International Journal of Advanced Science and Technology
Vol.82 (2015), pp.11-22
http://dx.doi.org/10.14257/ijast.2015.82.02

Imperceptible 3D Video Watermarking Technique Based on Scene Change Detection

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Abstract

In the recent past years the newly emerging trend of 3D movies and projection drawn huge attention of researchers and enterprises, ranging from movie producing companies and entertainment to researchers and program developers, similar to other multimedia files these types of media need to copyrighted, a 3D video required a significant amount of effort to become a tangible product. In this paper we will present a technique to watermark such media for copyright protection purposes for 3D video to achieve both imperceptibility and robustness, using a scene change detection technique to identify the best location (frame) to be impregnated with the watermark. The 3D video file has attributes such as color channel, stereo objects and depth prospective, in this paper we will focus on such features to inject our watermark, and then discuss the impact of such process on the resulting file. From the experimental results we have concluded that our algorithm has proven imperceptibility and robustness.

Keywords: *3D Video; DWT; Scene Change Detection*

1. Introduction

With the emerging development of 3D applications, the copyright protection becomes an important aspect of 3D content production. Video watermarking techniques can be used to protect copyright of 3D content. Video watermarking techniques can be grouped into two major classes: spatial-domain and frequency-domain techniques. Spatial-domain techniques embed a watermark in the frames of a given video by modifying its pixels directly. These techniques are easy to implement and require few computational resources; however, they are not robust against common digital signal processing operations such as video compression.

On the other hand, transform-domain watermarking techniques modify the coefficients of the transformed video frames according to a predetermined embedding scheme. The scheme disperses the watermark in the spatial domain of the video frame, hence making it very difficult to remove the embedded watermark. Compared to spatial-domain techniques, frequency-domain watermarking techniques proved to be more effective with respect to achieving the imperceptibility and robustness requirements of digital watermarking algorithms [1]. In 3D video watermarking technique the story is not so different, hence both rely on the same video formatting and structuring of visual data.

In this paper, we propose a digital blind watermarking algorithm with 3D video based on the transform domain of the blue channel; in order to protect 3D content copyright efficiently and to achieve both imperceptibility and robustness. The rest of the paper is organized as follows: the subsequent section presents the related work. The preliminaries about 3D video, DWT and scene change detection are shown in Section 3. In Section 4, we describe the proposed watermark technique for

ISSN: 2005-4238 IJAST

3D Video. In Section 5, we present experiments to demonstrate the performance of the proposed technique and Section 6 contains the conclusion.

2. Related Work

There is a little number of researches for 3D content watermarking, and most of these researches deals with stereo and DBIR (Depth-Based Image Rendering) 3D images and videos. An object-oriented watermarking scheme performed in the wavelet domain for stereo images is presented in [2]. The watermarking scheme relies on the extraction of a depth map from the stereo pairs to embed the watermark. In [3] a visual sensitivity model based method for watermarking high definition (HD) stereo images in DCT domain is produced. The watermarking scheme is based on the visual sensitivity model to determine the perceptual adjustment on watermark insertion. [4] is considered as a novel watermarking technique benefiting from the characteristics of seen and unseen watermarking techniques in 3D images, depending on variation of UVW properties in the rendering process. Another novel blind multiple watermarking scheme is proposed in [5] that is to deal with the content protection problem of DIBR 3D images. [6] also proposed a watermarking scheme for DIBR 3D images, by quantization on dual-tree complex wavelet transform (DT-CWT) coefficients with consideration of the imperceptibility. For robustness, two characteristics of DT-CWT are employed: approximate shift invariance and directional selectivity. Another approach of watermarking DIBR 3D images is proposed in [7] by using SIFT to select some robust areas and utilizing Spread spectrum technology to embed the watermark information into the DCT coefficients of the selected area. Virtual view invariant domain for 3D video blind watermarking is presented in [8]. The average luminance values along the rows of the video frames have been selected for watermark embedding. Yet in [9] a 3D video watermarking which focuses on perceptual embedding is introduced. The proposed scheme exploits visual characteristics, motion on z-axis and pixels to be hidden by rendering, from depth information. But, in our work we focus on imperceptibility and robustness in (red/cyan) anaglyph 3D video watermarking. The anaglyphic 3D technique is explored deeply in cyber space and in literature which considered best used technique for creating 3D perceived images and videos.

