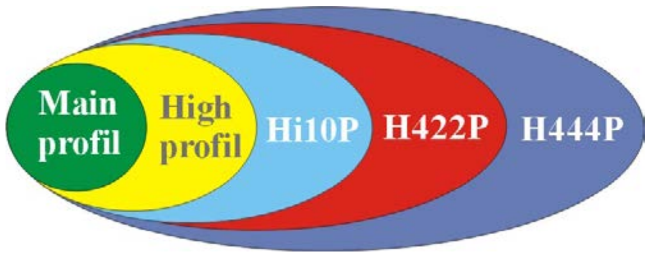


Fig. 1. FRExt expansion H.264/AVC standard

III. Algorithm for testing of robustness

In this chapter is proposed algorithm for testing of the robustness of the watermark that is inserted in the video. Input, and output parameters of this algorithm are:

Input: Uncoded video sequence (A), watermark (W) and inserting factor α.

Output: Decoded video sequence (A_w^*), extracted watermark W^*, binarized watermark (W_b^*) and PSNR.

Algorithm for testing of the robustness consists of the following steps:

Step 1: Insertion of the watermark W in uncoded video sequence A with CSP algorithm and inserting factor α, thereby forming a video sequence A_w [8].

Step 2: Coding video sequences A_w with H.264/AVC coder and forming sequence $A_{w\_H264}^*$.

Step 3: Decoding of sequence $A_{w\_H264}^*$ with H.264/AVC decoder and forming video sequence A_w^*.

Step 4: Extract the watermark W^* from video sequence A_w^* with CSP algorithm.

Step 5: Forming watermark W_b^* with binarization algorithm.

Step 6: Calculation PSNR for W^* and W_b^* watermarks.

IV. Experimental results and discussions

A. Experimental setup

For the purposes of assessing the robustness of CSP watermark is applied the algorithm described in Section III. The first frame of the test sequence is shown in Fig. 2a, while the mark is shown in Fig. 2.b. For comparison of the quality inserted watermark in the function of the number of bits in the sample, the test video sequence is used at the two sampling formats, as follows: 4:2:0 and 4:2:2. Format 4:2:0 is sampled with 8-bits, while the 4:2:2 format is sampled with 10 bits. In the video sequence (Fig 2a) is inserted the mark (Fig 2b), and after that is done encoding with H.264/AVC encoder. The watermark is inserted in each frame of uncompressed video

a) b)

Fig. 2. Test sequence with resolution of 384x216 pixels: a) First frame of video-sequence and b) watermark

test sequences with the constant value of the inserting factor α. In the process of encoding/decoding is used Reference Software JM 18.4 software [9], [10] is running in MATLAB. This JM software represents an official version of ITU-T and support FRExt profiles. Coding of the protected video was done for a group of code parameters that define the code profile. The chosen parameters of H.264 coder in relation to had the following values:

- **8-bits**:
  ProfileIDC = 100 (FRExt Profile, *LevelIDC= 40*)
  IntraPeriod=1,
  NumberReferenceFrames=1,
  RateControlEnable=0,
  InitialQP=28.
- **10-bits**:
  ProfileIDC = 122 (FRExt Profile, *LevelIDC= 42*),
  IntraPeriod=1,
  NumberReferenceFrames=1,
  RateControlEnable=0,
  InitialQP=28.

After decoding video sequences, watermark is extracted and binarization algorithm is applied on him. In the process of extracting the watermark is coming to rounding errors that negatively affect the appearance of the extracted mark. This is reason to apply the binarization process. Binarization process of watermark is performed on the basis statistical analysis of the distribution of values of pixels, which are displayed with the histogram. The decision threshold in the binarization process is located midway between the maximum values of the intensity in the histogram. Examples of histograms obtained for each value of the parameter α are shown in Tab. III. From accuracy of determining the threshold depends the quality of the binarized watermark. The quality of extracted mark is evaluated by PSNR which gives an objective assessment of the quality of the mark, i.e., the robustness of the CSP algorithm.

