A Robust Anaglyph 3D Video Watermarking based on Multi-sprite Generation

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Abstract: Collusion presents a malicious attack for video watermarking techniques. In the case of anaglyph 3D video, this attack is not yet considered. In fact, only several watermarking techniques were proposed for this type of media and they are not robust against dangerous attacks such as MPEG compression and collusion. In this paper, a robust anaglyph 3D video watermarking technique is proposed. It is based on multi-sprites as a target of insertion. This allows obtaining a robustness against collusion attacks. First, several sprites are generated from original video. Then, a hybrid embedding scheme based on the least significant bit and the discrete wavelet transformation based method is applied on every sprite to insert signature. This improves invisibility and robustness against usual attacks. Experimental results show a high level of invisibility and a good robustness against collusion, compression and against additional attacks such as geometric and temporal attacks.

1 INTRODUCTION

3D videos become more and more popular and increase daily due to the 3D technology evolution and the high speed of internet access. In fact, 3D video is getting a huge attention from public recently over 2D video. There are various display methods to see videos in 3D like the anaglyphic technique, the polarized light technique and the active shutter technique. The last two methods require a specific and expensive hardware. Indeed, an expensive display with an alternate liquid crystal shutter glasses which is used with an electronic device is needed for the active shutter system while a polarized display is required for the polarized system like a pair of a costly polarized filter glasses and others displays to obtain 3D videos. Finally, the anaglyphic system for 3D image which consists of two superimposed images representing the same scene from different angles where the left view in red and the right one in cyan (green + blue). It is a printed image to be observed in relief by using 3D glasses with two filters of different colors (chromatically opposite) placed in front of each eye of the observer. The visual cortex of the brain fuses the two colored images into the perception of a 3D scene. Anaglyph 3D system is the display method that has taken the attention of researchers lately in many domains because it is cheaper than other systems and it is the easy way to make the 3D visual experience succeeded without any special hardware, just only cyan-red glasses.

Due to the rapid evolution of the 3D technology, the transmission of 3D video in the internet became easier and everyone can access to their content. However, 3D videos cannot be distributed without any kind of protection from dangerous attacks. Digiatal watermarking techniques are the most efficient and suitable solutions to protect 3D videos thanks to the security and copyright protection provided to digital data (text, audio, image, video). Indeed, it consists of embedding a mark within a host 3D video, then of trying to extract it after any attack applied on marked 3D video.

Different watermarking works dedicated for 2D video have been proposed in the literature (Bayoudh et al., 2017b; Kerbiche et al., 2017) in recent years but concerning 3D videos, the field is still immature due to the variety of display ways and the 3D information data complexity. Regarding 3D anaglyph videos, some existing works were proposed and did not resist to most important attacks such as compression and collusion. This last attack tries to approximate

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and eliminate the embedded mark to obtain the original video. In order to resist this dangerous attack, several techniques of 2D video watermarking proposed using static mosaic or static multi-sprites as target of signature embedding (Bayoudh et al., 2017a; Bayoudh et al., 2015). In fact, the similar physical points in all frames forming the video should be marked similarly in order to withstand the collusion attack. That is why, the best embedding target is the mosaic image created from a video sequence.

In this paper, a robust anaglyph 3D video watermarking technique is presented. It is based on multi-sprite generation from every set of 25 frames composing the original video. The signature will be embedded in each sprite using a hybrid insertion scheme based on Discrete Wavelet Transform (DWT) and Least Significant Bit (LSB) insertion methods. This allows obtaining a high level of invisibility and maximizing robustness against usual attacks.Besides, the use of multi-sprites as an embedding target will allows robustness against collusion and compression attacks.

The rest of this paper is planned as follows: section 2 deals with the related works of both anaglyph 3D images and videos watermarking techniques. Section 3 presents the proposed technique for anaglyph 3D video based on DWT and multi-sprites generation. Section 4 analyzes the proposed scheme via the experimental results. Section 5 presents a comparative study between the existing works and the proposed method. Finally, section 6 draws the conclusion and some perspectives.

2 ANAGLYPH 3D IMAGE AND VIDEO WATERMARKING

Various watermarking techniques dedicated for anaglyph 3D images are proposed in the literature and they can be characterized by two criteria: the selected insertion domain and the chosen channel to embed the signature.

