Reliable SVD-based Watermarking Algorithm Applied on Uncompressed Video

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Abstract – **The need for copyright protection of video content becomes more pronounced on the Internet. One of the ways of copyright protection is inserting invisible information - the watermark in the video content. The efficiency of the proposed algorithm is shown based on SSIM parameters obtained by an iterative algorithm for correcting the quality of the extracted watermark, ie, the occurrence of false positive problems present in conventional SVD extraction of the watermark is prevented.**

Keywords – **Digital multimedia, SVD, Reliable watermark algorithm, H.264/AVC.**

I. INTRODUCTION

Storage and sharing of digital multimedia content on the Internet is becoming the dominant form of network traffic [1]. The modern network technologies are significantly contributed to support specific communication requirements especially in the wireless environment [2]. Cross-layer communication protocols provide significant network bandwidth required for multimedia content in real time [3]. Great communication capabilities of mobile devices, as well as the easy availability of multimedia content on the Internet, have produced a range of side effects. Characteristics of digital multimedia content when copying do not lost on quality, simplify the creation of illegal copies as well as their illegal distribution. Illegal copying and distribution of multimedia contents are specifically expressed in the music and film industry. The total pirated multimedia content accounts for about 35.2% on illegal film market [4]. This paper discusses the compression algorithms for specific video content, although the results can be applied to the majority of multimedia content. Compression video algorithms are based on the imperfections of the human visual system HVS (Human Visual System). H.264/AVC is one of the most popular video coding standards for video content [5], which is discussed in this paper.

In order to prevent illegal copying and distribution of multimedia content, several methods based on hardware and/or software solutions are developed. For protection against illegal copying of multimedia content in usage are various types of cryptographic methods, as well and techniques of inserting a watermark into the content. Some of these techniques include embedding the invisible digital information in multimedia content - watermark [6]. This concept is based on the legislation in the fight against piracy, which requires efficient and reliable proof of ownership of multimedia content. Content of the inserted watermark should unambiguously identify the owner of multimedia content and to all the time be present in it. Good inserted watermark must meet several basic criteria:

1. It should be invisible to the observer;
2. It should not cause a noticeable degradation of multimedia content;
3. It should be robust to attempt its removal;
4. It should robust to the occurrence of false positive problem;
5. It should robust to compression and transcoding video content to different bit rates.

For inserting a watermark in the video sequence in this paper, a modified SVD algorithm is used in the transformation DCT domain. Insertion of the watermark is done in uncompressed video sequence, so that the watermark is inserted into each frame. The basic idea of SVD algorithm for watermark insertion is based on the fact that most of the energy of the video frame is localized in a few singular values of the matrix that represents a frame. Small variations in the values of the singular values of video frames will not cause a noticeable degradation of quality. This characteristic of singular values has enabled the installation of singular values of the watermark in the original frame by minor modifications of singular values of video frames. However, the problem of the appearance of false positive problem with this algorithm is described in [7].

Specifically, this algorithm can extract any watermark you are looking for, so confirming his presence even though he is not inserted! To solve this problem, in this paper has been tested reliable SVD based watermarking algorithm [7], [8] which instead insertion singular values of the watermark inserts principal components of the watermark in each frame uncompressed videos. The fact that this algorithm belongs to the class of blind watermarking algorithms for extracting the watermark is necessary to possess the original image watermark. The second chapter presents the H.264/AVC encoder with their specificities and identifies potentially possible position for inserting a watermark in the algorithm for insertion. In the third chapter, the mathematical basis for the implementation of a reliable algorithm for injection and extraction of watermarks from videos based on SVD decomposition are given. The fourth chapter presents the results of watermark extraction for different watermarks, and the quality of the extracted trademarks is evaluated by objective parameter SSIM. In the fifth chapter are derived some results based on the results obtained.

