CB-SVD watermarking algorithm for video protection with reduced cyclic insertion scheme

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Abstract – **This paper presents the RCB-SVD watermarking algorithm for protecting video content from copying. The bit planes of the decomposed monochrome watermark are inserted into the video-frame color channels. A CB-SVD algorithm with a reduced cyclic insertion scheme was used to insert the watermark. Reduced insertion scheme reduces the level of degradation of video while simultaneously extracting a high quality watermark. The RCB-SVD algorithm does not have the lack of detection of a false watermark, as is the case with standard SVD algorithms. The built-in redundancy of the reduced cyclical insertion scheme increases the resistance to "frame-dropping" attacks. Compared to the previously announced results, repair of the extracted watermark was achieved by 9.87%.**

Keywords – ***Bit-plane decomposition; CB-SVD algorithm; Watermarking; Reduced cyclic insertion scheme.***

I. Introduction

A high performance level of modern communication networks has been achieved by combining new modulation techniques and new generation communication protocols [1]. In addition to the large network flow, modern communication networks also reduce packet latency to just a few milliseconds. Thus, 4G network technologies provided a latency of 50 ms, while from 5G technology it is expected that latency be only 1 ms. With 5G technology, the whole movie in HD format can be downloaded in less than 10 s. By using these technologies, the exchange of digital multimedia content has become a common user activity. Setting up, and then sharing multimedia content on social networks like *Facebook*, *YouTube* or *Instagram* can now be implemented with efficient procedures. By 2022, 82% of network traffic is expected to relate to some kind of video communication [2]. There is a rise in video surveillance, Internet video to TV and Consumer Video-on-Demand traffic.

However, the exchange of multimedia content on the network has led to an increase in security risks and the occurrence of copyright and identity abuse. Multimedia content can be downloaded indefinitely without loss, then modified and used illegally for commercial or other purposes. Especially important are the problems of copyright protection in this network environment. One way to reduce security risks, before sharing multimedia content, is to perform reliable user authentication [3].

In order to prevent the illegal use of multimedia content, numerous protection techniques have been developed. The problems of protecting multimedia content can be solved by the classic encryption technique. However, classical information-based security systems based on encryption are not adequate for application to multimedia content. The main disadvantages of standard cryptographic techniques can be described through the following facts:

a) *inefficiency*, it is necessary to transfer a huge amount of data further when exchanging encrypted multimedia content,

b) *incomplete protection*, multimedia content is protected only during network transfer,

c) *decrypting during playback*, multimedia content must be decrypted for reception, which potentially makes it unsafe.

Inserting invisible - secret information (watermark) into multimedia content is a frequently used technique to increase information security on a global computer network - the Internet [3] - [14]. In order to improve the performance of individual protection algorithms, *hybrid insertion techniques* are used [4]. These techniques involve the implementation of multiple transformation domains such as DCT, SVD and DWT. The watermark can bee a color picture [5], a monochrome (grayscale) image [6], or a binary image [7].

In this paper, several different binary images obtained by the decomposition of the monochromatic watermark [8], [9] are inserted into the multimedia content – color video sequence. The basic problem with this protection concept is that inserting a watermark leads to interference in multimedia content. A stronger inserted watermark results in the quality decrease of the multimedia content, but it ensures the extraction of a quality watermark. On the other hand, the poorly inserted watermark less degrades the quality of multimedia content, but does not provide high quality watermark extraction. Clearly, these are two opposing requirements that the multimedia content algorithm must reconcile.

In order to protect the video from copying, RCB-SVD watermarking algorithm with reduced cyclic insertion scheme based on [10] is shown in this paper. Prior to insertion, the monochromatic watermark was decomposed into 8-bit planes (binary images) which were then inserted into the color channels [11]. Application of a reduced cyclical insertion scheme removes noticeable video degradation while simultaneously extracting a high quality watermark. The problem of fake watermark detection in standard SVD algorithms is solved, and built-in redundancy increases resistance to frame-dropping attacks. Evaluation of the proposed algorithm was performed in the software package Matlab.