Regarding the first criterion, the authors choose to insert the mark into the coefficients bits recovered either after applying DWT (Zadokar et al., 2013; Devi and Singh, 2016), Discrete Cosine Transformation (DCT) (Munoz-Ramirez et al., 2015), or Fractional Fourier Transformation (FrFT) (Y and Krishna, 2016). The most of anaglyph 3D watermarking approaches are based on DWT domain to insert the signature by adding the mark coefficient bits of high frequencies sub-bands to those of the chosen original image view in order to ameliorate the invisibility and the robustness compromise of the proposed technique (Ruchika and Parth, 2015; Prathap and Anitha, 2014). The existing techniques based on DWT domain provide the highest invisibility level where the Peak Signal to Noise Ratio (PSNR) value is up to 50 dB and the best robustness level against usual attacks such as geometric attacks compared with the DCT and the FrFT based methods.

Concerning the second criterion, the mark is inserted either into blue or red image (Ruchika and Parth, 2015) or into all blue, red and depth images composing the anaglyph image (Sanjay R. and Ravindra B., 2015; Zadokar et al., 2013). The marked blue or red image will be then recombined with the unmarked host images to find the final marked anaglyph image. In the majority of the existing watermarking techniques, the writers insert the mark into the blue images of anaglyph image due to the insensitivity of the human eye to this color. This insertion process gives a good visual quality level and decreases the robustness against the majority of attacks (Prathap and Anitha, 2014).

Concerning anaglyph 3D videos, few number of existing works are proposed until now. In (Waleed et al., 2013), a blind DWT based watermarking technique is proposed. The mark is inserted in all the blue images of all frames composing the host anaglyph 3D video since the blue color change is slightly perceived by the human visual system. The problem of this technique is that when the mark is embedded only in blue images, a lack of robustness may be caused if the attack targets them then the embedded mark will be easily lost. Whereas in 2015, (Salih et al., 2015) an another blind watermarking scheme based on DWT is suggested. The mark is inserted into all blue images of all frames where a scene change is detected in the anaglyph 3D video to obtain a good invisibility level. In this proposed technique, the embedding of mark just into scene change frames detection can provoke a fragile watermarking scheme in a video with only one or few scenes. Moreover, in (Dhaou et al., 2018) a Groups of Pictures (GOP) decomposition based watermarking is proposed using the DWT domain where the mark is embedded into the three images types (I, B and R) of each set of GOP. In fact, the embedding method targets cyan images and red images in B and R images respectively. Whereas in I images, it targets all cyan, red plus depth images. So, if any manipulation tries to remove the mark embedded in any images type, it can be then extracted from the other types. The proposed scheme provides a high imperceptibility level and robustness against usual manipulations and it can't resists to collusion attack.

3 PROPOSED APPROACH

Based on the study of the art, all existing watermarking techniques proposed for anaglyph 3D videos present a good invisibility level with robustness against several usual attacks. However, these proposed techniques did not consider malicious attacks like MPEG compression and especially collusion attack. To find a good solution to this problem, a new robust watermarking technique dedicated for anaglyph 3D video is proposed in this paper. This technique is based on multi-sprites as a target of embedding. Multi-sprites are chosen thanks to their high quality of reconstruction compared with single mosaic.

The proposed method architecture is illustrated in Fig. 1 and is composed into three main steps. In fact, giving an original anaglyph 3D video, a sprite will be generated from every set of 25 frames. Then, signature will be embedded in each sprite. Finally, marked 3D anaglyph video will be reconstructed using the marked sprites.

3.1 Multi-sprite Generation

A sprite (mosaic image) is a panoramic view containing all information spread in the video sequence. It will characterize the evolution of the video in a single high resolution image and a unique physical point will represent each duplicated point along the video. The mosaic generation composed of three basic stages (Zeng et al., 2014). First, it consists in detecting features from all the video frames to select all interest points. The SIFT descriptor which is invariant to certain transformations (rotation, scaling, noises) is generated from all extracted interest points. Second, all extracted feature points from images are matched by calculating the distance between them to compare the features descriptor of each points. Next, the random sample consensus is applied to remove the expected mismatching between the corresponding images. Then, by applying the appropriate transformation, either both the two consecutive images, or the image and the active sprite are aligned. Finally, the image is integrated using a median or average intensity filtering. Image integration is done in order to create the sprite by choosing the equivalent part of the transformed image and linking it with the final sprite.