3. Preliminaries

3.1. 3D Video

3D video is getting immense public attention recently because of vivid stereo visual experience over conventional 2D video [10]. There are several techniques to visualize 3D objects, such as using polarized lens, active vision, and anaglyph. However, some of those techniques have certain drawbacks, mainly the special hardware requirements, such as the special display used with the synchronized lens in the case of active vision and the polarized display in the case of polarized lens. However, the anaglyph technique only requires a pair of spectacles constructed with red and blue filters where the red filter is placed over the left position producing a visual effect of 3D perception [11]. Anaglyph is the least expensive way to make the 3D visual experience achievable on ordinary monitors or even printouts, with no special hardware but only low cost dual colored glasses. Despite of the many inherited challenges, its resurgence has been seen recently thanks to the abundance of 3D content which is more easily accessible nowadays than ever [12].

3D video file has a number of properties that can be exploited to act as a host for our secret data; we will focus on one of these attributes namely the dual-channel video stream, using Anaglyph 3D as the name given to the stereoscopic 3D effect achieved by means of encoding each eye's image using filters of different colors, typically red and cyan. Anaglyph 3D images contain two differently filtered colored images, one for each eye. When viewed through the anaglyph glasses, each of the two images reaches one eye, revealing an integrated stereoscopic image. The visual cortex of the brain fuses this into perception of a three dimensional scene or composition.

3.2. DWT Decomposition Process

The Discrete wavelet transform (DWT) is more popular in signal processing applications. 2D DWT decomposes a video frames into sub-images, three details and one approximation. The approximation sub images is the lower resolution approximation image (*LL*) however the details sub images are the horizontal (*HL*), vertical (*LH*) and diagonal (*HH*) detail components [13]. It is possible to obtain coarser and coarser scales of the *LH*, *HL*, and *HH* sub-bands by iteratively repeating the wavelet transformation on the *LL* sub-band of each level. When *N* level is reached we will have $3N + 1$ sub-bands consisting of the multi-resolution sub-bands LL_N, LH_x, HL_x and HH_x where x ranges from 1 to N [14].

One of the many advantages over the wavelet transform is that it is believed to more accurately model aspects of the HVS as compared to the FFT or DCT. This allows us to use higher energy watermarks in regions that the HVS is known to be less sensitive to, such as the high resolution 32 detail bands *LH*, *HL*, *HH*. Embedding watermarks in these regions allow us to increase the robustness of our watermark, at little to no additional impact on image quality [15]. Our target sub-band is *HH* of DWT which is chosen for the embedding process.

3.3. Scene Change Detection

Scene change detection in videos is the main constraint of video processing applications used for the purpose of generating data required by video data processing systems. Digital watermarking still the main method used for this reason to extract robust frame non-similarity from consecutive frames, it uses χ^2 color comparison of histogram discussed in [16]. In this method the consecutive histogram χ^2 comparison of frames is done by sliding window detector by dividing the frames into more number of sub-windows (4×4) to improve the precision and recall values for videos. Precision is more important in detecting abrupt scene changes for the purpose of watermarking. The χ^2 color histogram comparison of sub-windows or blocks *bl* between two frame images F_i and F_j with color histograms H_i and H_j, using weights for brightness grade change of RGB color space can be written as in (1):

$$d_{\chi^2}(F_i, F_j, bl) = \sum_{k=1}^{N}\left(\frac{\left(H_i^r(k)-H_j^r(k)\right)^2}{max\left(H_i^r(k), H_j^r(k)\right)}\right)\times\alpha+\left(\frac{\left(H_i^g(k)-H_j^g(k)\right)^2}{max\left(H_i^g(k), H_j^g(k)\right)}\right)\times\beta+\left(\frac{\left(H_i^b(k)-H_j^b(k)\right)^2}{max\left(H_i^b(k), H_j^b(k)\right)}\right)\times\gamma \qquad (1)$$

Where α, β and γ are constants representing the brightness grade according to NTSC standard and has values α = 0:299, β = 0:587, and γ = 0:114.

The scene-based watermarking scheme is robust against various attacks because it does not require original video as well as watermarked video for original video and watermark video recovery as it has used blind technique for watermarking according to scene change algorithm. This scheme gives the perfect solution for where to do watermarking in video thus it will become robust against every attack [17].

