Watermark Based Security Measures for Video Standards

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ABSTRACT: *The use of watermark as a security measure and its impact on the video standards with AVC coder is explained with a discussion of SVD algorithm. We have explained the compressed video which determines the watermark quality is given. We have used the mean square error to detect the quality of separated watermark. We have also explained the standardized indicators for the video protection.*

Keywords: Singular Value Decomposition, Digital Watermark, H.264/AVC Codec, Multimedia

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1. Introduction

Development of the modern digital telecommunications and especially the universal mobile telecommunication systems UMTS (Universal Mobile Telecommunication System) 3G/4G has contributed to introduction of new mobile telecommunication services. A considerable increase of the number of users of UMTS and terminal devices supported by multimedia contents resulted in an enormous increase of the multimedia and especially video communication on the Internet. Although the Internet was designed to offer through applications the best possible communication services in every moment, it is usually not enough for realization of contemporary multimedia services [1]. The reason for this lies in the fact that the video is most demanding regarding the net resources it engages, so that it is necessary to develop effective optimization (compression) algorithms for its application [2], [3].

In this paper H.264/AVC standard for compressing the video contents was taken into consideration; it has considerable advantages in regard to the previous ones [4], [5]. This standard was developed by the organizations ITU-T VCEG and ISO/IEC MPEG and it is believed that it will conquer a considerable part of the video market. Possibility of protection of video contents from illegal copying and distribution with H.264 codec was especially taken into consideration in this paper. This problem becomes more and more important having in view the enormous increase of the video communication in the Internet. Illegal copying and distribution of the electronic contents are present in many areas of acting, yet the software, music and film industries are especially affected. The illegal film market takes ca. 35% of the total pirated contents. Although protection from copying can be realized by using hardware or software techniques, none of them proved to be totally reliable. The shortcoming of these techniques is that they prevent making the spare copies for the case where the original medium might be damaged. Another extreme in solving this problem is that the multimedia companies may abandon any kind of technical protection. The concept of the copyrights protection lean only on the law regulations in the battle against the piracy. The basic problem to be solved with this concept is how to prove the copyright of a video content.

In order to protect copyrights many sofisticated digital technologies have been developed which are based on the digital processing of the video signal. One of often used technologies for proving the copyright is watermarking into the original multimedia contents [6]. The watermark should with its contents in a unique way identify the owner of the multimedia contents and it should be therein as long as they last. The watermark technique is realized by inserting of small secret copyright information (watermark) into the digital contents so that it is indiscernible, yet at the same time robust to a try of degrading or removing from the multimedia contents. In real-time video applications it is exceptionally important for the watermark to be robust to compressing and transcoding the video contents by various bit rates. Basically, there are two big classes of algorithms for watermarking. The first class of algorithms is based on watermarking in the spatial domain. In these algorithms the watermark is hidden in values of the luminance or chrominance component of spatially arranged pixels. The algorithms which belong to this class are realized relatively simply, yet they are not robust enough in the processing of the video signal and especially in realization of the video compression. The second class of algorithms is based on inserting the copyright information into the transformation domain. The transformation domain can be realized by using DCT (Discrete cosine Transform), FFT (Fast Fourier Transform) or SVD (Singular Value Decomposition) transformation to the video contents and then the obtained transformation coefficients are modified suitably to inserted picture. By the inverse procedure the inserted information can be taken out of the protected video in order to prove the copyright [6], [7]. [8], [9], [10]. The algorithms of this class have better performances of robustness in relation to the watermark inserted in the spatial domain.

The algorithms for watermarking of a video coded by H.264 codec can be divided according to the place where inserting is done in the process of coding. Thus inserting the watermark can be done before the video compression, before or after quantization and during the process of coding. Having in view that the standard H.264/AVC belongs to a group of compression techniques with losses, it is very important to analyze the endurance of the watermark in a video when its removal is attempted. This paper presents the analysis of performances of an algorithm for watermarking based on SVD decomposition proposed in [9]. This class of algorithms is successfully applied for protection of pictures. Problems in application of this algorithm to a video are analyzed and the key parameters are also identified.

