Educating the Encrypted Low Resolution Watermark Impact on Video Content

Zoran Velickovic, Zoran Milivojevic and Marko Velickovic
College of Applied Technical Sciences
Nis, Serbia, A. Medvedeva 20
18000 Niš, Serbia
{zoran.velickovic@vtsnis.edu.rs} {zoran.milivojevic@vtsnis.edu.rs} {marko.velickovic93@yahoo.com}

ABSTRACT: *Learning the protection of video content and images is a difficult task. Normally adding the encryption of the watermark in the video is the technique. Using SVD algorithm, the watermark is encrypted with multistage Arnold transformation. We educate how the low resolution watermark yields a good PSNR than the high resolution watermark. We have developed the original algorithm for finding location and the frame is identified. We prove that the low resolution watermark provide some notable higher index than the high resolution watermark.*

Keywords: Digital video, Multistage Arnold transformation, Reliable watermarking SVD algorithm, H.264/AVC

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1. Introduction

The use of the multimedia content has become the standard on the Internet thanks to the exceptional communications features of modern network technologies. In terms of accessibility, sharing of digital multimedia contents, especially video, is becoming the dominant form of network traffic [1]. This fact is especially contributed by the Web portal Youtube, which has provided opportunities for every Internet user to upload his own video, and thus, he becomes available globally.

These circumstances, as well as the characteristics of digital multimedia contents that, unlike analog, while copying does not lose its quality, favored the occurrence of piracy, i.e. illegal copying and distribution of multimedia content on the Internet. Financial losses as a result of piracy in the modern world are measured in billions of dollars [2]. The protection of the video content from illegal copying and distribution becomes bound activity when posting the original video content.

The standard cryptographic techniques are applicable for copy protection of digital multimedia contents, but for practical application, methods based on inserting a watermark into a multimedia content are more convenient. The inserted watermark remains permanently in the multimedia content, and it is not removed even in playback. The feature of the digital watermark that never leaves multimedia, further increases the security level of the protected video. Also, this feature allows the survival of the watermark in the video content in the attempt of many malicious and destructive attacks on the video.

This paper deals with the insertion of the encrypted watermark in the uncoded video content in order to protect it rom copying and proving ownership of the multimedia content [3], [4]. This concept of copyright protection is enabled by anti-piracy legislation, which includes the efficient and reliable extraction of the watermark from the multimedia content. The extracted watermark should match the inserted watermark and unambiguously identify the author by the content and appearance, that is, the owner of the multimedia content.

The techniques of the watermark include invisible digital images in the video content to the eye of the beholder [5], [6]. The strength of the watermark embedding in the video can be regulated by the inserting factor whose value should cause only imperceptible artifacts in the video. The larger inserting factor provides the extraction of better quality of the watermark while the video is lower quality. In this paper, the low-resolution watermark embedding technique that causes significantly less artifacts in the video content for the same value insertion factor is proposed.

For the proposed technique it is characterized that the dimensions and watermark resolution are reduced before insertion, and then the watermark is encrypted by an algorithm based on the invertible chaotic maps [7]. In this paper, the use of two-dimensional invertible chaotic maps [8] is proposed, unlike [7] where the hybrid techniques to encrypt the watermark are used. Instead of directly inserting the original content of the watermark, the watermark is inserted in each video frame transformed by multistage Arnold transformation. Applying multistage Arnold transformation, a cryptologic space is significantly increased and thus, the protection of the video content is set to a higher level. To obtain the original watermark from the encrypted one, the inverse multistage Arnold transformation [6] has to be applied. In addition to knowing the transformation parameters, it is necessary to know the initial conditions for the application of the inverse Arnold transformation, because the chaotic maps are especially sensitive on them.

The standard SVD algorithm [3], [5], [7] of the watermark insertion requires the same dimensions of the video and watermark, which, in this case, is not permitted. Before the insertion of the low-resolution watermark, it is necessary to determine a location in a frame where the watermark will be inserted. The selection of the optimal location of the watermark insertion is based on a choice part of a video frame with the greatest contrast of texture. The reason for this lies in human HVS [9] who is less sensitive to changes of parts of an image with greater texture contrast. Thus, the optimal location of the watermark should enter the least noticeable artifacts in the video frame. This idea has the consequence that the location of insertion depends on the content of the video frame. The locations where the watermark is inserted into individual frames can be used as a key in the watermark extraction process, and they are usually remembered in the form of a two-dimensional vector.