B. Test sequences

In the video sequence of resolution 384x216 pixels (Fig. 2a) is inserted the mark with the same resolution (Fig. 2b). Uncompressed video sequence with inserted watermark is encoded using the H.264/AVC codec. The video-sequence which is used in the algorithm for testing the robustness of the CSP watermark is part of *Kimono1.yuv*. This sequence is sampled in both formats (4:2:0 and 4:2:2) and can be found at the URL: *ftp://hvc:US88Hula@ftp.tnt.uni-hannover.de/testsequences*.

TABLE I
EXTRACTED AN BINARIZED WATERMARKS, 8-BITS

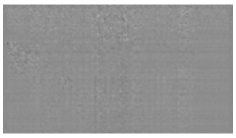
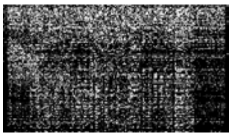
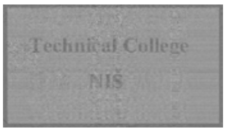
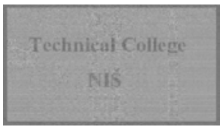
α	Extracted watermark W^*	Binarized watermark W_b^*
0.01		
0.02		
0.03		
0.04		
0.05		

TABLE II
EXTRACTED AN BINARIZED WATERMARKS, 10-BITS.

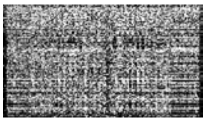
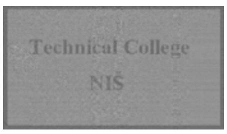
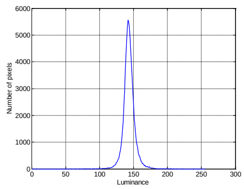
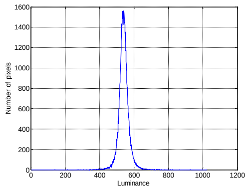
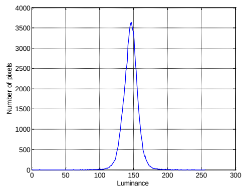
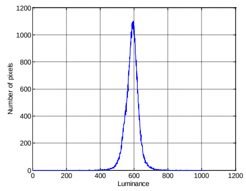
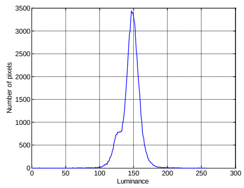
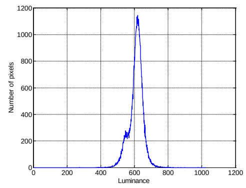
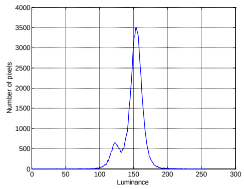
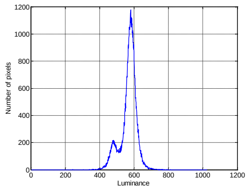
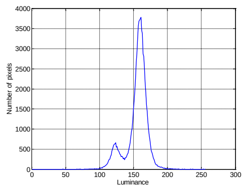
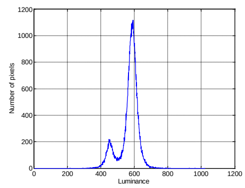
α	Extracted watermark W^*	Binarized watermark W_b^*
0.01		
0.02		
0.03		
0.04		
0.05		

TABLE III
HISTOGRAMS FOR EXTRACTED WATERMARKS FOR 8 AND 10 BITS

α	8-bits	10-bits
0.01		
0.02		
0.03		
0.04		
0.05		

C. Results

Visual representation of extracted (W^*) and binarized (W_b^*) watermark are shown in Table I, for the video sequences encoded with 8 bits, and in Table II, for video sequences encoded with 10-bits. Histograms of extracted watermarks for 8-bits and 10-bits encoded sequence are shown in Table III. In cases where the histogram does not have a clear expressed peaks, binarization process has no significant effect on the quality of the watermark. PSNR values in function of insertig factor α, for the original and binarized watermark version when the video sequence is sampled with 8-bits, are shown in Fig. 3, while the PSNR values in function of insertig factor α, for the original and binarized watermark version when the video sequence is sampled with 10 bits, are shown in Fig. 4.