The structure of the paper is the following. In the second section the applied SVD algorithm for watermarking is presented, while peculiarities of H.264 codec are given in the third section. The effect of the rounding during the insertion of the watermark and its influence on the quality of the watermark, i.e. of a video, were separately analyzed.

2.The SVD Watermarking Algorithm

For inserting the watermark into a video an algorithm based on SVD decomposition was applied, suggested also in [9].

This algorithm results from the idea presented in [8]. In spite of a good concept suggested in [9], a problem of false detection of the watermark was identified. This imperfection was eliminated by an algorithm from [9]. Inserting the watermark into a picture is can be done by the algorithm realized in the following steps:

Input: The matrix of the picture A_{mxn} Watermark W_{mxn}.

Output: The picture with the watermark Aw_{mxn}.

Step 1: Decomposition of the matrix of the picture:

$$A = USV^T, (1)$$

where A is the original picture, U and V the orthogonal matrices whose dimensions are m x m and n x n, respectively, S the diagonal matrix whose dimensions are mxn with the elements that represent singular values. The columns of the matrix U are left singular vectors, while the columns of the matrix V are the right singular vectors of A. The pair singular vectors specify the geometry of the picture, while the singular values specify the luminance of the picture.

Step 2: SVD decomposition of the watermark:

$$W = U_w S_w V^T{}_w = A_{wa} \; V_W{}^T . \tag{2}$$

Step 3: Inserting Awa into the diagonal matrix S:

$$S_1 = S + aA_{wa}. \tag{3}$$

Step 4: Forming the picture with a watermark :

$$A_w = US_1 V^T . \tag{4}$$

Extraction of the watermark out of the picture $A^*{}_w$ that is potentially different from A_w because of superimposed noises, is realized by the algorithm that consists of the following steps:

Input: The picture with the watermark $A^*{}_w$.

Output: watermark W^*.

Step 1: Forming the difference between the original A and the picture with the watermark $A^*{}_w$

$$\left(A_w^* - A\right) = A_1 \tag{5}$$

Step 2: Counting of the watermark W^*:

$$W^* = \frac{\left(U^{-1} A_1 \left(V^T\right)^{-1}\right)}{\alpha} V_w^T . \tag{6}$$

In Figure 1 there is an example for the black and white watermark imprinted into a video.

Figure 1. The original watermark used in this paper

3. H.264/AVC VIDEO CODEK

The new standard for compression of the video, known under the designation H.264/AVC, includes the widest spectrum of video formats. This standard ranges from the modest video applications on the Internet to the high definition video applications. This paper is considering CIF video format whose resolution is 352x288 pixels and it is often applied on the Internet. For coding of one frame of the uncompressed CIF video format it is necessary to have 1216512 b/frames. If the resolution of the video formats (SD format, HD 720p and HD 1080p formats) increases, the number of bit/frame increases enormously. This is the reason, among other things, why the video applications belong into the most demanding multimedial applications. Obviously, a kind of compression technique over the multimedial contents is necessary. The standard compression techniques without losses are not applicable to the multimedial contents because they do not have the necessary compression performances.