The insertion of the reduced and encrypted watermark in the video part of the frame is realized by the reliable SVD algorithm [3], [5]. Before presenting the protected video to customers it can be coded. In this paper we used the H.264/AVC encoder. The extracted watermarks are variable quality, and it is necessary to apply the advanced algorithm for watermark quality corrections [7], [8].

The structure of the work is as follows. The second section discusses the application of the multistage Arnold chaotic 2D map to encrypt the contents of the watermark. The third chapter shows the original algorithm to select the optimal location of the watermark in the frame based on the cooccurence matrix. The fourth chapter presents the application of the proposed algorithm for the protection video encoded with an H.264/AVC encoder and the obtained results are analyzed. In the fifth chapter the corresponding conclusions based on conducted tests are derived.

2. Multistage Arnold Transformation

The cryptographic techniques based on two-dimensional (2D) maps are chaotic deterministic systems whose behavior is highly dependent on the initial conditions. The basic idea of the 2D chaotic map is to make relocation pixels of the original image for the spatial decorrelation of adjacent pixels. Spacious pixels decorrelation actually represents watermark encryption which makes it unrecognizable to the observer.

2.1. Arnold transformation

For the image encryption invertible Arnold transformation [7] whose generalized form is defined with equations (1) and (2) is most commonly used.

The arranged pairs (x_n, y_n) and (x_n+1, y_n+1) are the coordinates of the image pixel (in our case the watermark) before and after

$$\begin{bmatrix} x_{n+1} \\ y_{n+1} \end{bmatrix} = \begin{bmatrix} 1 & b \\ a & ab+1 \end{bmatrix} \begin{bmatrix} x_n \\ y_n \end{bmatrix} \bmod N$$

$$x_n, y_n \in [0,1,2,...,N-1] \times [0,1,2,...,N-1]$$

transformation, respectively. The symbols a and b are positive integers that represent known parameters of Arnold transformation. It should be noted that, according to the definition, the transformation matrix determinant is equal 1, and thus, a transformational space is preserved. The parameter N is the dimension of the square image (watermark) in pixels. The main benefit of Arnold transformation is practically the watermark encryption, so that its content is not recognizable to the eye of the beholder. Another important feature of Arnold transformation is that it has a cyclical nature, i.e. after T iterations of Arnold transformation the initial image is received (in our case the original watermark).

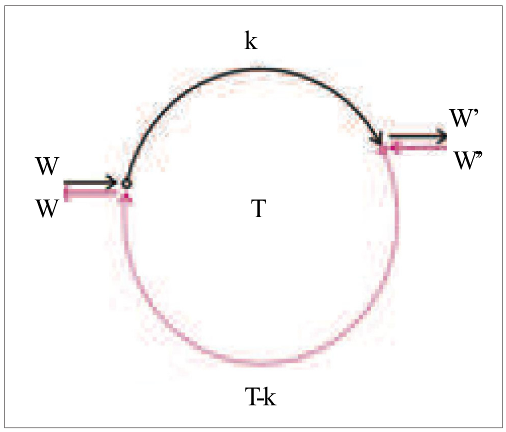

Figure 1. The basic parameters of the generalized Arnold transformation

The period T depends on transformation parameters N, *a, and b,* but there are not generalized analytical method for its calculation. Determination of period T is usually done in practice, successive applications of Arnold transformation and analysis of the obtained results. If Arnold transformation is applying k times, the original image is obtained by the inverse Arnold transformation (further application of Arnold transformation T-k times). Figure 1. shows the basic parameters of the generalized Arnold transformation. The original watermark is indicated by W, while the transformed watermark is labeled as W^T. A period of Arnold transformation is marked as T, and a number of the consecutive Arnold transformation for obtaining a transformed watermark is labeled as k (solid lines). In order to obtain the original watermark from the transformed one, it is necessary to perform the inverse Arnold transformation (more T-k consecutive Arnold transformation), which is shown in Figure 1 (dashed lines).