4. The Proposed Watermarking Technique

The watermark is embedded in the selected 3D video frames depending on the proposed method discussed in this section.

4.1. Watermark Embedding Process

The embedding system uses the blue channel to embed the actual data (watermark). Cones are the sensors in the human eye responsible for color vision. Detailed experimental evidence has established that the 6 to 7 million cones in the human eye can be divided into three principal sensing categories, corresponding roughly to red, green and blue. Approximately 65% of all. Cones are sensitive to red light, 33% are sensitive to green light, and only 2% are sensitive to blue light. Human eye is less sensitive to blue light, so we embed the image in blue channel [18]. For embedding the watermark, a 1-level DWT is performed to the blue channel. Watermark information is embedded in the high frequency bands (*HH*) of that channel since it includes the edges and textures of the image and the human eye is not generally sensitive to changes in such sub bands, this allows the watermark to be embedded without being perceived by the human eye [19]. Also, *HH* is robust against various normal image processing and attacks.

The following steps are the description of the proposed embedding process; Figure 1 is the representation of these steps.

1. Convert the binary image watermark into a vector $W = \{w_1, w_2, \ldots, w_m\}$ of binaries.
2. Detect the scene changes from the 3D video by applying the χ^2 color comparison of histogram.
3. Extract the blue channel from each RGB selected frame and decompose it into one-level DWT.
4. Split the *HH* and divide it into non-overlapping blocks of dimension 8×8; $H_1, H_2, \ldots, H_b$. Here b is the number of blocks.
5. Apply the binary image watermark bits W into *HH* blocks. The embedding process for each watermark bit is done by replacing the first coefficient in the first column in the block with the maximum coefficient$+\delta$ in the same column if the embedded bit equal to 1, else the replacement is done with the minimum coefficient$-\epsilon$, where δ and ϵ are the diversity strength factor parameters for the watermark. The size of watermark should be equal (or less) to b.

For each block H_i and watermark bit W_i:

$$H_i{}'(1,1) = \begin{cases} maximum\left(H_i(r,1)\right) + \delta & if\ W_i = 1 \\ minimum\left(H_i(r,1)\right) - \epsilon & if\ W_i = 0 \end{cases} \tag{2}$$

6. Reconstruct the watermarked blocks into *HH* and perform inverse DWT to obtain the watermarked blue channel, and combine the blue channel with the red and green channels to make the 3D watermarked scene.
7. Combine the 3D watermarked scenes with other frames to produce the watermarked anaglyph 3D video.

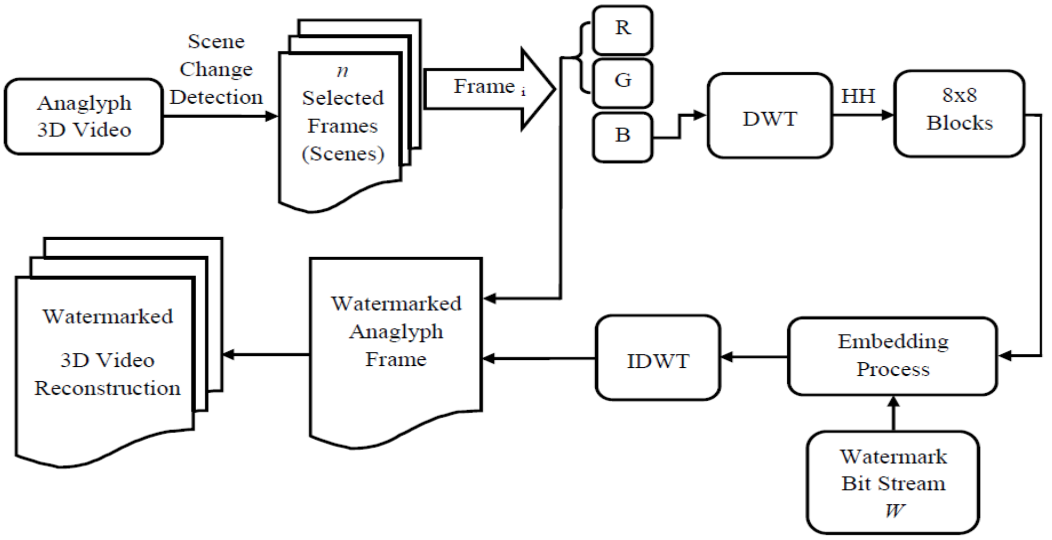


Figure 1. Embedding Process

4.2. Watermark Extraction Process

The original 3D video is not required during the extraction process, for successful extraction of the watermark we follow these steps; see Figure 2.