A sprite can describe all the frames composing the video in a unique image, but it can causes many difficulties like an important time processing during generation and a distortion effect in mosaic image. In fact, if a video sequence has too much frames, the recovered mosaic will has a large size. This can causes first complexity during the generation of mosaic and it can be applied only if all frames are available.

Multi-sprites are considered as a solution in order to avoid the problems mentioned previously. In fact, the multi-sprite generation consists in generating multiple mosaic images from a video sequence in the same scene rather than one mosaic image using diverse parameters (Barhoumi et al., 2011) to select the best frame number per sprite. They are generated with the same way of single sprite but the only difference between them is that the whole video sequence is first divided into sub-sequences basing on a pre-determined parameter. Next, each sub-sequence is manipulated as a whole video sequence and the single sprite generation method is done to get the wanted sprites. If one sprite is produced with too much frames, the time processing will be increased and the quality of the reconstructed sprite will degrade the video quality.

In order to reduce these two problems, the video will be simply divided into unit of a second segment. So, for every second, the set of frames constituting it is considered as a sub-sequence and a sprite will be generated. In this case, the generation of one sprite for each 25 frames per second is proposed. Fig. 2 presents sprites generated from the sequence video "BigBuckBunny", where each sprite is generated from 25 frames.

Several watermarking techniques based on mosaic images as an embedding target have been proposed for 2D video contents (Koubaa et al., 2012). These techniques are robust against malicious attacks such as collusion. As a matter of fact, this last one consists in estimating the inserted mark and then eliminating it from marked videos in order to recover original ones. There are two types of collusion attacks: In the first type, the attacker takes a number of samples of the same video, which are marked with different signatures, and essays to discover similar frames. The unmarked video is obtained by averaging the neighboring marked video frames, which permits mixing the different signatures. In the second type, the attacker takes various videos marked with the same signature. To obtain unmarked videos, the attacker has to estimate the inserted signature by averaging the different marked videos, and then eliminate it from all these videos.

Different 2D video watermarking techniques, which withstand collusion attacks are proposed, but regarding anaglyph 3D video there are no existing technique robust against collusion. In fact, a video watermarking based on the Spread Spectrum

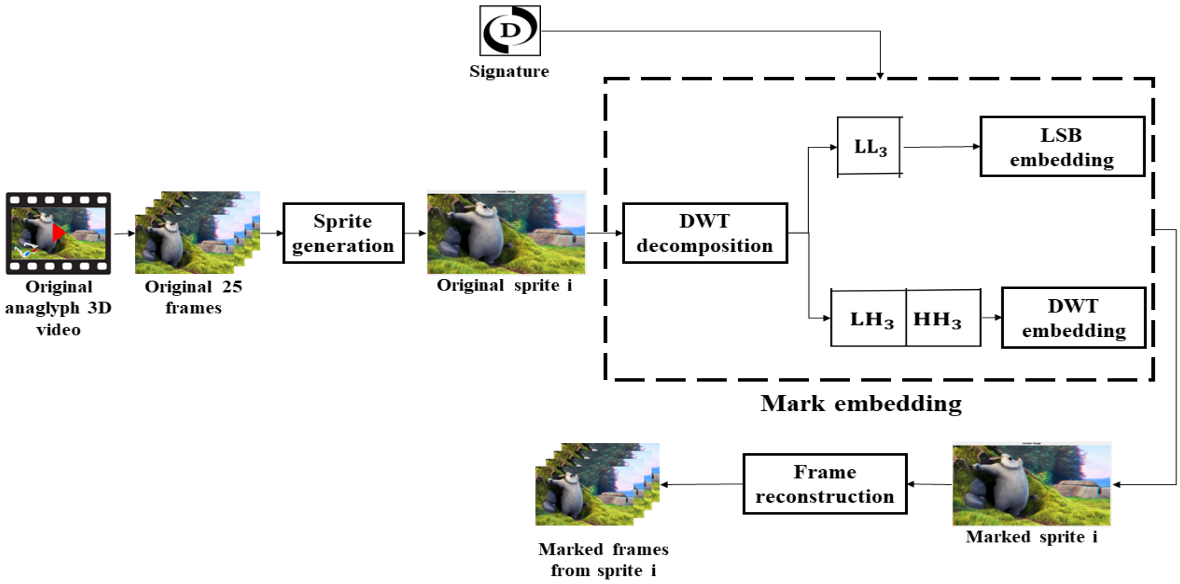

Figure 1: The general flowchart of the proposed approach.