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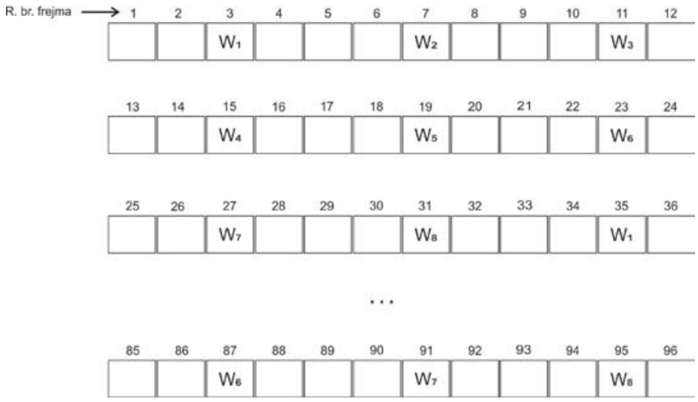

Fig. 1. Reduced cyclical scheme for inserting bit planes W_1 – W_8 into frames of unencrypted video.

Below follows a reduced insertion model, that is, the extraction of the decomposed watermark into multiple frames in the color domain of the video. Evaluation of the proposed method was carried out and the obtained results were analyzed. In the last section some conclusions and recommendations were made.

II. RCB-SVD ALGORITHM

The RCB-SVD video protection algorithm is based on the results published in [4] - [11]. Unlike [10] where the linear cyclic scheme of insertion is applied, in this paper a reduced cyclical insertion scheme is proposed. Fig. 1 shows a proposed reduced insertion scheme that reduces the level of interference in the video and provides extraction of the better watermark quality. The RCB-SVD algorithm is based on bit plane decomposition of the grayscale watermark and SVD decomposition of the frame and bit plane plane. The insertion and extraction algorithm is shown in more **I** and **E** steps respectively.

Step $\mathbf{I}_1$: Perform the bit-plane decomposition of the monochromatic watermark $W_m \times n$. In order to perform the decomposition of the watermark in eight bit-planes, first should be present the values of all the pixels of the watermark w_i with the corresponding binary values b_i, k as follows:

$$b_{i,k} = \left\lfloor \frac{w_i}{2^{k-1}} \right\rfloor mod\ 2, \quad k = 1, 2, \dots, 8; \tag{1}$$

$$i = 1, 2, \dots, m \times n$$

In the expression (1), the w_i is represented the i-th pixel of the monochromatic watermark. The mark $b_{i,k}$ would represent 8 bits of binary value of the i-th pixel. The bit plane to the watermark $\mathbf{W}_k$ is formed from all k bits of all pixels of the watermark:

$$\boldsymbol{W}^k = b_{i,k} \tag{2}$$

Step $\mathbf{I}_2$: The chrominent component of the frame U from the YUV video format is divided into unconnected blocks $\mathbf{H}_{i,j}$ dimensions of 4×4 pixels.

Step $\mathbf{I}_3$: For each block $\mathbf{H}_{i,j}$ from the **U** component, perform the SVD decomposition:

$$\boldsymbol{H}_{i,j} = \boldsymbol{U}_{i,j} \times \boldsymbol{S}_{i,j} \times \boldsymbol{V}_{i,j}^T \tag{3}$$