1. Detect the scene changes from the 3D video by applying the χ2 color comparison of histogram.
2. Extract the blue channel from each RGB watermarked scene and decompose it into one-level DWT.
3. Split the HH and divide it into blocks of dimension 8×8.
4. The extraction process is done by computing the average of the first column of each watermarked block, and if the average is greater than the first coefficient in the first column then the watermark bit is equal to 0, else the watermark bit is equal to 1.

For each block H_i:

$$W_i' = \begin{cases} 0 & if\ H_i'(1,1) < Average \\ 1 & if\ H_i'(1,1) \geq Average \end{cases} \quad (3)$$

Where $W_i^{'}$ is the extracted watermark bit.

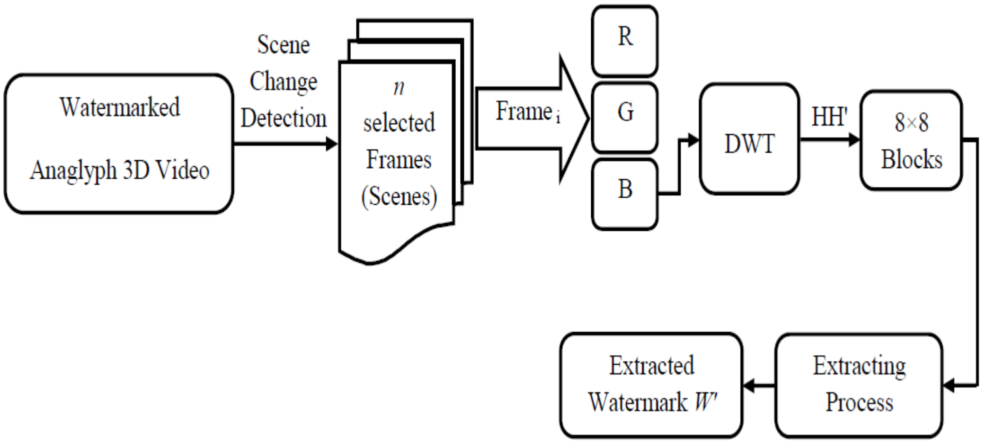


Figure 2. Extracting Process

5. Experimental Results

The Peak signal to noise ratio (PSNR) is a common quality measurement of watermarking system. PSNR is defined as Equation (4).

$$PSNR = 10\log_{10}\left(\frac{255^2}{\frac{1}{m\times m}\sum_{i=1}^{m}\sum_{j=1}^{m}[I(i,j)-I'(i,j)]^2}\right) \quad (4)$$

Where: $m\times m$ is the size of the image, and $I(i,j)$, $I'(i,j)$ are the pixel values of the host and the attacked frames.

To measure the impact of watermarking on the 3D video, from [20] we applied the PSNR equation for 3D video. The following Equation illustrates the PSNR for watermarked 3D video with n frames. PSNR is expressed in decibels (dB).

$$PSNR_{3D\ video} = \frac{\sum_{i=1}^{n} PSNR(i)}{n} \quad (5)$$

In order to measure the robustness of the watermarking system, the normalized correlation coefficient (NC) of the extracted watermark Wi' is applied in conjunction to the original one Wi; the maximum value of this measure is 1 which determines the best robustness of the watermarking process.

$$NC = \frac{\sum_{i=1}^{M} Wi\, Wi'}{\sqrt{\sum_{i=1}^{M} Wi^2}\sqrt{\sum_{i=1}^{M} Wi'^2}} \quad (6)$$

Where: M is the size of the original and extracted watermark bit vectors.

The proposed algorithm is applied to four different scenes for each of Ballet and Breakdancers videos sequences [21] .The camera resolution is 1024×768 and the capture rate is 15 fps. The watermark image created is a binary image of size 62×47 that reads "Jumana" as shown in Figure 3. We have embedded the watermark into the selected scenes of the anaglyph 3D videos using the algorithm described in the previous section.