However, compression techniques with losses can reach desired performances with an acceptable level of degradation of the multimedial contents. H.264 is a compression standard that offers excellent compression solutions in relation to the previous ones. In comparison to other codec, H.264/AVC realizes the higher degree of compression for the same quality of the picture. In order to make H.264 standard applicable for the widest possible group of devices, various profiles are defined that determine a group of tools for generating the comprised video stream. Every profile is predetermined for a defined class of application. H.264 defines the following profiles: Baseline, Constrained Baseline, Extended, Main and several classes of High profile. The Baseline profile is convenient for video applications with small delaying (e.g. videoconferences) with not so demanding hardware recourses on reception, while High 10 and High444Pred profiles are meant for the professional usage. Imposing restrictions for the size of syntactic elements in H.264 stream defined the levels that determine the necessary computer power and memory demands for realization of H.264 decoders. H.264 compression algorithms are based on removing the redundant information out of video (temporal and spatial prediction). The frame prediction is done on the base of one or more previous or future frames called referent frames. Prediction reliability is attained by compensation of the movements between the referent and the current frames. Macroblock MB is a region in the picture determined by 16x16 pixels and represents the fundamental unit the movement is compensated over. So we differ frames of type I (intra), P (inter) and B (bidirectional) that uses one or more (previous or future) referent frames. A powerful mechanism for investigating the similarities in the current picture or pictures that precede, i.e follow, represents the base for the prediction models of H.264 coder. By predicting the contents of certain parts of the picture on the base of noticed similarities it is possible to form a “residual” frame with considerably less data. The result of this access can be neglecting the fine details in the frame which will have a negative effect on the inserted watermark. The result of this access is also the variable quality of the video and the separated watermark especially with lower bit rates.

4. Experimental Results and Discussions

4.1. Experimental Setup

The experimental results obtained by inserting/separating the watermark out of the uncompressed video by the proposed SVD algorithm were presented in the first part of this section. The second part of this section brings the results of separating the watermark out of the protected compressed video coded by H.264 coder. The watermark from Fig. 1 is inserted into the uncompressed video sequence Foreman_cif.yuv of resolution 352x288. The watermark is inserted into every frame of the uncompressed sequence with the constant value of the imprinting factor a. The quality of the watermark separated out of the uncompressed video was especially analyzed in the function of the inserting factor a and of the available number of bits for coding the video source. Since the video was coded with 8 bits and in the process of inserting the watermark it comes to rounding (cutting) not-integer-values of samples, the separation of the video watermark itself is made difficult. In order to explore dependence of the quality of the inserted watermark on the number of bits for coding the wholes series of simulations was performed.

4.2. Experimental results

In the simulation tests it was noticed that the quality of the separated watermark depends on the number of bits available for placing the sequence whit an inserted watermark. This is the reason why we do in this paper first analyze the influence of the number of bits for coding the video source to the quality of the separated watermark. Figure 2 presents the watermarks separated out of the uncompressed sequence for and a) 8 bits b) 9 bits c) 10 bits and d) 11 bits available for coding the samples. In Fig. 2 it can be noted that for the same value of the inserting factor a the subjective quality of the separated watermark increases with the increase of the number of coding bits. The objective estimation of the quality of the separated watermark is presented in Fig. 3 in the function of the mean square error MSE:

$$MSE = \frac{1}{N_x \cdot N_y} \sum_{x=0}^{N_x-1} \sum_{y=0}^{N_y-1} \left[W(x,y) - W'(x,y)\right]^2 \qquad (7)$$

The analysis was done on the base of value of the mean square error of a separated watermark. The obtained results are presented in Figure 3. With the increase of the number of bits for coding the source, the mean square error of the separated