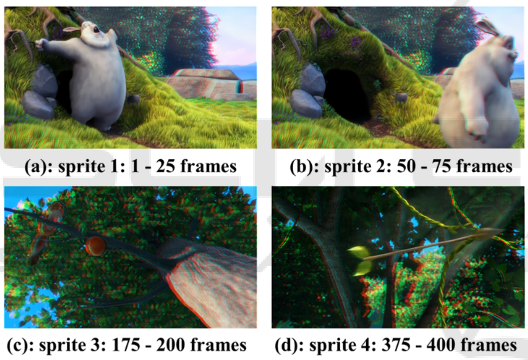

Figure 2: Sprites generated from "BigBuckBunny".

(SS) technique was put forward in (Koubaa et al., 2012), where the mark was embedded in the mosaic image obtained from the whole video sequence using a spatial domain, and which was robust against MPEG4 compression, frame dropping and collusion attacks. A video watermarking based on a dynamic multi-sprite generation and SURF descriptor was put forward in (Bayoudh et al., 2017a) to resist collusion attack where a signature was inserted into the different sprites. Another scheme robust against collusion attacks was proposed in (Bayoudh et al., 2015), where the mark was embedded in mosaic images generated from each group of frames of the host video using the LSB algorithm. In (Kerbiche et al., 2018), a video watermarking based on feature regions detected using the crowdsourcing technique was presented. After the detection of regions of interest, the mark was inserted utilizing a multi-frequency domain in the generated mosaic image. This approach was robust against most manipulation and collusion attacks.

3.2 Signature Embedding and Detection Methods

The signature embedding process is based on a hybrid insertion using the DWT and LSB techniques where the signature is embedded in each generated sprite to enhance both the robustness and invisibility of the proposed method. The signature embedding technique is divided into different steps. First, based on sprite size, the signature spreading is applied. Then, the signature and each sprite are decomposed using 3^{rd} level of wavelet transformation which is obtained by decomposing the sub component LL_1 and critically sub sampled to LL_2, HL_2, LH_2, and HH_2. This process will be then applied for the sub component LL_2 in order to obtain LL_3, HL_3, LH_3 and HH_3. In fact, to obtain marked coefficients, the high frequency coefficients (HH_3) and (LH_3) of the signature are added to those of the sprite using an invisibility factor. High frequency sub-bands are chosen because they are the good areas for signature embedding since the HVS is insensitive to these high frequency components and they provide a good tradeoff between capacity and invisibility. At the second step, the low frequency sub-band (LL_3) in each sprite is going through an LSB embedding technique where the signature is embedded in the least significant bits of each low frequency sub-band (LL_3) of sprite pixels which contains the total of image energy and information. Embedding the mark in low frequency make the scheme robust against compression attacks but it degrade the visual quality of the marked media that is why we use to embed the mark in the least significant bit of (LL_3) sub-band. Indeed, the LSB technique is the well-known and traditional method used to insert the mark in a host media due to its simplicity (Sharma, 2012). It consists in embedding the mark bits in the least significant bits i.e the first bit of the original media pixels since the insertion in the first bit does not affect on the visual quality of the marked media. The marked sprites will be obtained by applying the 3-level of Inverse Decomposition Wavelet Transform (I-DWT) to the corresponding marked sub-bands. After all, the marked sub-sequences will be reconstructed from the obtained marked sprites and recombined in order to generate the marked 3D anaglyph video.