Step $\mathbf{I}_4$: Modify the elements from the second and third row of the first column of each matrix (elements $u_{2,1}$ and $u_{3,1}$) based on the value of each individual bit w from the corresponding bit level as follows [11] - [13]:

$$if\ \ w = 1, \begin{cases} u_{2,1}^* = sign(u_{2,1}) \times \left(U_{avg} + \frac{T}{2}\right) \\ u_{3,1}^* = sign(u_{3,1}) \times \left(U_{avg} - \frac{T}{2}\right) \end{cases} \tag{4}$$

$$if\ \ w = 0, \begin{cases} u_{2,1}^* = sign(u_{2,1}) \times \left(U_{avg} - \frac{T}{2}\right) \\ u_{3,1}^* = sign(u_{3,1}) \times \left(U_{avg} + \frac{T}{2}\right) \end{cases} \tag{5}$$

$$U_{avg} = \frac{(|u_{2,1}| + |u_{3,1}|)}{2} \tag{6}$$

where T represents the desired threshold in the difference between the elements $u_{2,1}$ and $u_{3,1}$ of $\mathbf{U}_{i,j}$ the matrix. The modified matrix is denoted by $\boldsymbol{U}_{i,j}^*$.

Step $\mathbf{I}_5$: Perform the inverse SVD transformation to obtain a block with the inserted bit from the watermark.

$$\boldsymbol{H}_{i,j}^* = \boldsymbol{U}_{i,j}^* \times \boldsymbol{S}_{i,j} \times \boldsymbol{V}_{i,j}^T \tag{7}$$

Step $\mathbf{I}_6$: Repeat steps 4 and 5 for all bits from the appropriate bit plane watermark.

Step $\mathbf{I}_7$: Repeat steps 2-6 for all bit watermark planes for all video frames using the reduced insertion scheme shown in Fig. 1. In this way, a video with the embedded watermark is obtained. For the extraction of the watermark thus inserted, it is *not necessary* to have the originals of either the video or the watermark, so this algorithm belongs to the class of *blind* algorithms.

A part of the RCB-SVD algorithm for watermark extraction is shown in 8-steps **E** [11] - [13].

Step $\mathbf{E}_1$: The component **U** of protected frame divide into nonoverlapped blocks $\mathbf{H'}_{i,j}$ of a dimension of 4 × 4 pixels.

Step $\mathbf{E}_2$: Perform SVD decomposition of all blocks $\mathbf{H'}_{i,j}$ from frame:

$$\boldsymbol{H}'_{i,j} = \boldsymbol{U}'_{i,j} \times \boldsymbol{S}'_{i,j} \times \boldsymbol{V}'^T_{i,j} \tag{8}$$

Step $\mathbf{E}_3$: The value of the corresponding extracted watermark w' is obtained using the following terms:

$$w' = 1, \begin{cases} 0, \ if\ u'_{2,1} > u'_{3,1} \\ 1, \ if\ u'_{2,1} \le u'_{3,1} \end{cases} \tag{9}$$