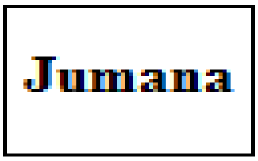


Figure 3. Original Binary Watermark

Since the magnitudes of the high frequency coefficients of DWT increases as we move to the higher level of decomposition, it is possible to use smaller scaling factors for watermark embedding hence we are using the lower level of decomposition. Extensive experimentation has been done to calculate the scaling factors for the watermark where concluded manually (δ = 1.8, and ϵ = 1.9), to obtain a tradeoff between imperceptibility and robustness.

The visual distortion introduced by the watermark embedding process cannot be perceived by the HVS in watermarked Scenes. The Watermarked scenes without added noise or other attacks show that the technique ensures high degree of imperceptibility see Figure 4. The extracted watermark is shown in Figure 5.


(a) (b)


(c) (d)

Figure 4. The First Scenes from 3D Anaglyphs Videos Sequence (a) Ballet and (b) Breakdancers. And, the Watermarked 3D Anaglyphs without Attacks for (a) The First Scene in Ballet 3D Video Sequence with PSNR= 64.8091 dB, and (b) The First Scene in Breakdancers 3D Video Sequence with PSNR= 63.0032 dB

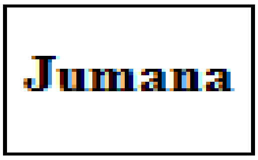


Figure 5. The Extracted Watermark from HH1 given NC=1

The achieved PSNR values are considered to be a high imperceptibility values. Figure 6 illustrates the plots of PSNR versus selected scene number for the 3D video sequences after watermark embedding. Table 1 shows a comparison of the imperceptibility values between the proposed 3D video watermarking technique and the existing techniques in [7] and [9].

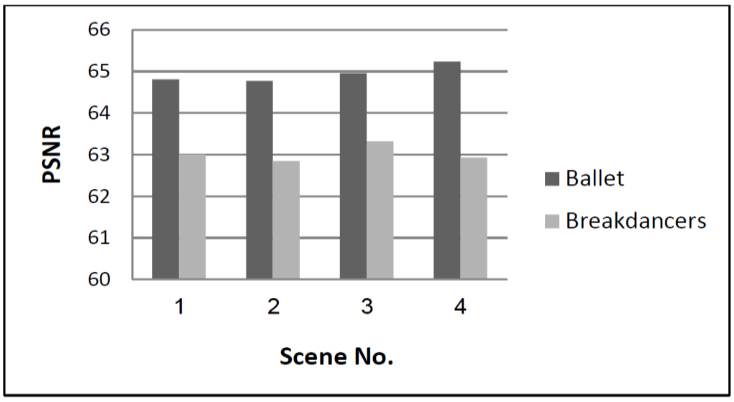
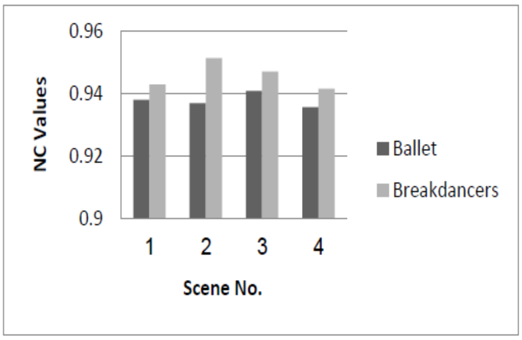


Figure 6. The PSNR versus Selected Scene Number for Ballet and Breakdancers 3D Videos Sequences after Watermark Embedding

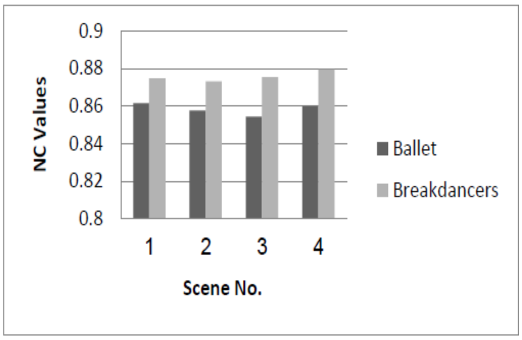
Table 1. Comparison of the Average PSNR between the Proposed Technique and other Techniques

Watermarked 3D video sequences	Proposed	Wang et al., [137]	Lee et al., [139]
Ballet	65 dB	59 dB	43 dB
Breakdancers	63 dB		46 dB

