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ENHANCED WAVELET PACKET BASED UN COMPRESSED VIDEO WATERMARKING ALGORITHM WITH FRAME SELECTION AND HVS CRITERIA

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ABSTRACT

Digital video is a group of moving visual images, text and sounds. The popularity of using digital video in Internet leads to illicit copying and dispersal of content. In order to avoid this, video watermarking technique are used as a preventive measure for illegal copying of copyrighted material. In this paper, watermarking algorithm for identification of optimal frames and embedding of nested watermark using static block selection is proposed. The nested watermark is embedded in the uncompressed video data and is extracted without the use of original video sequences. These algorithms preserve the video quality and provide more security. The performance of the algorithm is analyzed using Peak Signal to Noise Ratio, Normalized Correlation and Mean structure similarity index with respect to various attacks. Experimental evaluation demonstrate that the proposed algorithm perform satisfactorily compared to traditional algorithms in terms of payload, transparency and it is also robust against various attacks.

Keywords: video watermarking, human visual system, nested watermark.

1. INTRODUCTION

The popularity of digital video has extremely increased as the number of videos is used during communication, entertainment and edification. It is considered as a vital tool which combines all types of multimedia elements like audio, text, static and moving images. Video communication provides the advantage of being valuable and has the power to convey a great deal of information in a time-constrained environment. Also, as a result of the recent development in IT (Information Technology), huge amount of high quality digital contents is also generated from HDTV (High Definition Television) broadcasting and DVD. The swift growth in the network protocols and infrastructure, along with sophisticated services like high speed internet have made it possible to store, stream and share a large scale of videos in an easy and cost effective manner.

However, these advancements prove to be challenging while taking the intellectual video content protection into consideration [1]. This has necessitated the need for techniques that control access to video content by restricting viewing rights, reproduction rights or copying rights. Media protection or Digital Rights Management (DRM) is the set of techniques used for this purpose [2]. Out of these techniques, digital watermarking in DRM has given more attention while proving the integrity and validity of the owner [3, 4].

Video watermarking [5, 6, 7] makes the digital video content so that a particular copy can be traced back to the original user and is mainly used as a protective measure for unauthorized copying of copyrighted material.

To protect video content using watermarking, there are two crucial questions that have to be handled carefully i) when to embed watermark ii) where to embed watermark. In uncompressed video medium, the watermark is embedded into the raw frames of the video signal. The watermarking algorithm work is not influenced by the compression algorithm and therefore is more robust. Here, both compression and watermarking algorithms seek irrelevant data for embedding and therefore has to be designed carefully. These algorithms result with more quality degradation and therefore the proposed algorithm try to minimize them.

The paper explains the various techniques used in proposed watermarking algorithms for uncompressed video data and discusses the experimental results based on performance metrics and finally concludes the paper.

2. METHODOLOGY

The increase in the development of digital communication medium needs a method capable of offering a good content protection for multimedia contents like images, video and audio. In order to increase the protection of copyright information, the embedding procedure uses a nested watermark, created using visual cryptography (VC) technique [8]. This section presents the watermark generation procedure and watermarking technique for uncompressed video domain based on the effective, amalgamation of several schemes. It is grouped into two stages. The first stage selects the place of embedding the copyright watermark whereas the second is used to embed and extract watermark from uncompressed video data.

2.1. Watermark generation procedure

Nested watermarking is the procedure of embedding a watermark into another watermark. The procedure for creating the nested watermark for binary image consists of the following steps.

- Perform Visual Cryptography on the copyright image to obtain Share 1 and Share 2.
- Read Share 1.

- Perform 2D DWT on Share 1 to obtain LL, LH, HL and HH sub bands.
- Read binary image.
- Add binary image in LL sub band.
- Perform IDWT to get nested watermark.

The reverse process is used to obtain the copyright image and binary image.

2.2. Selection of embedding frames

In uncompressed domain, the first stage is to find the frames where insertion of watermark has minimum alteration and maintains transparency. The procedure consists of two steps. The first step identifies low motion activity frames where the insertion of watermark will not be visible to the human visual system and the second selects frames from this subset that has minimum impact on visual quality after insertion of watermark. Identification of Low Motion Activity Frames Algorithm for Uncompressed domain (ILMAF-UC) is proposed for this purpose. The steps are shown in Figure-1.

2.2.1 ILMAF-UC algorithm

To identify low activity frames, a motion activity measure, that describes the level of intensity of activity, action or motion in the video sequence, is used. This measure is estimated using a block matching method that uses an Enhanced Adaptive Rood Pattern Search Algorithm (EARPS) to estimate motion intensity.