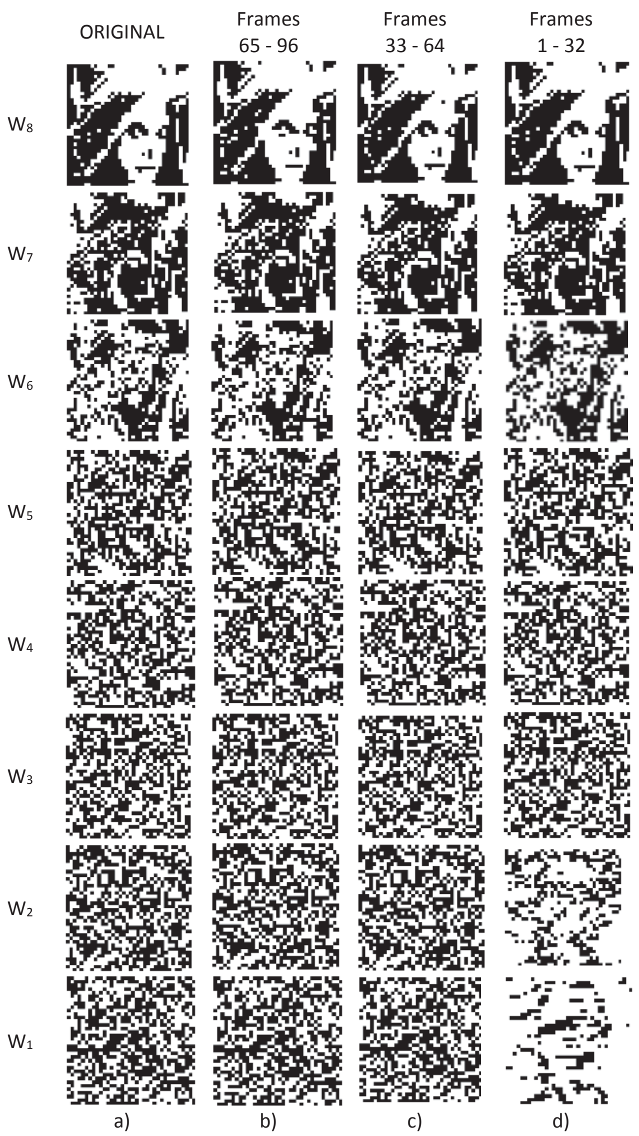

Fig 2. Bit planes W_1 do W_8 a) original watermark, b) extracted from frames 65-96 c) 33-64 d) 1-32 encoded video.

Step **E**$_4$: Repeat steps 2 and 3 for all no overlapped blocks of the frame.

Step **E**$_5$: Create a binary image of the corresponding bit-plane watermark.

Step **E**$_6$: Repeat steps 1-5 for eight frames from the video.

Step **E**$_7$: Form the grayscale watermark of 8 binary bit-planes.

Step **E**$_8$: Repeat steps 1-7 for all frames in which the bit-plane component of the watermark is inserted into the reduced insertion scheme shown in Fig. 1.

III. Experimental results

The monochromatic watermark used in the experimental part of this paper is shown in Fig. 3a). The illustrated watermark represents an adapted central part of the famous monochrome Lena.bmp image in a resolution of 36 × 36 pixels. Before inserting into a frame of uncoded color video - *Foreman.yuv* at a resolution of 288 × 288 pixels, the watermark was decomposed into 8 bit W_1 - W_8 planes. Bit planes W_1 - W_8 are obtained by bit-plane decomposition in the manner described in the chapter "RCB-SVD algorithm". In Figure 2a), the images of bit planes of this monochrome watermark are shown. The MSB bit plane of the watermark W_8 is located at the top of the column *original*. Other bit-plane decomposition of watermark W_7-W_1 are shown below in this column. If we observe the displayed bit planes, it can be noticed that with approaching the LSB bit plane W_1, the watermark decomposition takes a stochastic character. This is why in this paper the GMSAT algorithm [14] does not use the scribbling of images as shown in previous works [6]. Only the bit planes W_8, W_7, and W_6 can be protected to increase the security level.

In this paper, a cyclic set of decomposed bit watermark planes are embedded in the first 96 frames of the color video *Foreman.yuv*. The reduced bit-planes insertion scheme is shown in Fig. 1. According to the reduced insertion scheme in the first two frames, no bit planes of the watermark are inserted. The first bit plane W_1 is embedded in the third frame. Then skips three frames and the other bit plane W_2 is embedded in the seventh frame. The process of inserting bit planes continues along the reduced scheme to the last frame to be protected. When all bit levels are inserted, bitwise W_1 is inserted cyclically. The insertion of watermark components according to the considered algorithm is performed in chrominant components of the frame with threshold T = 0.04. This threshold value is commonly used in algorithms of this type [5], [12], [16], but even with a lower threshold value, excellent results are obtained. A reduced insertion scheme provides a certain level of redundancy of watermark components. In this paper, the algorithm for repairing the extracted watermarks described in [13] was applied. If 96 frames of a non-encoded video are inserted bit planes according to the scheme shown, 24-bit planes can be extracted at the reception - 3 complete watermarks.