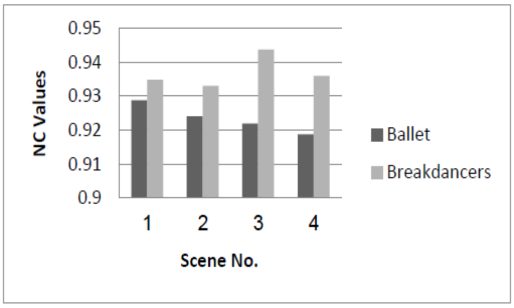
To evaluate the robustness of the proposed technique, different types of attack were performed on the watermarked scenes. Noisy attacks are obtained by adding 1% and 5% salt & pepper noise and adding Gaussian noise with mean=0 and variance=0.0005 to the watermarked scenes. The reconstructed watermark is detected after noisy attacks which show our technique is robust to these types of attack and the NC values are acceptable, see Figure 7 (a-c). Gamma Correction 1.5, Intensity Adjustment ([0 0.8], [0 1]), histogram equalization and 30% cropping are applied to the watermarked scenes, the NC values for the reconstructed watermark under these attacks are almost perfect as shown in Figure 7 (d-g). The lossy JPEG compression attack is performed by compressing the watermarked scenes. When the quality factors is 75, the reconstructed watermark can still detect with acceptable NC values, see Figure 7 (h). Gaussian low pass filtering attack with window sizes of 5 × 5, 3 × 3 and 2 × 2 was applied to the watermarked scenes. In Gaussian low pass filter of sizes 5 × 5, 3 × 3, for all watermarked scenes, the NC values for the reconstructed watermark are equal to 1, and with size 2 × 2, the NC values are between 0.77-0.82 as shown in Figure 7 (i). The total results and impact of the attacks on the watermarked 3D videos sequences are shown in Figure 8 which demonstrates the values of PSNR with respect to attack types.