2.2. Multistage Arnold Transformation

The basic idea of multistage Arnold transformation is based on the sequential application of multiple Arnold transformation (stages) with different parameters. The transformation parameters of i-th stage a_i, b_i, the number of consecutive stages k_i and period of Arnold transformation stage T_i actually represent keys for watermark encryption/decription. It is clear that with the increasing number of stages in the multistage Arnold transformation the number of transformation parameters is growing which exponentially increases the transformation and search space.

In Figure 2 multistage three-stage Arnold transformations has been shown, which has been used in the evaluation section of this paper. In Figure 2 three stages have been applied - different Arnold transformation in a row.

The first stage has a period $T_1 = 24$, the second $T_2 = 48$ and the third $T_3 = 96$. The number of successive transformations of the first stage is k_1 = 8, the second stage k_2 = 31 and third stage k_3 =12. In the case of Figure 2, at the outlet of the third stage the transformed watermark is received that will later be inserted into each frame of the uncoded video.

3. The Location of the Lowresolution Watermark

HVS (Human Visual System) is a dynamic visual human tool by which he learns, recognizes and understands the world around him. In the literature the characteristics of HVS related to sensitivity and brightness are often considered. Some of the HVS characteristics which are interesting for the process of the watermark insertion in the video are: image brightness, image edge and image texture.

3.1. Image Brightness
The Human visual system is able to recognize a large number of gray levels in the image, while it is significantly less sensitive to the presence of color. Although HVS is able to detect small changes in image brightness, there are limits below which it is not possible to detect changes.

3.2. Image Edge
The edges in the image represent the locations where the significant variations in brightness of pixels to a given direction are detected. By detecting the edges in the image, actually homogeneous discontinuity parts of the picture are detected. The watermark insertion in areas with pronounced edges in the image will be less noticeable.

3.3. Image Texture
The texture is an important feature of the image area, and in this paper is used for selection of the most suitable locations in the frame for the watermark insertion. By means of HVS the ability of human to get ahead of the changes in the brightness of pixels that appears in the homogeneous regions of the image compared to those with high contrast is explained. How can this fact affect the selection of a location for the watermark insertion in the video content? If you want to accepted this fact in the process of the watermark insertion, the insertion should be avoided in those parts of the frame that holds the homogeneous regions. In this paper, a texture as a part of the frame with the greatest contrast will be submitted for the watermark insertion. This conclusion can be formulated as follows: Insert the watermark in the parts of the frame with the highest texture contrast. The texture contrast Con can be determined on the basis of co-occurrence matrices as follows:

$$Con = \sum_{x=0}^{N-1}\sum_{y=0}^{N-1}(x-y)^2 c(x,y) \quad (3)$$

where $c(x, y)$ is a co-occurrence matrix of size $N \times N$ pixels. The co-ocurrence matrix contains information how often a pixel with gray level i is located in horinzontal direction of pixels with gray level j. If there is a significant variation in the picture, a co-occurence matrix $c(x, y)$ will generally have the elements outside the main diagonal, and the contrast of the

a) b)

Figure 3. Two watermarks used in the work a) high resolution watermark HiRLena 288×288 pixels and b) low resolution watermark LowRLena 72×72 pixels

Texture will be higher. The co-occurrence matrix with elements grouped in and around the main diagonal corresponds to a homogeneous region of the image. For the purpose of this study each frame is divided into 16 nonoverlaped region of the same size 72×72 pixels whose contrast of texture is determined.