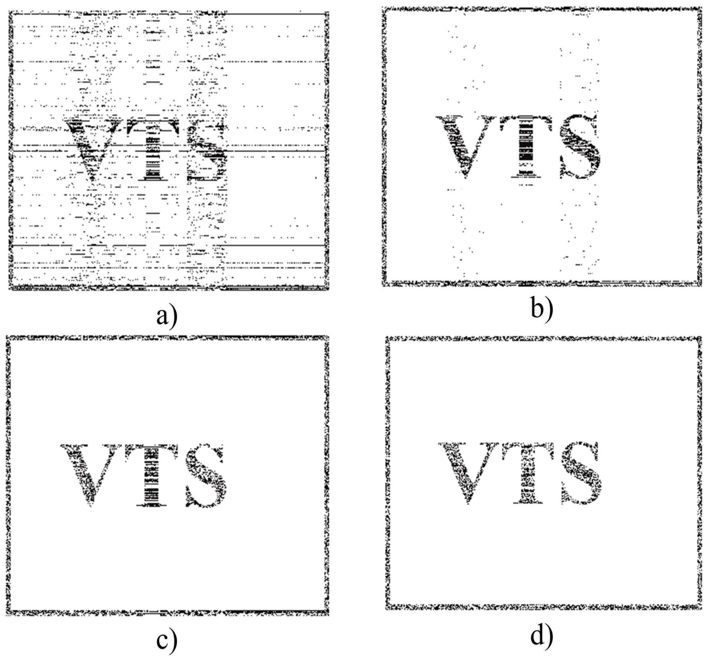


Figure 2. The watermark separated out of the first frame of the uncompressed video when coding is realized with a) 8 bits b) 9 bits c) 10 bits d) 11 bits and for a = 0.002

watermark in the uncompressed video considerably decreases, i.e. the quality of the watermark increases, which was the expected result. In the second part of the experiment the obtained protected video is coded by H.264/AVC coder.

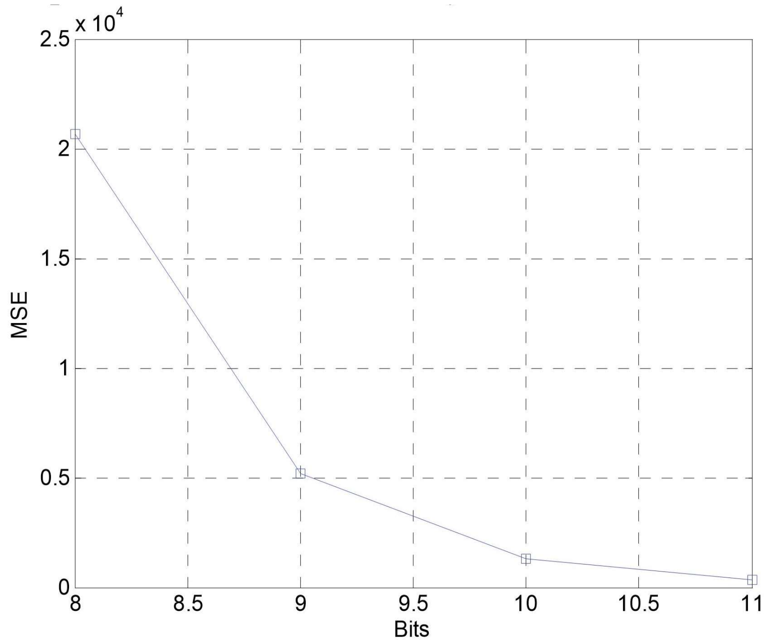
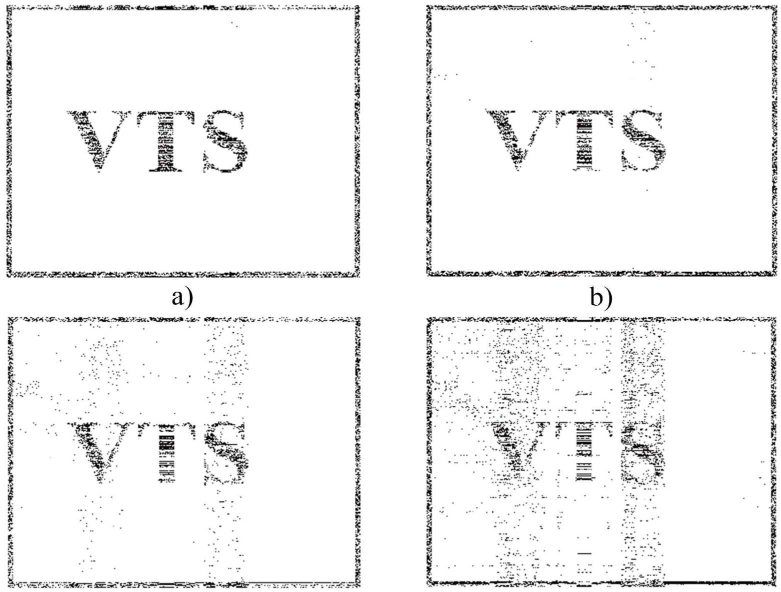