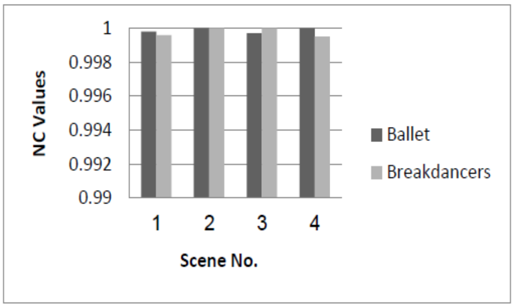


(a) Salt and Pepper Noise 1%



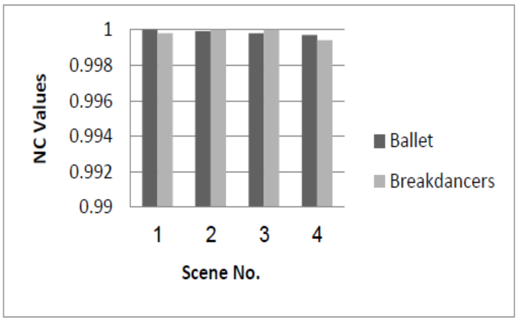
(b) Salt and Pepper Noise 5%

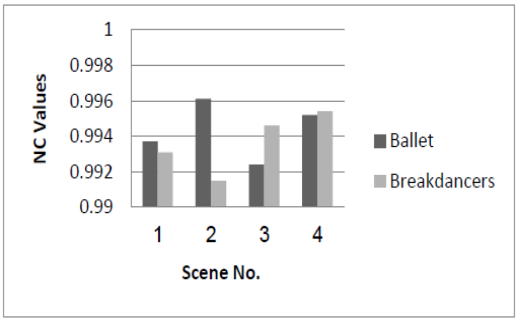




(c) Gaussian Noise

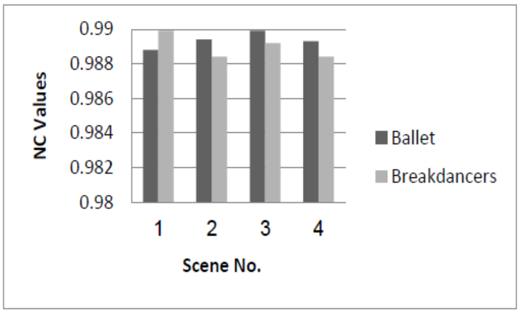
(d) Gamma Correction 1.5

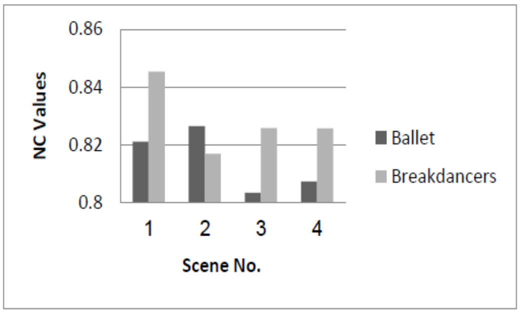




(e) Intensity Adjustment ([0 0.8], [0 1])

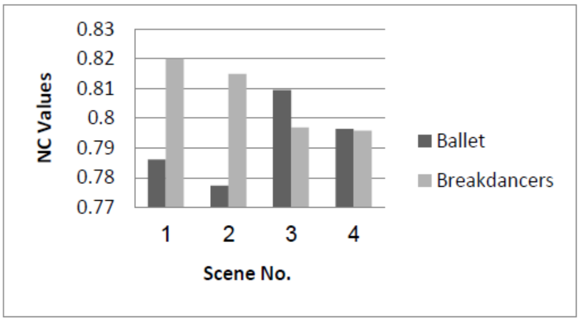
(f) Histogram Equalization





(g) Cropping 30%

(h) JPEG Compression



(i) Gaussian Low Pass Filter

Figure 7. The NC Values for Reconstructed Watermark under Different Types of Attack by (a) Salt and Pepper Noise 1%, (b) Salt and Pepper Noise 5%, (c) Gaussian Noise, (d) Gamma Correction (1.5), (e) Intensity Adjustment ([0 0.8], [0 1]), (f) Histogram Equalization, (g) 30% Cropping, (h) JPEG Compression with QF=75 and (i) Gaussian Low Pass Filter of Size 2×2

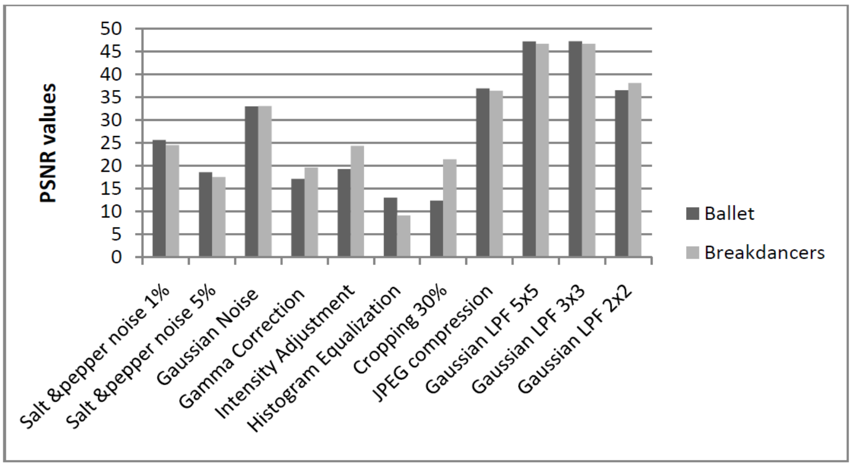


Figure 8. Effect of Attacks on PSNR Values

6. Conclusion

In this paper a blind and imperceptible 3D video watermarking technique is proposed by embedding the watermark bits into the blue channel with the performance of DWT, the main conclusion was that regardless of the qualities of the watermarking technique, the anaglyph 3D video in its nature depends on two aspects: the first one is the illusion of depth perceived by the human visual cortex and the second is a chromatically opposite colored lenses glasses both significantly preventing the chance of perceiving any distortion in some sense, also the common nature of such videos is that they always comprises high resolution videos which provide a high data rate cover media. There is an urgent need for creating an imperceptible and robust watermark for such files since there is a little number of literatures exploring the specifics of these files. The obtained results of PSNR and NC values show promising results of a fair tradeoff between imperceptibility and robustness. The proposed technique describes effective 3D videos watermarking technique, since resulting watermarked 3D videos does not have any degradation leading to a loss to its commercial value with PSNR values higher than 63 dB. Finally, the proposed technique is robust against different kinds of attacks.

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