The detection step consists of verifying the presence of the mark in a given anaglyph 3D video where the original generated sprites are required during the detection. In fact, multi-sprites will be generated from the marked anaglyph 3D video. Then, the 3^{rd} level DWT is applied on each sprite and the LL_3, HH_3 and LH_3 sub-bands are selected. The least significant bits are extracted from the LL_3 sub-band coefficients of each sprite to recover the bits of embedded spread mark. In addition, the coefficients of the spread signature are extracted from the selected high frequencies sub-bands HH_3 and LH_3 and the I-DWT is applied to recover the mark. Finally, the spread mark is divided into a set of marks and the one which have the best correlation is chosen.

4 EXPERIMENTAL RESULTS

To evaluate the proposed approach, a set of robustness and invisibility tests are applied on five original anaglyph 3D videos, which have different characteristics such as background texture, movement, resolution and number of frames. In fact, the first video presents slow movement, textured frames and it is composed of 650 frames with a resolution of 1280 × 720 whereas the second sequence has a rapid movement, textured frames and is composed of 300 frames with the same resolution as the first video. The third video has a medium movement, textured 250 frames and a resolution of 480 × 360. The fourth and the last videos present a slow movement, textured frames and are composed of 150 and 400 frames respectively with a resolution of 1280 × 720 and 640 × 320 respectively. As a signature, a binary image with size of 32 × 32 is used.

After signature embedding, no differences between original (Fig. 3.a) and marked (Fig. 3.b) anaglyph 3D videos can be observed.

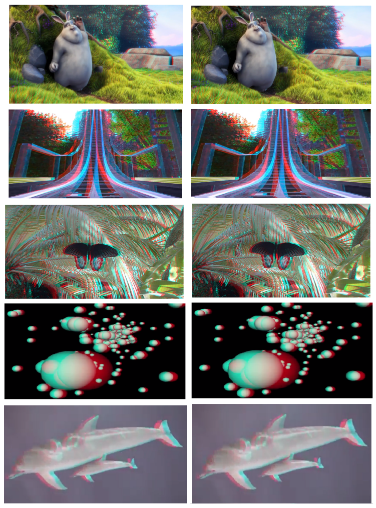

Figure 3: a- Original frames. b- Marked frames.

In order to prove the high level of invisibility of the proposed approach, the average of the PSNR values is calculated between all original and marked frames forming the video sequence. In fact, usually a high level of invisibility is obtained with a PSNR superior to 40 dB. The obtained PSNR values for anaglyph 3D test videos are illustrated in figure 4. They show that the proposed watermarking technique provides a high invisibility with the embedded mark in different test videos where the minimum PSNR value is about 54 dB and its maximum is about 59 dB.

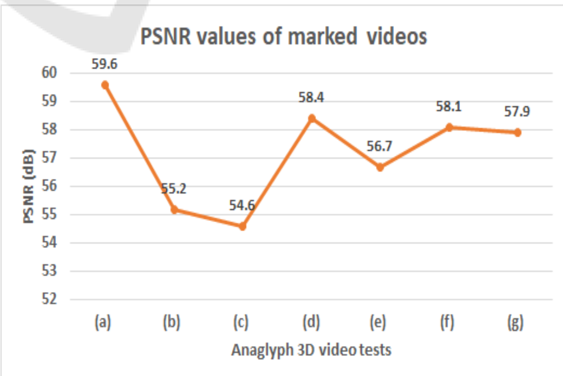

Figure 4: Invisibility evaluation using the PSNR values.

To evaluate the robustness of the suggested scheme, various usual and malicious attacks are experiment. First, these attacks are applied on the marked anaglyph 3D video, and then the Normalized Correlation value (NC) and the Bit Error Rate (BER) are calculated between original and extracted mark to prove the robustness against an attack by quantifying the visual quality of the extracted mark. In fact, the NC and BER reflect respectively the degree of similarities and dissimilarities between original and extracted mark. The maximum NC value is close to 1 if there is a correspondence between original and extracted mark and it converges to 0 if there is a difference. Contrary to NC value, the BER value is close to 0 if there is a similarity between original and extracted mark and it converges to 1 if not.