Figure 3. MSE of the separated watermark in the function of the number of bits for coding the video source for a=0.002



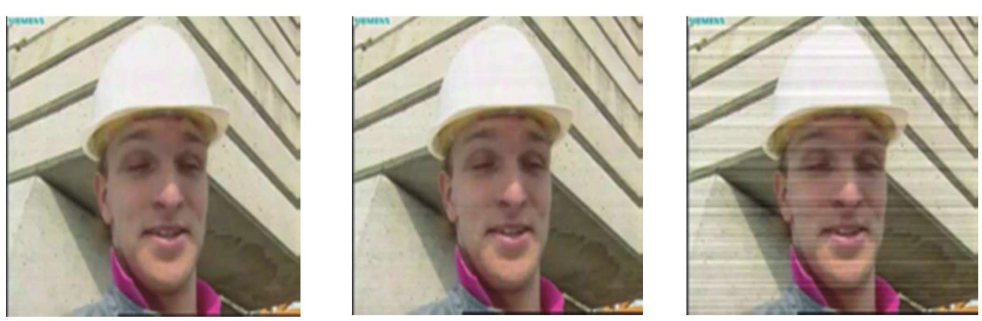
a) b) c) d)

Figure 4. The watermark separated out of the compressed video by H.264 coder from a) the first, b) second, c) third, and d) forth frame when the coding of the watermark is realized with 8 bits and $\alpha = 0.002$

JM referent software was used for coding and decoding the video sequences. It represents an official version of ITU in the version 14.2 FRExt [11], [12]. 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 [11] had the following values: *IntraPeriod* = 12, *NumberReferenceFrames* = 5, and *RateControlEnable* = 0, *InitialQP* = 28. The value of the code parameter QP is in this case adapted to the demanded bit rate and the maximally attainable quality of the video. The starting value of the code parameter in the beginning of GOP is *QP* = 32. The analysis of the influence of the prediction schemes and the demanded bit rate on duration of the watermark after coding will be presented in the following papers.

4.3. Analysis of the results

The watermarks separated out of the protected and compressed video sequence are presented in Figure 4. Figure 4 presents the watermarks separated out of a) the first, b) second, c) third, and d) forth frame where the coding of the watermark was realized with 8 bits and factors of inserting $\alpha = 0.002$. Because the coding of the video source with more than 8 bits is not a standard procedure, here we have a presentation of a coded video by H.264 codec with 8 bits, yet with the variation of the imprinting factor a. Newer versions of the video coder will have the possibility of coding the video source by the greater number of bits.



a) b) c)

Figure 5. The first frame of the video coded by H.264 codec where the watermark with a) a=0.005 b) =0.01 c) a=0.05 was inserted

Therefore, the developing version of JM software 18.6 offers the possibility of video coding in resolution from 8 to 16 bits. In addition to the quality of the separated watermark, its invisibility is one of the most important demands. The illustration of degradation of the video contents in the function of the imprinting factor a is presented in Fig. 5. The first frames of the coded video with the watermark are presented. The simulation was performed for the following values of the parameter α = [0.005 0.01 0.05].

5. Conclusion

In this paper the performances of the algorithm for insertion /extraction of the watermark from the coded video with H.264/AVC coder are analyzed. The effects of rounding in the process of the watermarking are identified and confirmed through simulation. The quality of the separated watermark for the standard parameters of a protected video coding was analyzed on the base of the mean squared error. Values of the optimal parameters of imprinting and coding should be found in a compromise between the quality of the video and the quality of the separated watermark. The following works will be tested the robustness of the proposed solutions to various types of attacks. There will also be tested video encoding with more bits than the Internet standard.

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