Insertion is done in a non-encoded video domain, and then encrypted with encrypted video by H264 / AV encoder. Since the H.264 / AV algorithm belongs to the loss coder class, many of the details present in the video are ignored and are forever lost. This will inevitably cause errors in the decoding process that the human eye does not notice. However, errors that occur during decoding will have an impact on the extraction of the inserted watermark. The encrypted video sequence was encoded by the JM reference software of ITU in version 18.4 FRExt [15]. The encoding quality is defined by a set of FRExt parameters: IntraPeriod = 12, NumberReferenceFrames = 5 NumberBFrames = 1. In Figure 2b), 2c) and 2d), the extracted bit planes of the W_1 - W_8 monochromatic watermark from the encoded frames 65 - 96, 33 - 64 and 1 - 32 are shown. Figures 3b), 3c) and 3d) show grayscale watermarks obtained by composing extracted bit planes from frames 65 - 96, 33 - 64, and 1 - 32. Below the figures, the obtained SSIM values of the extracted watermarks are shown.

Errors are evident first in the extracted bit plane (Fig. 2), and then in the composite monochromatic watermark obtained from them (Figure 3). In order to improve the quality of extracted watermarks, an algorithm for its repair was applied [14]. The redundancy provided by the RCB-SVD algorithm enables the extraction of the watermark.

In the shown example, the complete three grayscale

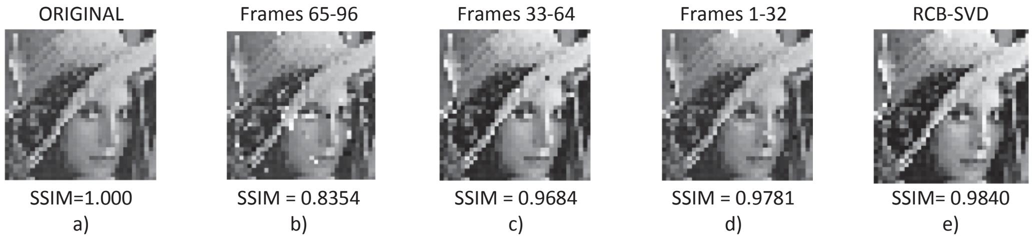

Fig 3. Watermark a) original b) extracted from frames 65-96 c) 33-64 d) 1-32 encoded video e) corrected.

watermarks with various SSIM values of 0.8354, 0.9684 and 0.9781 were extracted. After the repair, a watermark was obtained, the appearance of which is shown in Fig. 3e) with SSIM index 0.9840. It should be noted that for the application of this repair algorithm, the origin of the watermark must be known. An objective assessment of the quality of the extracted watermark measured by the SSIM index for the presented case is 0.9840, which is the highest index compared to each individual index of the extracted watermark. Compared to the previously published results [11], a significant correction of the extracted watermark was achieved by 9.87%.

IV. Conclusion

Protecting multimedia content from copying has become an increasingly important activity of the author before their publishing on the Internet. Inserting a watermark into video is a technology that provides copy protection for the entire duration of the existence of video content. In this paper, we present the CB-SVD algorithm with a reduced insertion scheme of the monochromatic watermark in the frames RCB-SVD. Prior to insertion, the monochromatic watermark was decomposed into 8 bit planes (binary images), which were then inserted with a reduced cyclic scheme into the color video channels. Using a reduced cyclical insertion scheme, the extraction of a high quality watermark is possible with the significantly higher quality of the protected video. Evaluation of the proposed algorithm was carried out on the known color video sequence Foreman, while a modified inserted monochrome image of Lena was used as a watermark in a resolution of 32 × 32 pixels. The proposed reduced insertion model causes significantly less video distortion, which outperforms the performance of standard SVD algorithms. The problem of extracting a false positive watermark was blocked. The built-in redundancy of this algorithm increases the resistance to frame-dropping attacks while at the same time allowing the extracted watermark to be repaired. Compared to the previously announced results, repair of the extracted watermark was achieved by 9.87%. In the continuation of the research, the RCB-SVD algorithm performance will be determined in the presence of different types of attacks. The results presented justify the application of the RCB-SVD algorithm to protect the video from copying.

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