4. Experiments and Results

For the comparison of the obtained results, a central part of the famous image "Lena" at the resolution of 288×288 pixels ("HiRLena") was used as the watermark in the first experiment, while in the second experiment the lower resolution watermark of 72×72 pixels ("LowRLena") was used. In Figure 3 the watermarks which are used in a) the first and b) the second experiment are presented. Three-stage Arnold transformation is applied in order to encrypt watermarks, prior to their insertion in the video. The parameters of the applied multistage Arnold transformation are $a_1 = 1$, $b_1 = 1$, $a_2 = 4$, $b_2 = 2$, $a_3 = 5$, $b_3 = 8$, and the parameter N for the first watermark was 288, and for the second 72. The encrypted watermarks are inserted into the famous uncoded video "Foreman.cif" in resolution of 288 × 288 pixels. The watermark "HiRLena" is inserted in each frame, while the watermark "LowRLena" is inserted only in the selected part of the frame size of 72×72 pixels. The watermark insertion is realized by the reliable SVD algorithm in all video frames with the constant insertion factor $a = 0.05$. After the video protection, video sequence encoding by means JM reference software of ITU in version 18.4 FRExt [10] was done. In Figure 4 the 50th decoded video frames protected with watermarks a) Hirl and b) LowRLena are presented. By comparing the quality of frames displayed in Figure 4, there is evidence of greater presence of artifacts in the frame in Figure 4a). This result was expected thanks to the size of the inserted watermark. The watermark "LowRLena" is inserted in the top right corner of the frame, the presence of certain artifacts in this section can be identified with careful observation. The potential locations for inserting the lowresolution watermarks are frame segments of 72 × 72 pixels. For the shown experiment, there are a total of 4 × 4 = 16 potential locations in the frame that have been marked by a number of columns and rows of non-overlapped segments. For the shown 50th frame, the algorithm for choice the location is selected location labeled (1, 4) because in this

a) b)

Figure 4. The appearance of 50th decoded video frames protected with watermarks a) HiRLena and b) LowRLena

frame it possesses the biggest textures contrast. The location of the low-resolution watermark insertion can be used as a key in the watermark extraction process which further increases the search space. PSNR (Peak Signal-to-Noise Ratio) is an objective measure of the quality of each frame of the video, and the video itself. In Figure 5 the PSNR for the first 50 decoded video frames protected with the watermark inserted by HiRLena, or LowRLena is presented. In Figure 5 it can clearly be seen that the quality of the videos inserted by the watermark LowRLena is almost 10dB better.

Using the advanced algorithm for correcting the extracted watermark, the SSIM index of 0.84488 for the watermark LowRLena and 0.6765 for watermark HiRLena is realized. The presented data clearly show that the SSIM index was higher in extraction of the low-resolution watermark LowRLena of about 25%. Figure 6 shows a) the progressive correction of the SIM index of the extracted watermark achieved in 26 iterations and b) the appearance of the repaired watermark.

5. Conclusion

The protection of the original video content becomes very important activity before their publishing. The watermark insertion in the video itself has significant advantages over the use of standard cryptographic techniques because it permanently inserts