The proposed EARPS algorithm is given below:

Step-1: [Prediction] the median prediction based on neighboring blocks is performed for finding the predicted MV. Calculate the SADp at the location of the predicted MV and perform threshold-based early termination. If the termination condition is satisfied, the MV search terminates. Otherwise, go to Step-2.

Step-2: [Initial Search Centre] Calculate the SAD0 at the position (0, 0). If the SAD0 is smaller than threshold T, search stops. Otherwise, compare SADp with SAD0, and the position with the minimum SAD is set as initial search centre (ISC), and then go to Step-3.

Step-3: [URP Initial Search] Place the centre of URP on the ISC and perform early termination criterion. If the SAD of the current point is smaller than threshold T, or the MBD point still locates at the ISC after the four vertex points have been checked, search stops. Otherwise, go to Step-4.

Step-4: [Adaptive Search] Set the center point of EARP at the MBD point found in Step 3 and check its vertex points. If the termination condition is satisfied, the MV search will be terminated. Otherwise, go to Step-5.

Step-5: [Refined Local Search] Place the centre of URP on the position that incurs the MBD point in Step-4. Use URP repeatedly until the termination condition is satisfied, or the MBD point is still at the centre of URP.

After estimating the motion activity using the above algorithm, the frames are categorized as very low, low, medium, high and very high activity frames. Only the very low, low and medium frames are selected for the embedding process.

Edge detection technique is then used to identify the embedding regions in each of these frames. The algorithm treats the selected frames as a sequence of images and segments each frame as embed region (ER) and other region (OR). The ER is further divided into three regions namely, low complex (smooth), medium complex and high complex regions. By determining the amount of smooth, medium and high complex regions in the frames, a frame is respectively identified as smooth, medium or high complex frames. During embedding, no data is embedded in the high complex frame and 2/3rd of embedding is done in smooth and rest is done in medium frames.

2.3. Embedding and extraction algorithms for uncompressed video

The watermarking algorithms proposed for the uncompressed domain have various features that make it different from existing algorithms. They are:

- Embedding procedure is block-based
- Embedding is performed in the relevant border region of video
- Exploit the characteristics of the HVS in wavelet packet coefficients
- Usage of Artificial Neural Network

Thus, combining the various features with wavelet packets, the paper proposes the Enhanced Wavelet Packet-based watermarking algorithm based on Geometric Warping with HVS based criteria using neural network combined with Static Blocking Algorithm (WGSBS algorithm).

2.3.1. WGSBS embedding algorithm

WGSBS embedding Algorithm is shown in Figure-2. The algorithm uses the frames and regions selected using ILMAF-UC and perform DWPT to obtain subbands which are then segmented into non-overlapping 8 x 8 blocks. The Just Noticeable Difference [9] HVS characteristics are then calculated to obtain the allowable visibility ranges for all coefficients of a wavelet-packet transformed image. The inclusion of JND increases the imperceptibility of the algorithm. An Artificial Neural Network (ANN) is then used to memorize the relationships between the original wavelet coefficients and its watermark version. A geometric warping method [10] [11] is then used to embed the watermark in the selected regions of the frames. After which an inverse DWPT is performed to obtain the watermarked video. The geometric warping method is enhanced through the use a

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block selection algorithm. The block selection algorithm aims to reduce the artifacts or flickering effects introduced by the original warping method. Static block-based watermarking techniques consist of dividing the frames into non-overlapping blocks of pixels and inserting a watermark into each block.