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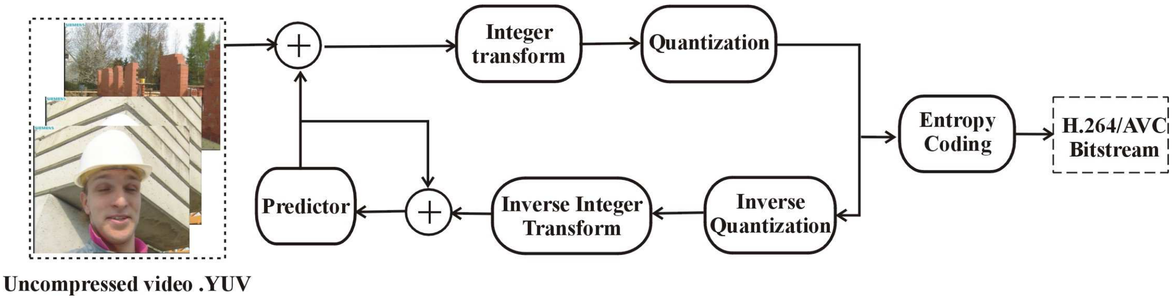


Fig. 1. Basic processing blocs of H.264/AVC encoder

II. H.264/AVC ENCODER/DECODER

Video presents a series of correlated images in the spatial and temporal domain [5]. When say H.264/AVC video, actually we refer to the video sequence, which is represented by a specific format. Video compression algorithms implemented in H.264/AVC standard are based on the elimination of additional information from the temporal, ie, the spatial domain [4]. The specific format is defined in the standard, which is implemented using the H.264/AVC syntax elements that describe different aspects of coding sequences, as well as the ways in which they presented individual elements. The syntax of H.264/AVC encoder is a hierarchical structure consisting of video sequences on top of the hierarchy to the individual frames and macro blocks on the bottom. The control parameters are stored in a special syntax section PS (Parameter Sets) or they are part of the macro blocks. Syntax elements are stored in an array of bytes RBSP (Raw Byte Sequence Payloads), which was later encapsulated in NALUs (Network Abstraction Layer Units). VCL (Video Coding Layer), which is part of the H.264/AVC standard, defines coded parts of the image (slices) in NALU. Each slice consists of a header and data are coded macro blocks. The coded sequence begins with IDR (Instantaneous Decoder Refresh) followed by the other coded parts - Data Partition Slices. Specialized NALU's Parameter Set and Supplemental Information Ehancement are not part of the VCL and carry additional information, which is not necessary for decoding H.264 stream.

Fig. 1. shows the basic blocks for processing of uncompressed video, which compose the H.264/AVC encoder. Predicting the content of the current frame is performed in the block “*Predictor*” based on one or more previous or future frames. The frames based on which the contents of the current frame are called reference frames. H.264 / AVC standard defines the frames of type I (intra), P (inter) and B (bidirectional) that uses one or more (past or future) reference frames. A powerful mechanism for exploring the similarities in the current figure or figures, which precede, respectively, below, is the basic strength of H.264 encoder. Anticipating the contents of certain parts of the image based on the perceived similarities, it is possible to form a "residual frame" with much less data. The consequence of this approach can be neglect of fine detail in the frame, which will have a negative effect on the inserted watermark. The consequence of this approach is the variable quality of the video, thus separated watermark, especially at lower bit rates. In previous studies, we tested the survival of the inserted watermark in the video encoded H.264/AVC encoder [8].

For professional use, the standard version of the H.264/AVC encoder is extended giving new coding tools. This is the extended version is known as FRExt. FRExt version of the H.264/AVC standard is enriched with a new High profile (HP). HP support higher resolution video without changing the sampling scheme.

III. ALGORITHMS FOR WATERMARK INSERTING/EXTRACTING

A. Algorithms for watermark insertion

Insertion of watermark to video content can be realized in each of the processing blocks of H.264/AVC encoder. Depending on the position of the processing block algorithms differ inserting the watermark inside or outside reconstructive loop of H.264 encoder. Insertion of the watermark in the video before encoding is the first option that was used in this and previous papers [9]. This insertion algorithm is implemented outside of the reconstructive loop of H.264/AVC encoder. Another possibility is the insertion of watermark into the structure of video codecs (such as "motion vector" or a new syntax element Reference Index). A third possibility occurs in the process of transformation, whereas the fourth option occurs in the quantization process. It is clear that the last three algorithms implemented within reconstructive loop of H.264/AVC encoder. Last possibility of inserting a watermark in compressed video stream and it is implemented outside the loop reconstructive H.264/AVC encoder.