Foremost, the usual and spatial attacks are evaluated by applying geometric attacks such as rotation with various angles (50° and 90°), scaling (reduction of 15% and 50% and enlargement of 250%), cropping and resizing. Indeed, The obtained NC values are between 0.8 and 0.9 and the BER values are between 0.001 and 0.003. These results confirm the robustness of the proposed method against geometric attacks due to the invariance of DWT to these attacks and the repetition of the mark in each sprite of the sub-sequence video. Second, different noise attacks such as salt & pepper, Gaussian and Speckle noise are applied to the marked anaglyph 3D video. The obtained NC and BER values are about 0.9 and 0.002 respectively almost times and the detection of the mark is possible after these noise attacks. Then, the average and Gaussian filters are applied to the marked anaglyph 3D video. The BER was almost about 0.002 with a correlation about 0.85 almost times. This robustness was enhanced because of the invariance of the used DWT transformation. In addition, the blurring attack is applied on the marked video by using a low-pass filter with a Gaussian variance equal to 5 and the detection of the mark succeeds where the NC and BER values are about 0.9 and 0.001 respectively for most of video test.

At a second step, temporal manipulations are evaluated by implementing various transformations on the marked anaglyph 3D videos. First, the frame based attacks are applied on the marked video like frame suppression and swapping. Due to the embedding of the mark in the different sprites of the video, the detection of the signature succeeds where the average of the NC and the BER values were about 0.9 and 0.001, respectively. Then, the histogram equalization and intensity adjustment manipulations are applied on the different marked video tests by enhancing the contrast of the marked video sequences. After these attacks, the mark still readable with an average of NC and BER values about 0.9 and 0.002, respectively. Moreover, The proposed approach is evaluated against the MPEG-4 compression with a variable bit rate (from 2 Mbps to 512 kbps) by using the mediacoder software application [1] which was adapted to transcode the marked video. The obtained results show the robustness against compression because of the use of multi-sprites as an embedding target where the average of the NC value was close to 0.9 and the corresponding average BER value was about 0.001. Finally, the collusion attack which is considered as the most dangerous and malicious attack in video watermarking is tested. It consists in estimating the embedded mark and removing it easily from the marked video without damaging its quality. The two collusion types are performed during the evaluation. The recovered results of both BER and NC value are respectively close to 0.002 and 0.9 and they confirm the robustness of the suggested scheme against collusion attack due to the use of multi-sprites which allows marking the same physical points of each video frame similarly.

Fig. 5 and Fig. 6 illustrate respectively the average of the obtained NC and BER values after applying the usual, spatial and temporal attacks on the different marked video tests.

5 COMPARATIVE STUDY

To prove the efficiency of the suggested method, obtained results are compared with three anaglyph 3D watermarking existing methods (Waleed et al., 2013; Salih et al., 2015; Dhaou et al., 2018) based on the invisibility and robustness criteria. The PSNR values are calculated for existing and proposed approaches. These values show that the proposed scheme presents a good level of invisibility with a PSNR value of about 59 dB. The video reconstruction from multi-sprites caused a little invisibility degradation compared with others approaches.

The robustness comparison showed that the proposed approach is robust against almost of usual such geometric attacks, noises, filtering, scaling, blurring, intensity adjustment, histogram equalization, frame based attacks in addition to the most malicious attacks which are MPEG compression and collusion. However, the other existing methods cannot resist these two last dangerous attacks and the frame based attacks such as frame suppression and swapping. In brief, Table 1 summaries the robustness results for each existing techniques.

[1]http://www.mediacoderhq.com

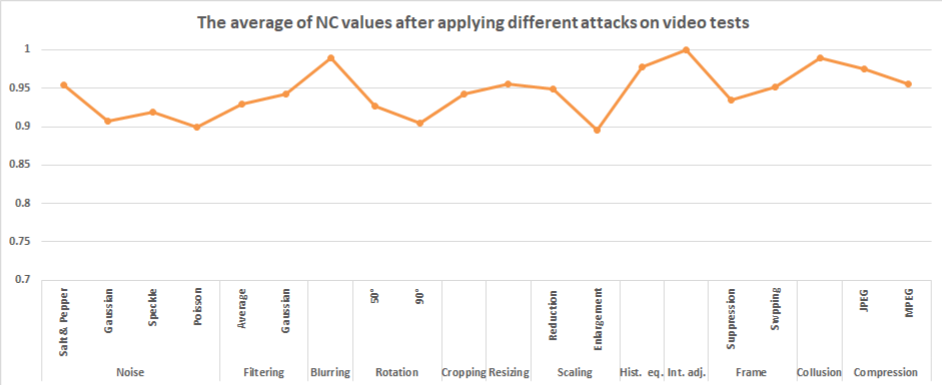

Figure 5: Robustness results: the average of NC values obtained after applying attacks for different test videos.