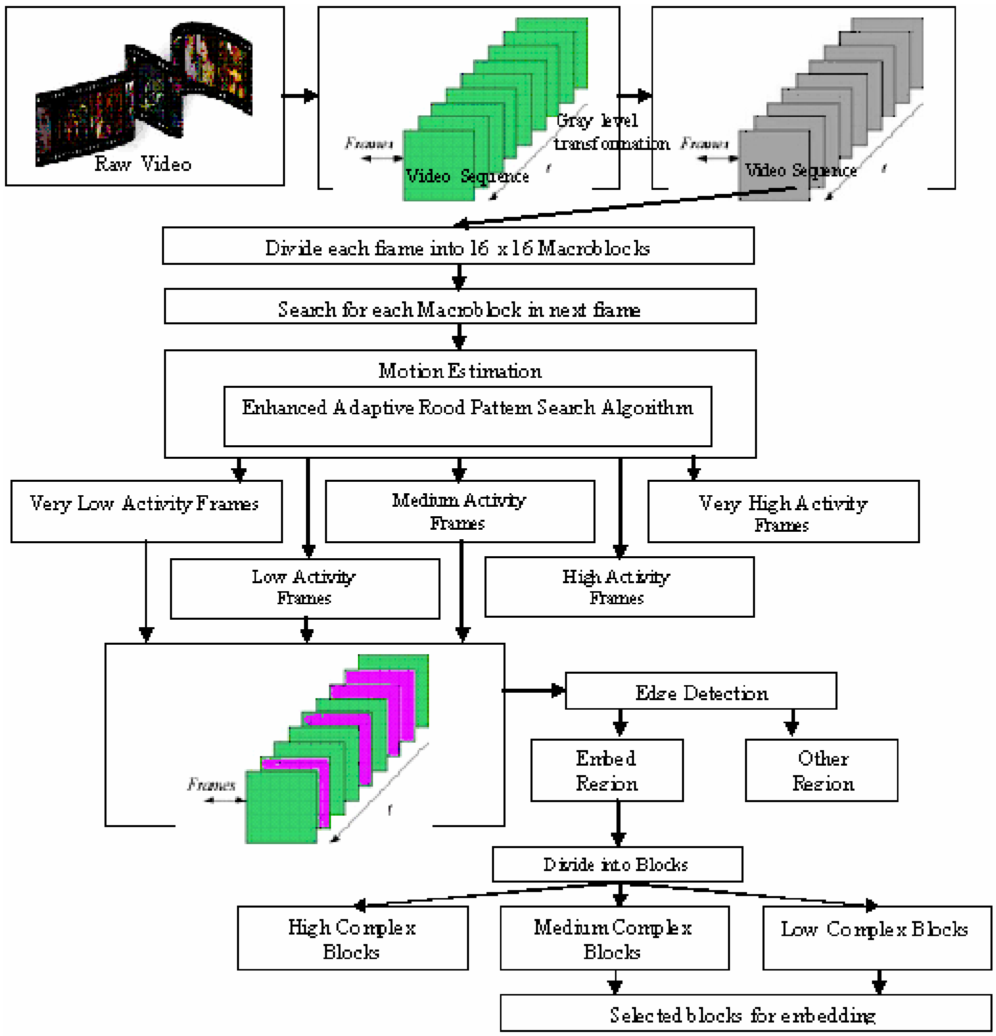

Figure-1. Steps in ILMAF-UC algorithm.

2.3.1.1. Block selection procedure

To avoid blocking artifacts the geometric warping method uses a block selection procedure. In block selection technique, the selected blocks should maintain a minimum distance d to each other in order to prevent artifacts and flickering effects. The minimum distance can be calculated using Equation (1).

$$[d_i = \lfloor \log(d.(i_{size} - 1) + 1) + 0,.5 \rfloor \quad (1)$$

Where d is the distance and I is the dimensions (x, y or t). The steps involved in the block selection algorithm [10] used are given in below:

Step-1: Select a block group which is of arbitrary forms.

Step-2: The minimum distance dx, dy and dt is computed for each dimension x, y and t of the block group.

Step-3: The numbers of blocks inside an ellipsoid are counted for each block. The semi-axes of the ellipsoids are defined by dx, dy and dt. The current block defines the center of the current ellipsoid.

Step-4: The blocks with the least neighbors are chosen for watermarking. If more than one chosen blocks inside an ellipsoid, only one of them (the first) is used for watermarking.

Step-5: The chosen blocks and all blocks within the ellipsoids around the chosen blocks will not be considered in the next steps.

Step-6: The steps 3-4 are repeated until all blocks are chosen for watermarking.