In this paper, watermark insertion algorithm before encoding the video content is used. The applied concept allows insertions of the watermark in each frame, which will in the extraction process to provide a range of extracted watermarks from each frame. There are the two major classes of algorithms for watermarks insertions in uncompressed video. The first class of algorithms is based on inserting a watermark in the spatial domain, while the second class of algorithms is based on modifying the coefficients in the transformation domain. In case the first class of algorithms applied to images or video, watermark is hidden in the values of luma and/or chroma components spatially distributed pixel images [7], [8], [9].

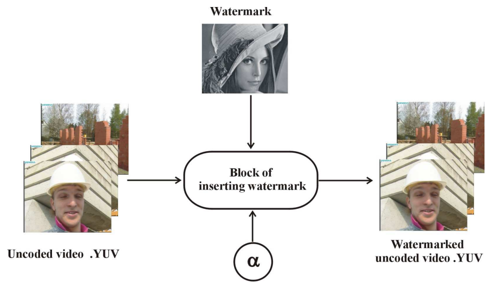


Fig. 2. Insertion of the watermark before encoding H.264 / AVC encoder

Algorithms which belonging to this class is relatively easy to implement but are not sufficiently robust when processing video signals, especially in the implementation of video compression. Another class of algorithms is based on the modification (modulating) the transformation coefficients of videos based on the transformation coefficients of the watermark. The transformation coefficients can be obtained by the DCT (Discrete Cosine Transform), FFT (Fast Fourier Transform) or SVD-a (Singular Value Decomposition). The inserted information can be extracted by inverse procedure from the modified transformation coefficients [7]. The algorithms of this class have higher performance robustness in relation to the watermark inserted in the spatial domain. Fig. 2. shows the algorithm inserting a watermark in each frame uncompressed video with inserting factor $0 < \alpha < 1$, while the encoding profile defined set of parameters H.264/AVC encoder.

B. Reliable SVD algorithm

In this paper, for inserting a watermark in the video sequence, algorithm based on SVD decomposition are used. This algorithm represents an improved version of the algorithm presented in [7], which eliminates the problem of false positives watermark. Applying this algorithm to each frame of the uncompressed video sequence, protected video are obtained. The input or the output parameters of the algorithm for the installation of the watermark are:

Input:
- A series of matrix $A_{m\times n}$ which representing uncompressed frames of video sequences.
- Matrix $W_{m\times n}$ which representing figure – watermark for embedding in video sequence.
- Inserting factor α.

Output:
- Video with embedded watermark – series of the matrix $A_{w_{m\times n}}$.

The algorithm for inserting a watermark in a video frame is displayed in four **I** steps:

Step I$_1$: SVD decomposition of the matrix, frame A:

$$A = USV^T , \tag{1}$$

where A is the original frame, U and V are orthogonal matrices of dimensions m × n and n × n, respectively, with a diagonal matrix S of dimension m × n with elements that represent singular values. The columns of the matrix U are called the left singular vectors, while the columns of the matrix in the right singular vectors. Singular vectors specified image geometry while singular values specified luminance (energy) images.

Step I$_2$: SVD decomposition of watermark:

$$W = U_w S_w V_w^T = A_{wa} V_w^T . \tag{2}$$

Step I$_3$: Insertion of the principal components of the A_{wa} in diagonal matrix S with inserting factor α:

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

Step I$_4$: Creating images with watermark:

$$A_w = US_1V^T . \tag{4}$$

The extraction of the watermark from image A_w^* that is potentially due to superimposed noise different from A_w, are implemented by algorithm, which consists of three **E** steps:

Input:
- Video with inserted watermark, series of matrices A_w^*,
- Original video, a series of matrices *A*,
- Inserting factor α.

Ouput:
- Extracted watermark *W**.