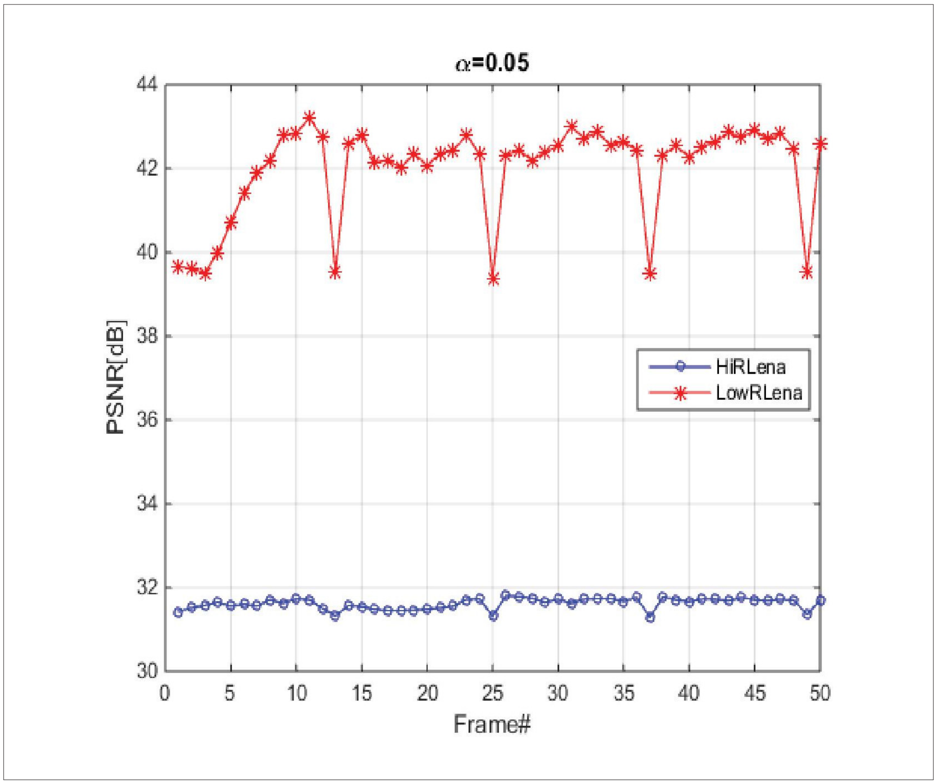

Figure 5. PSNR values for the first 50 frames of decoded H.264/AVC video when the high-resolution watermark (HiRLena) and lowresolution watermark (LowRLena) are inserted

into the video, and it is not removed during playback. In this paper, a watermark content is encrypted before the insertion by applying multistage Arnold transformation. In this way, the encrypted space is significantly increased. The paper shows that by inserting the encrypted lower resolution watermark a higher quality of the protected video is obtained. The lower resolution

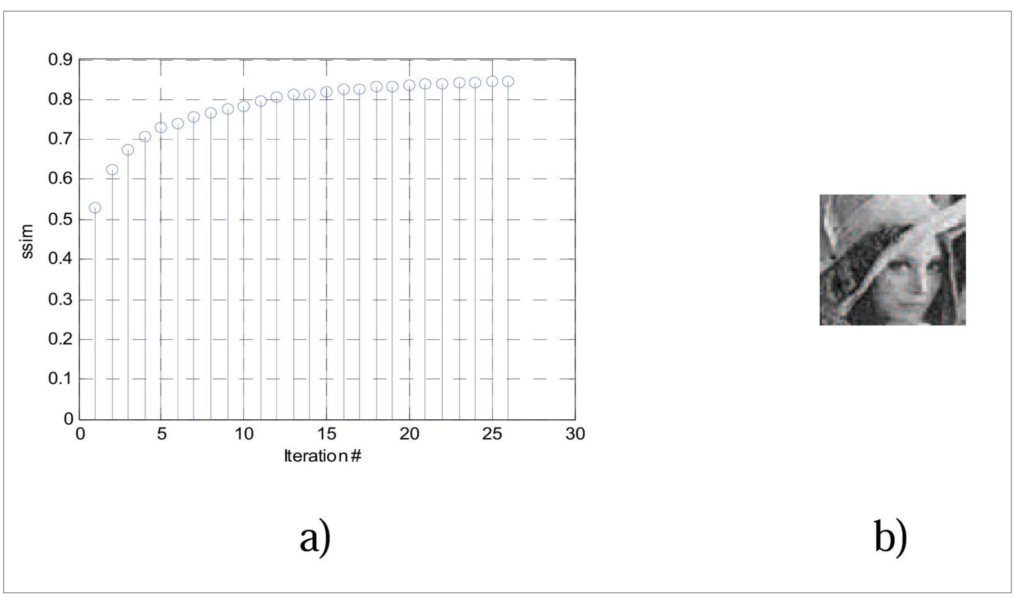

Figure 6. a) The progressive correction of the SIM index of the extracted low-resolution watermark, "LowRLena" achieved in 26 iterations and b) the appearance of the repaired watermark with SSIM = 0.84488

insertion requires determination of the location where it will be inserted into the frame. For these purposes, the original algorithm based on texture contrast of selected parts of the frame is developed. The watermark insertion is performed by the reliable SVD algorithm, thereby the occurrence of false watermarks is eliminated. After the extraction of the low-resolution watermark LowRLena, a greater SSIM index has been achieved by about 25% compared to the higher resolution watermark HiRLena. When this is not in contradiction with the implementation of the video, it is good to insert the lower resolution watermark because it will result in fewer artifacts in the protected video, and at the same time the quality of the extracted watermark will be significantly higher.

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