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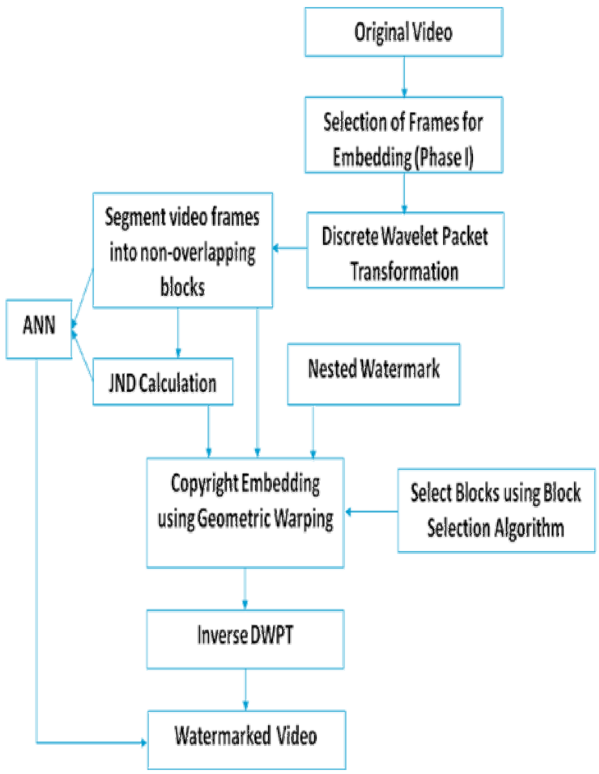

Figure-2. WGSBS embedding algorithm.

2.3.2. WGSBS watermark extraction process

The procedure for extracting the watermark is given in Figure-3.

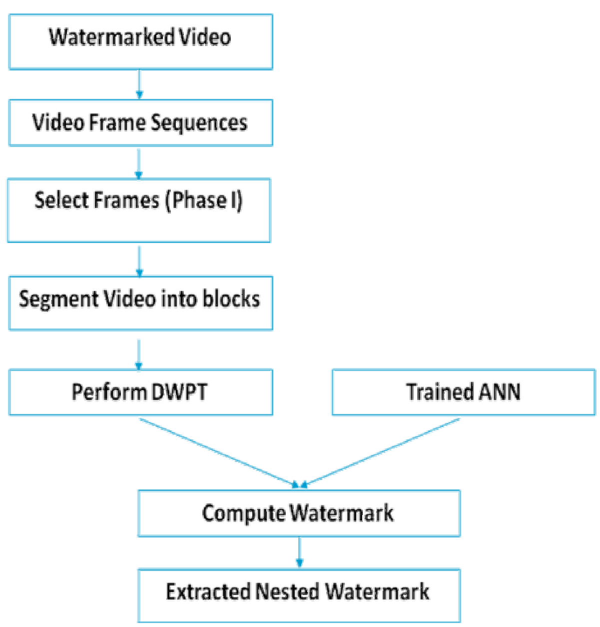

Figure-3. Watermark extraction process.

The extraction algorithm first selects the frames where the watermark is embedded, performs static block selection and then performs DWPT to receive coefficients. These coefficients along with the trained ANN are then used to compute and extract the nested watermark. From the nested watermark, the copyright image is obtained by performing XOR operation. Thus, to extract the watermark, the original video is not needed.

3. RESULTS AND DISCUSSIONS

During experimentation several videos were used which were collected from You Tube and www.elementaltechnologies.com/resources/ 4k-test-sequences. The files were obtained for uncompressed formats. Three metrics, namely, Peak Signal to Noise Ratio normalized coefficients and Mean structure similarity index were used to analyze the performance of the proposed algorithm.

The attacks considered during performance evaluation categorized into six groups, were selected. They are frame attacks (average, drop and swap), geometric attacks (cropping and rotation), removal attacks (collusion), noise attacks (impulsive and Gaussian), processing attacks (Sharpening, blurand brighten) and compression attacks (JPEG and MPEG), were considered. In this paper three videos for uncompressed domain were taken as test videos, namely, foreman, mobile and phone. Sample frames from each video and copyright image are shown in Figure-4 (a)-(c). The sample videos selected were with different bit rates.

 (860MB)	 1.2GB
(a) Foreman (352 x 288)	(b) Mobile (352 x 289)
 (1.3GB)	
(c) Phone (352 x 288)	(d) Copyright

Figure-4(a)-(c). Sample frames.

- **Peak signal to noise ratio**

PSNR is often used as a visual quality measurement between the original and a watermarked video. It is computed using the following equation.

$$PSNR = 10 \log_{10}\left[\frac{R^2}{MSE}\right] \quad (2)$$

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Table-1. Psnr (Db) of watermarking algorithms for uncompressed domain.