Step E1: Creating differences from the Original and watermarked frame:

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

Step E$_2$: Computing *principal* component:

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

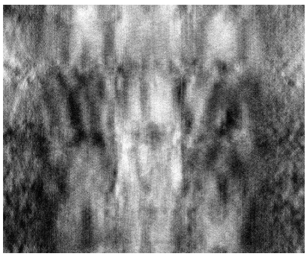
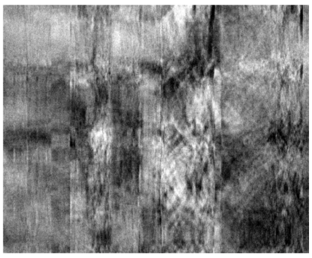
Step E$_3$: Computing watermark *W** as follows:

$$W^* = A_{wa}^* V_w^T \tag{7}$$

IV. Experiment and Results

As watermarks in this paper are used central parts of the figures [10]: ”*Baboon*”,”*Boat*” and “*Lena*” shown in the left column of Table I, respectively. Resolution of images that are used as watermarks and the resolution of the video to be protected are 352 × 288 pixels. In the experiments, we used the first 50 frames of uncompressed video stream “*Foreman.cif*”. For inserting the watermark in all frames, the constant factor of insertion α = 0.05 is used. The encoding and decoding of video sequences was performed JM reference software ITU (International Telecommunication Union) in version 18.4 FRExt [11]. Basic encoding parameters used in the experiment belong HIGH profile: ProfileIDC=100, IntraPeriod=12, NumberReferenceFrames=5, and NumberBFrames=7. To improve the quality of the extracted watermark was used in the presented iterative algorithm [9].

TABLE I
WATERMARKS APPLIED IN EXTRACTION ALGORITHM (LEFT COLUMN) BABOON, BOAT AND LENA, AND EXTRACTED WATERMARKS (RIGHT COLUMN)

Watermarks used in extraction algorithm	Extracted watermarks
	
	
	

To protect the video sequence "*Foreman*", watermark "*Lena*" is inserted in each frame. The watermark is inserted/extracted using a reliable SVD algorithm described in Chapter II. In the process of extracting, all three watermarks from Table I are used. To assess the quality of the extracted watermark SSIM parameter [12] was used. In the right column of Table I shows the obtained results - extracted watermarks. From Table I it can be concluded that in cases where wrong watermark ("*Baboon*" and "*Boat*") is used in the extraction process, the algorithm failed to allocate inserted watermark. Also, based on the obtained results, can be concluded that the reliable SVD algorithm is resistant to the occurrence of false positive problem. SSIM parameter was 0.122 when watermark "*Baboon*" is used in the extraction process, while, for the case of using watermark "*Boat*", SSIM parameter was 0.125, which clearly shows that the occurrence of false alarm problem solved.

In the case when the original watermark "*Lena*" is used in the process of extracting", reliable SVD algorithm has shown excellent results. SSIM parameter in this case was 0.64, which is more than five times better compared to the use of incorrect watermark. From the presented examples can be clearly concluded that the proposed reliable SVD algorithm for insertion/extraction of the watermark can be effectively applied to protect the video of code H.264/AVC encoder. The results indicate that the false positive problem solved efficiently, which was removed a basic lack of standard SVD algorithm for insertion/extraction watermark. All the advantages of the standard SVD algorithm are preserved, and reliable SVD algorithm eliminates the drawbacks described above.

V. CONCLUSION

In order to prevent illegal copying and distribution of video content is often used technique for inserting a watermark in uncompressed video. In the process of encoding video content H.264/AVC encoder comes to video degradation, and therefore the inserted watermark, which significantly complicates the extraction. This paper, analyzes the reliable SVD algorithm for insertion/extraction of the watermark from the video that is coded H.264/AVC encoder. Results of this study show that the reliable SVD algorithm is resistant to the occurrence of false positive problems when inadequate watermarks are used in the extraction process. When used properly watermark in the extraction process, using an iterative algorithm to improve the extracted watermark, obtained satisfactory results. In this way, the authors of multimedia content can prove ownership of the video content and thus gain their copyright. Reliable SVD algorithm can be efficiently used to protect video content while preserving all the positive characteristics of classical SVD algorithm.

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