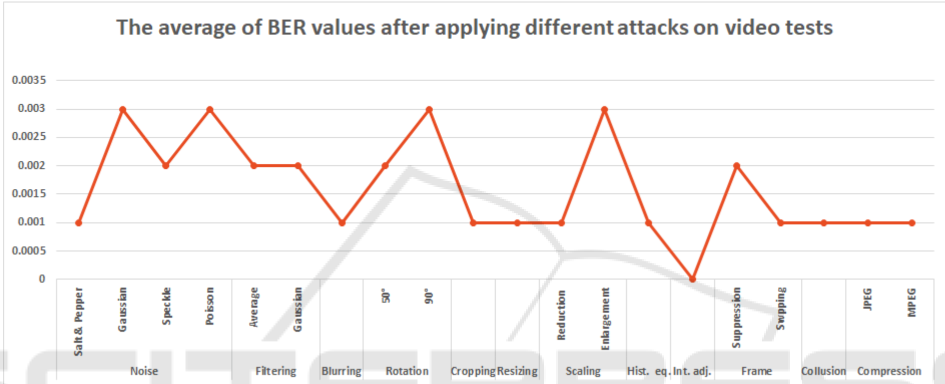

Figure 6: Robustness results: the average of BER values obtained after applying attacks for different test videos.

Table 1: Robustness comparison.

Attacks	Noise	Filtering	Blurring	Rotation	Cropping	Scaling	Frame Supp. / Swap.	Histogram Eq.	Intensity adj.	JPEG	MPEG-4	Collusion
Proposed approach	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
(Waleed et al., 2013)	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-	-
(Salih et al., 2015)	✓	✓	✓	✓	✓	✓	-	✓	✓	✓	-	-
(Dhaou et al., 2018)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-

6 CONCLUSIONS

This paper presented a new anaglyph 3D video watermarking approach which is robust against MPEG compression and collusion attacks. In fact, it is based on multi-sprites which present an efficient embedding target for 2D and 3D videos. In order to maximize the trade-off between invisibility and robustness against usual and malicious attacks, a hybrid scheme based on LSB and DWT insertion was applied for every sprite generated from each set of 25 frames. The signature was embedded in both high and low frequencies, obtained after DWT composition, by applying the LSB on LL sub-band and DWT on LH and HH sub-bands. The choice of multi-sprites as an insertion target provides a robustness against collusion attack and a high quality of marked video reconstruction compared with single sprite generated from the whole video. Besides, the use of DWT as embedding domain and the LSB technique maximizes the level of invisibility and the robustness against usual attacks.

Experimentations show that the proposed method is robust against several attacks like geometric

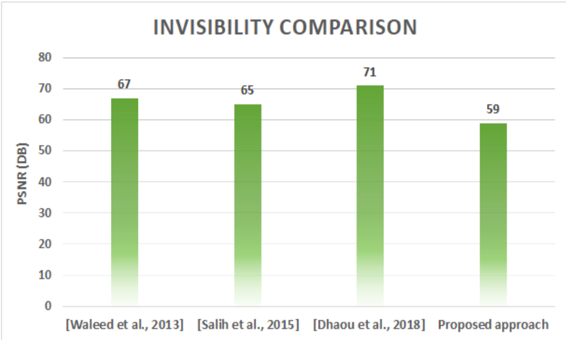

Figure 7: Invisibility comparison based on the PSNR values.

attacks, compression, noises, filtering, frame suppression and against collusion with an average NC value higher than 0.8 and average BER value lower than 0.006. Moreover, the proposed technique allows obtaining a high visual quality level. In addition, the comparison of the proposed method with existing works shows the good performance of the proposed technique to resist the majority type of attacks with a good invisibility level. As future work, the invisibility level can be enhanced by improving the embedding scheme and the generation step of multi-sprites.

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