Attack category and type		HVS	Geo	DWPT	WGSBS
Frame attacks	Average	43.37	44.23	44.07	45.77
	Drop	42.43	43.46	43.17	44.92
	Swap	43.10	44.10	43.52	45.12
Geometric attacks	Cropping	43.81	44.73	44.33	45.61
	Rotation	42.17	43.86	42.77	44.58
Removal	Collusion	43.12	44.21	43.71	45.27
Noise attacks	Impulsive	41.94	43.60	42.76	43.68
	Gaussian	42.27	43.52	42.89	44.53
Processing attacks	Sharpening	42.43	44.46	43.12	45.13
	Blur	41.29	42.85	42.15	43.67
	Brighten	42.19	43.16	43.03	44.00
Geometric attack	MPEG	42.39	43.45	44.02	44.66
	JPEG	42.14	42.69	42.48	43.68

From the above table, it can be seen that WGSBS have increased the performance in terms of quality when compared conventional (HVS and DWPT) and existing (GEO) algorithm.

- **Normalized correlation**

Normalized correlation (NC) is calculated using Equation (3).

$$\text{NC (Normalized correlation)} = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} W(i,j)W'(i,j)}{\sum_{i=1}^{M}\sum_{j=1}^{N} W(i,j)^2} \quad (3)$$

Table-2. Robustness (NC)-uncompressed video.

Attack category and type		HVS	Geometric	DWPT	WGSBS
Frame attacks	**Average**	**0.67**	**0.75**	**0.70**	**0.79**
	Drop	0.70	0.78	0.73	0.81
	Swap	0.66	0.74	0.69	0.78
Geometric attacks	Cropping	0.69	0.72	0.74	0.81
	Rotation	0.73	0.74	0.79	0.84
Removal	Collusion	0.66	0.72	0.75	0.82
Noise attacks	Impulsive	0.68	0.70	0.73	0.83
	Gaussian	0.63	0.73	0.76	0.85
Processing attacks	Sharpening	0.67	0.72	0.77	0.87
	Blur	0.63	0.70	0.73	0.83
	Brighten	0.62	0.71	0.76	0.82
Geometric attack	MPEG	0.71	0.72	0.74	0.84
	JPEG	0.74	0.75	0.78	0.86

Table-2 also show maximum performance when no attack was performed on the watermarked video. The near to unity values obtained show that the proposed algorithms are good at resisting attacks and does not degrade watermarked video quality even in the presence of attacks.

ARPN Journal of Engineering and Applied Sciences

- **Mean structure similarity index**

This measure is used to identify the similarity between 2 videos and the results are shown in Table-3.

$$MSSI\ (x,y)=\frac{1}{M}\sum_{j=1}^{M}\frac{(2\mu_x\mu_y+c_1)(2\operatorname{cov}_{xy}+c_2)}{(\mu_x{}^2+\mu_y{}^2+c_1)(\sigma_x{}^2+\sigma_y{}^2+c_2)}$$

Table-3 shows that WGSBS has high value when compared with other traditional algorithm and also introduce minimum video degradation even in the presence of various attacks.

Table-3. MSSI of watermarking algorithms for uncompressed domain.

Attack category and type		HVS	Geo	DWPT	WGSBS
Frame attacks	Average	0.9002	0.9178	0.9040	0.9234
	Drop	0.9058	0.9201	0.9092	0.9292
	Swap	0.9027	0.9148	0.9053	0.9268
Noise attacks	Cropping	0.8972	0.9099	0.9028	0.9216
	Rotation	0.8942	0.9073	0.8976	0.9160
Removal	Collusion	0.8918	0.9043	0.8948	0.9113
Compression attacks	Impulsive	0.8863	0.9015	0.8906	0.9073
	Gaussian	0.8838	0.8975	0.8881	0.9031
Processing attacks	Sharpening	0.8806	0.8939	0.8835	0.8993
	Blur	0.8849	0.8971	0.8885	0.9034
	Brighten	0.8821	0.8934	0.8859	0.8994
Geometric attack	MPEG	0.8762	0.8881	0.8804	0.8951
	JPEG	0.8742	0.8858	0.8783	0.8893

Experimental results proved that the proposed model has improved the watermark embedding and extraction processes in terms of transparency (PSNR), robustness (NC) with and Mean Structure Similarity Index (MSSI) respect to attacks. The WGSBS algorithm with Frame selection technique worked better than other traditional algorithm. All the algorithms are resistant to the selected attacks and the results further prove that proposed algorithm increase security while maintaining the visual quality.

4. CONCLUSIONS

This paper proposed a new watermarking algorithm ILMAF-UC based WGSBS for copyright protection of uncompressed video data. To increase the security of the copyright watermark, the concepts of visual cryptography and nested watermarks were combined. This technique is tested on uncompressed video data and experimental results prove that the proposed algorithm for uncompressed domain is efficient in copyright protection and has a high degree of invisibility against various attacks than the traditional algorithms.

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