Based on the results shown in Tables I-III and Figures 3 and 4, it can be concluded that:

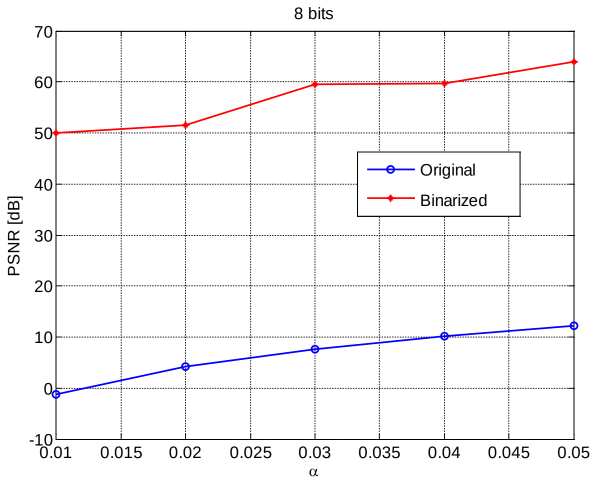


Fig. 3. PSNR as a function of inserting factors α for a) an original and b) binarized version of watermarks for 8-bits coding video-sequence

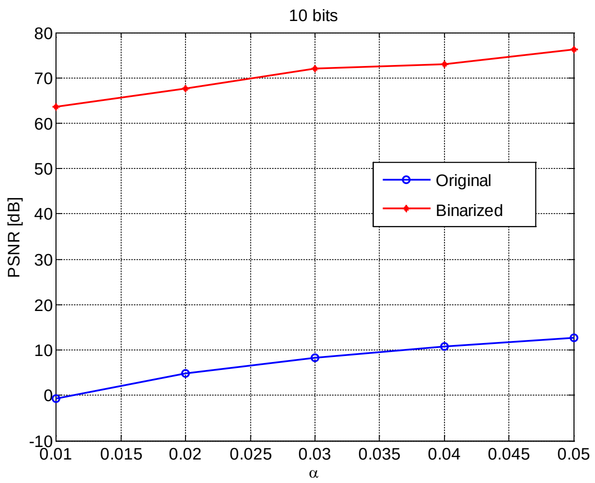


Fig. 4. PSNR as a function of inserting factors α for a) an original and b) binarized version of watermarks for 10-bits coding video-sequence

a) With increasing inserting factor α, the quality of separated watermark leads to an increase in both analyzed length of codewords.

b) The lower limit of visibility of the watermark for 8-bits is α=0.03, and for 10-bits the boundaries is α=0.02 (Tables I and II).

c) With respect to PSNR, binarized version of the watermark is approximately 10dB higher in the sequence of 10-bits, than sequence compared to one with a 8-bits for all of the analyzed parameter α (Fig. 3 and 4).

d) Binarized watermark gives a higher quality in the 8-bits (extracted watermark: from PSNR=0dB to 12dB; binarized watermark: from 50dB to 64dB) and 10-bits sequence (extracted watermark: PSNR=0dB to 12.5 dB, binarized watermark: from 62dB to 76dB).

e) PSNR for binarized watermark in 10-bits is an average of 12dB higher than watermark by 8-bits.

f) The upper limit of the inserting factor is set to α=0.05 and represents the limit of significant degradation of the video.

g) The quality of the watermark represented by means of a PSNR (Fig. 3 and 4), separated from the video sequence sampled with 10-bits, is increased compared to the watermark extracted from the sampled sequence of 8-bits.

V. Conclusion

Based on the experimental results presented in this study it can be concluded that the resistance of the watermark in H.264 encoding depends on the number of bits which is sampled video. This is the consequence of rounding which is done by CSP algorithm when inserting and extraction of the watermark. It is clear that the fault of rounding error have smaller values in the video sampled with 10-bits of those sampled with 8-bits. As an objective measure of quality was used PSNR, where the higher value of PSNR means higher the quality watermark, i.e., a greater robustness. Based on a detailed analysis of PSNR, it can be concluded that the robustness of the watermark inserted in video sequences sampled with 10-bits is larger than the one sampled with 8-bits on average by about 0.5 dB for a extracted, to 12dB for binarized watermark. Based on these results it can be concluded that robustness of watermarking based on SVD transformation increases with the number of sampling bits of video sequence and can be recommended for its use in FRExt profile of H.264 encoder.

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